

India Missile Chronology

Last update: June 2012

This annotated chronology is based on the data sources that follow each entry. Public sources often provide conflicting information on classified military programs. In some cases we are unable to resolve these discrepancies, in others we have deliberately refrained from doing so to highlight the potential influence of false or misleading information as it appeared over time. In many cases, we are unable to independently verify claims. Hence in reviewing this chronology, readers should take into account the credibility of the sources employed here. Inclusion in this chronology does not necessarily indicate that a particular development is of direct or indirect proliferation significance. Some entries provide international or domestic context for technological development and national policymaking. Moreover, some entries may refer to developments with positive consequences for nonproliferation.

2012

26 April 2012

India successfully launches its first indigenous radar imaging satellite. The Risat-I will orbit the earth at an altitude of 480km (300mi) and has the ability to collect images despite cloud cover or darkness, which is useful for monitoring crops and natural disasters such as floods and droughts. Although the satellite is suitable for defense-related surveillance, Indian Space Research Organization Chairman K. Radhakrishnan asserted that “this is not a spy satellite.”

-- Jay Menon, “India Puts Risat-I into Space,” *Aerospace Daily & Defense Report*, 27 April 2012, www.lexisnexis.com; “Earth Observation Satellites,” Indian Space Research Organisation, www.isro.org; V. Ayyappan, “RISAT-I, First Microwave Radar Imaging Satellite, Launched Successfully,” *The Times of India*, 26 April 2012, <http://timesofindia.indiatimes.com>; Nirmala Ganapathy, “India Launches ‘Eye in the Sky’ Satellite; Meant Mainly for Agriculture and Disaster Control, It Can Also Be Used for Defence Needs,” *The Straits Times*, 27 April 2012, www.lexisnexis.com.

20 April 2012

India is developing multiple independently-targetable reentry vehicle (MIRV) technology for its Agni-V missile. V.K. Saraswat – chief of the Defence Research and Development Organisation (DRDO) –states that the “work is on” to equip India’s longest-range missile with the capacity to carry multiple warheads on a single missile.

-- “Agni-V May be Equipped with Multiple Warheads: DRDO Chief,” *The Economic Times* (India), 10 May 2012, <http://articles.economictimes.indiatimes.com>; Vipin Narang and Christopher Clary, “Capability Without Strategy,” *Indian Express*, 22 May 2012, www.indianexpress.com.

19 April 2012

India successfully tests a nuclear-capable long-range ballistic missile (LRBM), its most powerful missile to date. The three-stage solid-fueled, road-mobile Agni-V is designed to reach targets up to 5000km, and can carry a 1.5-ton

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payload. The Defence Research and Development Organization (DRDO) is responsible for the Agni program, and is expected to test the Agni-V several more times before the missile is inducted into the country's strategic force in 2014-2015. V.K. Saraswat, director of the DRDO, calls the missile launch "a game-changer," asserting that the Agni-V test indicates the country has the "boost capability" to launch an anti-satellite weapon.

-- "India Launches New Generation Strategic Missile Agni 5," DRDO Press Release, 19 April 2012, <http://drdo.gov.in>; "Agni-V Gives India Long-range Missile Strike Capability," *The Hindu*, 19 April 2012, www.thehindubusinessline.com; "India Test-Fires Agni-V Long-Range Missile," *Aerospace Daily & Defense Report*, 20 April 2012, www.lexisnexis.com; "Can Show Anti-satellite Capability if Gov't Gives Nod: DRDO Chief," *Indian Express*, 21 April 2012, www.indianexpress.com.

4 March 2012

The Indian Army successfully tests a BrahMos land-attack cruise missile (LACM), signifying the operationalization of a second BrahMos regiment into the Indian Army. The missile is designed to destroy targets within a range of 290km, and will be deployed with an Army regiment somewhere in India's western sector near Pakistan. The missile is a product of BrahMos Aerospace, a collaborative venture between the Defence Research and Development Organisation (DRDO) in India and the Federal State Unitary Enterprise NPO Mashinostroyeniya (NPOM) in Russia.

-- "Second BrahMos Regiment Operational Along Border," *Times of India*, 5 March 2012, <http://timesofindia.indiatimes.com>; "BrahMos Cruise Missile Test Fired," *Indian Express*, 5 March 2012, www.indianexpress.com; "BrahMos Cruise Missile Successfully Test-fired," *The Hindu*, 4 March 2012, www.thehindubusinessline.com.

10 February 2012

The Defence Research and Development Organisation (DRDO) tests the Air Defence Missile AAD-05. The AAD-05 interceptor missile destroyed a modified Prithvi missile at an altitude of 15km off the coast of Orissa in the Bay of Bengal.

-- "Successful Demonstration of Ballistic Missile Defence Capability," DRDO Press Release, 10 February 2012, <http://drdo.gov.in>; "India Successfully Test-fires Missile Interceptor," *Times of India*, 10 February 2012, <http://timesofindia.indiatimes.com>.

2011

1 December 2011

India's Strategic Forces Command (SFC) successfully performs a test of the nuclear-capable solid-fueled Agni-I ballistic missile, which has a range of 700km and has already been inducted into the Indian Army. The launch is a "practice-drill" in order to "train the user team [SFC] to launch the missile" from a road-mobile launcher system.

-- "Agni-I Missile Successfully Test-Fired off Odisha Coast," *The Hindu*, 1 December 2011, www.thehindu.com; "India Carries Out Yet Another Flight Test of Agni I Ballistic Missile," DRDO Press Release, 1 December 2011, <http://drdo.gov.in>.

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15 November 2011

India successfully tests the Agni-IV ballistic missile. The nuclear-capable missile reaches a height of 900km after being launched from Wheeler Island off India's west coast, and lands at its target 3,000 km away in the Bay of Bengal. The test is the first to use a newly designed rocket motor and guidance system.

-- "India Test Fires N-capable Agni-IV," *Indian Express*, 16 November 2011, <http://www.indianexpress.com>; "India Launches New Generation Strategic Missile Agni 4," DRDO Press Release, 15 November 2011, <http://drdo.gov.in>.

30 September 2011

India conducts another test of the Agni-II ballistic missile. The two-stage, solid-fueled missile was dispatched from a rail-mobile launcher on Wheeler Island, off the Orissa coast. Agni-II is a medium-range ballistic missile (MRBM) able to reach targets up to 2,000km away, and it has already been inducted into the Indian strategic arsenal.

-- "Agni-II Soars in Success," *The Hindu*, 30 September 2011, www.thehindu.com; "Agni-II Launched," DRDO Press Release, 30 September 2011, <http://drdo.gov.in>.

26 September 2011

India successfully tests the Prithvi-II short-range ballistic missile (SRBM). The missile is tested from a mobile launcher, and reaches its target in the Bay of Bengal with an accuracy of 10m. Prithvi-II is capable of reaching targets within 350km, and is tested by the military as a part of regular training exercises.

-- "India Successfully Test-Fires Nuclear-Capable Prithvi-II Missile," *Indian Express*, 26 September 2011, www.dnaindia.com; "Another Successful Flight Test of Prithvi (P-II)," DRDO Press Release, 26 September 2011, <http://drdo.gov.in>.

24 September 2011

India successfully test-fires the nuclear-capable Shourya, a short-range ballistic missile (SRBM) with a range of up to 700km. This is the third successful test of the Shourya since 2008, and production of the missile for induction into the Indian Army is expected to begin shortly.

-- "India Test-fires Nuke-capable Shourya Missile," *Times of India*, 24 September 2011, <http://timesofindia.indiatimes.com>. "India Successfully Test-fires Shourya Missile," *The Hindu*, 24 September 2011, www.thehindu.com.

21 July 2011

India tests the new Prahaar short-range ballistic missile (SRBM). The Prahaar has a range of 150km and can be used in battlefield operations. It is unclear whether the missile is nuclear-capable, although the Defence Research and Development Organisation (DRDO) claims the missile is "capable of carrying different types of warheads." The DRDO also compares the Prahaar to the U.S. Army's Advanced Tactical Missile System (ATACMS).

-- "'Prahaar' Missile Successfully Test-fired," *The Hindu*, 21 July 2011, www.thehindu.com; "'Prahaar' – New Surface to Surface Tactical Missile Successfully Launched," DRDO Press Release, 21 July 2011, <http://drdo.gov.in>.

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18 July 2011

Defense Research and Development Organization (DRDO) sources say that the first test of the rapid reaction, short-range, tactical missile Prahaar is likely to be conducted on July 21. The missile will be tested at the Integrated Test Range in Balasore, Orissa.

—"Flight-test of Prahaar missile likely on July 21," *The Hindu*, 18 July 2011, www.thehindu.com.

3 July 2011

The Defense Research and Development Organization (DRDO) develops a new short-range, tactical missile called Prahaar. The missile has a range of 150km and is said to be more accurate than the currently-deployed unguided missiles.

—"New short-range missile test July-end," *Deccan Chronicle*, 3 July 2011, www.deccanchronicle.com.

25 June 2011

India and Pakistan exchange proposals on nuclear and missile confidence building measures, including a proposal to incorporate cruise missile tests in their 2005 agreement on Pre-Notification of Flight Testing of Ballistic Missiles.

—"India, Pak exchange proposals on conventional, nuclear CBMs," *Indian Express*, 25 June 2011, www.indianexpress.com.

20 June 2011

The Defense Research and Development Organization (DRDO) proposes removing the 3,100-mile (4988km) restriction on the range of its missiles to allow it to produce an intercontinental ballistic missile with a range of over 6,200 miles (9977km). The Indian government adopted a voluntary restriction on missile range in 2006 after the test of the Agni-III ballistic missile, which has a range of 1,860 miles (2993km). The final decision on this proposal will be taken by the Cabinet Committee on Security.

—"India Weighs Developing ICBM with 6,200-Mile Reach," *Global Security Newswire*, 20 June 2011, <http://gsn.nti.org>.

11 June 2011

The Chief of Air Staff, Air Chief Marshal PV Naik calls for expanding India's strategic missile force to include an intercontinental reach. Naik says that "India should pursue an ICBM program to acquire ranges of 10,000km or more."

—"Air Chief in favour of flexing missile power," *The Hindustan Times*, 11 June 2011, www.hindustantimes.com.

10 June 2011

The Prithvi-II surface-to-surface missile is successfully tested from the Integrated Test Range at Chandipur in Orissa. The nuclear-capable missile has a range of 350km.

—"Prithvi-II successfully flight-tested," *The Hindu*, 10 June 2011, www.thehindu.com.

3 June 2011

Dr. Vijay Kumar Saraswat of the Defense Research and Development Organization (DRDO) says that the 5000km-range ballistic missile Agni-V will be tested for the first time by the end of 2011. He says, "This missile would be based on the concept of re-entry vehicle capable of covering whole of Pakistan and China." Regarding the Agni-III,

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Saraswat stated that, "Agni-III is already inducted. Its development has been completed and is under production."
—"India to test-fire Agni-V by year-end," *The Hindu*, 3 June 2011, www.thehindu.com.

23 April 2011

The Indian Air Force issues a request for information (RFI) for long-range air-to-air missiles for deployment on its fighter aircraft. The missiles will allow the aircraft to shoot down targets without aerial combat. The missiles are expected to have ranges of over 100km.

—"IAF to Procure Long-Range Missiles for its Fighters," *The Tribune*, 23 April 2011, www.tribuneindia.com.

19 March 2011

The Indian government's Cabinet Committee on Security clears induction of two regiments of Akash surface-to-air missiles for the Indian Army. The missile has a range of 25km.

—"25 yrs in the making, Army inducts Akash," *The Times of India*, 19 March 2011, www.timesofindia.com.

15 March 2011

India's solid-propelled Advanced Air Defense (AAD) interceptor missile fails to launch during a test targeting a Prithvi missile. Initial analysis suggests that the target missile's deviation from its trajectory could have led to coordination problems.

—"India's Missile Defense Test Fails," *Rediff.com*, 15 March 2011, www.rediff.com.

13 March 2011

BrahMos Aerospace Chief Executive Officer A. Sivathanu Pillai says that the supersonic version of the BrahMos cruise missile could be deployed on the fifth generation fighter aircraft that is being developed in cooperation with Russia. The air variant of the BrahMos will be tested in 2012, while the submarine version of the missile is scheduled to be tested by the end of 2011.

—"BrahMos Underwater Test-Firing by Year-end," *The Hindu*, 13 March 2011, www.thehindu.com.

11 March 2011

The Prithvi-II nuclear-capable ballistic missile is successfully test fired. Propelled by twin liquid propulsion engines, the missile has a range of 350km with a payload of 500-1000kg. A Defense Research and Development Organization (DRDO) spokesman says that the missile features anti-ballistic missile systems and has "achieved single digit accuracy reaching close to zero circular error probability."

—"Prithvi II, Dhanush Test-fired Successfully," *The Times of India*, 11 March 2011, www.timesofindia.com.

7 March 2011

The Defense Research and Development Organization (DRDO) successfully tests an interceptor missile against a modified Prithvi ballistic missile. According to V.K. Saraswat, Scientific Adviser to the Defense Minister, the test shows that "India has all the technologies and building blocks which can be used for anti-satellite missions."

—"Capability to Neutralize Enemy Satellites Proved," *The Hindu*, 7 March 2011, www.thehindu.com; "Interceptor Missile Test-Fired Successfully," *The Hindu*, 7 March 2011, www.thehindu.com.

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5 March 2011

BrahMos Aerospace Chief Executive Officer A. Sivathanu Pillai says trials for the air-launch version of the BrahMos cruise missile will begin in 2012. According to Pillai, the missile has been modified to fit into a Sukhoi fighter, notably the Su-30 MKI which has the ability for mid-air refueling. The missile's weight has been reduced to 2.5 tons, and several other modifications are also underway such as fire control and software.

—"Trials of BrahMos Air version from 2012: Sivathanu Pillai," *The Hindu*, 5 March 2011, www.thehindu.com.

25 January 2011

The United States removes several state-owned Indian defense organizations from its Entity List in an easing of export control regulations. The companies include subsidiaries of the Defense Research and Development Organization (DRDO) and the Indian Space Research Organization (ISRO). Additionally, the U.S. Commerce Department transfers India to a group of countries in the Export Administration Regulations (EAR) that are part of the Missile Technology Control Regime (MTCR). This move acknowledges India's adherence to the regime.

—Chidanand Rajghatta, "U.S. Removes ISRO, DRDO from export control list," *The Times of India*, 25 January 2011, <http://timesofindia.indiatimes.com>.

2010

28 November 2010

Sources in the Defense Research and Development Organization (DRDO) say that the K-15 submarine-launched ballistic missile is currently in production. The missile has been renamed the "B-05." Additionally, a DRDO missile scientist says that the 5,000 km-range Agni-V ballistic missile is likely to be tested for the first time in 2011.

—T.S. Subramanian, "Agni-II+ launch before December 10," *The Hindu*, 28 November 2010, www.thehindu.com.

26 November 2010

The Strategic Forces Command successfully tests the 700 km-range Agni-I nuclear-capable ballistic missile off the coast of Orissa state.

—"Nuke command tests Agni-I," *The Telegraph*, 26 November 2010, www.telegraphindia.com.

10 October 2010

The Director General of the Defense Research and Development Organization (DRDO), V.K. Saraswat says that a modified variant of the Agni-II nuclear-capable ballistic missile, called "Agni-II Plus," will be launched in 2011.

—Amruta Byatnal, "Agni-II Plus to be Launched in 2011: DRDO," *The Hindu*, 10 October 2010.

25 September 2010

A test of the Prithvi-II nuclear-capable ballistic missile ends in failure, as the missile fails to take off from its launcher. The missile, which has been inducted into the air force, is tested by personnel of the Strategic Forces Command.

—Y. Mallikarjun, "Prithvi-II Fails to Take Off," *The Hindu*, 25 September 2010.

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13 September 2010

The Director General of the Defense Research and Development Organization, V.K. Saraswat, says that the Agni-V intermediate-range ballistic missile will be tested in 2011. Eventually, both sea and land-based platforms will be able to launch the missile, which will have a range of at least 5,000km.

—Ananya Dutta, "Saraswat: Agni-V Will Be Test-Fired in 2011," *The Hindu*, 13 September 2010.

6 September 2010

The BrahMos cruise missile is successfully tested from the Integrated Test Range at Chandipur. This is the missile's 23rd test. The test unveils a new capability in the missile — that of a steep-dive mode, in which the missile dives vertically, rather than descending towards its target in a gradual manner.

—T.S. Subramanian, "BrahMos Tested in Steep-Dive Mode," *The Hindu*, 6 September 2010; "India Test-Fires BrahMos Cruise Missile," *The Times of India*, 5 September 2010.

28 August 2010

According to Defense Minister A.K. Antony, India is preparing to carry out the first test of its longest range, nuclear-capable ballistic missile, the Agni-V, which is slated to have a range of 5,000km. The Agni-V will be a three-stage, solid-fueled missile.

—"Agni-V Will Be Test-Fired Soon, Says Antony," *The Hindu*, 28 August 2010; "Agni-V Ready for Testing," *The Tribune*, 28 August 2010.

26 August 2010

According to the Managing Director of BrahMos Aerospace Limited, A. Sivathanu Pillai, the BrahMos cruise missile is likely to be inducted into the Indian Air Force by 2013, after completion of flight tests in 2012.

—"BrahMos Likely to be Inducted into Air Force by 2013," *The Hindu*, 26 August 2010.

24 August 2010

The Indian government is considering deploying two nuclear-capable ballistic missile systems on its northeastern border with China. The two missiles are the 2000km range Agni-II, and the 350-km range Prithvi-III.

—"India Mulls Deploying Missiles Near China Border in North-East," *The Hindustan Times*, 24 August 2010.

27 July 2010

The Defense Research and Development Organization (DRDO) successfully tests an endo-atmospheric interceptor missile as part of its missile defense program. The interceptor missile successfully strikes the target missile, a Prithvi, 15km above the Bay of Bengal.

—"Bull's Eye," *The Telegraph*, 27 July 2010.

7 June 2010

In a boost to its fledgling missile-defense capabilities, India will acquire "x-band" radars from a U.S. company which can spot missiles up to 4,600 km away. Current Indian radar capability can track objects up to 600-800 km away.

—Ajay Banerjee, "India to Acquire 'x-band' Radars," *The Tribune*, June 7, 2010, www.tribuneindia.com.

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4 June 2010

The Indian government is finalizing a joint "missile co-development project" with France to produce short-range surface-to-air missiles for the military. The new missile development program will adopt the template of the joint Indo-Russian BrahMos cruise missile project. The missile, tentatively titled "Maitri" ("friendship"), could also be exported.

—Manu Pubby, "After Russia and Israel, India to Develop Missile With France," *The Indian Express*, June 4, 2010, www.indianexpress.com.

17 May 2010

The military's Strategic Forces Command successfully tested the 2,000-km range nuclear-capable Agni-II ballistic missile. The missile has been inducted into the armed forces and the test came after unsuccessful tests in May and November 2009.

"N-Capable Agni-II Test-Fired Successfully," *Indian Express*, May 17, 2010, www.indianexpress.com.

14 April 2010

The Indian Army has agreed to acquire the Akash medium-range surface-to-air missile from the public sector Bharat Dynamics Ltd. The missile has an interception range of 30 km at a height of 18,000 meters. The Indian Air Force already placed orders for two squadrons of the missile in 2008 and has now contracted for six additional squadrons.

—K.V. Prasad, "Army Agrees to Acquire Indigenous Akash Missile," *The Hindu*, April 14, 2010, www.thehindu.com.

30 March 2010

The Indian government has concluded an agreement with BrahMos Aerospace for supply of BrahMos cruise missiles to the Indian Air Force. This is separate from a different project to equip the air force with a smaller variant of the missile for the Sukhoi MKI fighter aircraft. Under the latest agreement, the air force will acquire the Block II advanced variant of the missile which has more precise strike capabilities.

—Manu Pubby, "BrahMos Cleared for Air Force," *The Indian Express*, March 30, 2010, www.indianexpress.com.

29 March 2010

The Indian Army successfully tested the 700 km-range nuclear-capable Agni-I ballistic missile in the Bay of Bengal. The test of conducted as part of a training exercise.

—Y. Mallikarjun, "Hat-Trick for Missile Technologists, Armed Forces," *The Hindu*, March 29, 2010, www.thehindu.com.

28 March 2010

The Strategic Forces Command carried out successful tests of the ship-based Dhanush and the surface-to-surface Prithvi-II missiles. The nuclear-capable Dhanush, a naval version of the Prithvi, has a range of 350 km. The Prithvi-II has a range of about 290 km.

—Y. Mallikarjun, "Dhanush, Prithvi-II Test-fired Successfully," *The Hindu*, March 28, 2010, www.thehindu.com.

16 March 2010

Indian defense scientists aborted the test of their ballistic missile system after the "enemy" ballistic missile, a

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modified Prithvi, failed to reach the required height of 110 km. Following this, the interceptor missile, termed the Advanced Air Defence (AAD) system, was not launched.

—Y. Mallikarjun and T.S. Subramanian, "Setback to Ballistic Missile Defence Trial," *The Hindu*, March 16, 2010, www.thehindu.com.

12 March 2010

The Defence Research and Development Organization (DRDO) will test the 5,000 km-range nuclear-capable Agni-V missile in 2011, according to a senior Indian defense scientist. The three-stage missile will have a payload of 1.5 tons.

—"Agni-V to be Test-fired Within a Year," *ExpressBuzz.com*, March 12, 2010, <http://expressbuzz.com>.

17 February 2010

V.K. Saraswat, scientific adviser to the defense minister has confirmed that the Shaurya missile being developed is a submarine-launched cruise missile. It will have a range of 750 km and can deliver a one-ton nuclear warhead.

—Ajai Shukla, "Shaurya Surfaces as India's Underwater Nuclear Missile," *Business Standard*, February 17, 2010, www.business-standard.com.

17 February 2010

According to a senior Indian defense official, the nuclear powered submarine being developed for the Indian Navy, INS Arihant, is likely to be armed with the nuclear-capable 700 km-range K-15 submarine-launched ballistic missile.

—Rahul Singh, "Arihant to be armed with ballistic missiles," *The Hindustan Times*, February 17, 2010, www.hindustantimes.com.

16 February 2010

New Delhi is planning to deploy six Akash missile squadrons in northeastern India to counter the potential air threat from China. The Akash is a surface-to-air missile with an interception range of 25 km.

—Rajat Pandit, "India to Deploy Akash Missiles in North-East to Deter China," *The Times of India*, February 16, 2010, <http://timesofindia.indiatimes.com>.

11 February 2010

The scientific adviser to the defense minister, V.K. Saraswat, has said that Indian defense scientists monitored China's test last month of a ballistic missile defense system, while also saying that Beijing was behind in India in development of missile defense technology.

—Manu Pubby, "India to Test 5,000-km N-Missile," *The Indian Express*, February 11, 2010, www.indianexpress.com.

11 February 2010

According to V.K. Saraswat, scientific adviser to the defense minister, the Agni-III is ready for induction into the armed forces. He also said that the 3,500 km-range ballistic missile is more accurate than the Chinese DF-21 missile. Speaking at a news conference, Saraswat and Avinash Chander, the Agni-III program director, also claimed

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that the missile's technology could be helpful in development of an anti-satellite missile.

—"Missile India: Mine is Better Than China's," *The Telegraph*, February 11, 2010, www.telegraphindia.com.

8 February 2010

India successfully tested its longest range missile, the 3,500 km-range nuclear capable Agni-III. The Agni-III is a two-stage missile. The test was carried out by the army and the missile is now ready to be inducted into the armed forces.

—T.S. Subramanian and Y. Mallikarjun, "Agni-III Launch a Complete Success," *The Hindu*, February 8, 2010, www.thehindu.com; T.S. Subramanian and Y. Mallikarjun, "DRDO Raises the Bar, Sets Its Sights on 5,000-km Agni-V," *The Hindu*, February 8, 2010.

2 February 2010

An installation test-flight of the BrahMos cruise missile will take place in 2010 from a stealth frigate that is currently being constructed for the Indian Navy in Russia. The test will take place in the Baltic Sea. Three such Talwar-class ships built in Russia will be armed with BrahMos missiles.

—T.S. Subramanian, "BrahMos Installation Test Flight in Baltic Sea," *The Hindu*, February 3, 2010, www.thehindu.com.

24 January 2010

The Indian government is planning to swiftly induct the Block II variant of the BrahMos land-attack cruise missile into the army. This version comes with "multi-spectral seekers" enabling "target-discriminating capabilities," giving it enhanced accuracy for surgical strikes.

—Rajat Pandit, "Army Plans Induction of BrahMos With 'Surgical Strike' Option," *The Times of India*, January 24, 2010, <http://timesofindia.indiatimes.com>.

6 January 2010

The Indian Air Force will be equipped with the air-launch version of the BrahMos cruise missile by 2012, according to the head of BrahMos Aerospace, Sivathanu Pillai. He said that the missile has been developed and the process of integrating it with the Sukhoi fighter aircraft was in progress. Trials of the missile will take place in 2011.

—"BrahMos Missile to be Inducted Into Air Force in 2012," *The Times of India*, January 6, 2010, <http://timesofindia.indiatimes.com>.

2009

14 December 2009

The Indian navy successfully tested the 350 km-range nuclear-capable Dhanush missile. This was the sixth test of the Dhanush, the naval variant of the Prithvi.

—"Dhanush Missile Successfully Test-Fired," *The Times of India*, December 14, 2009, <http://timesofindia.indiatimes.com>.

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30 July 2009

The Indian army carried out a successful test of the land attack variant of the BrahMos cruise missile at the Pokharan test range in Rajasthan state. According to a source, "with this launch, the requirement of Army for the land attack version with block-II advanced seeker software with target discriminating capabilities has been fully met and this version is ready for induction." This was the fourth test of the block-II variant this year, with the first resulting in failure. The land-attack BrahMos first entered into service with the Indian army in June 2007.

—Vimal Bhatia, "Army Test-Fires BrahMos Again," *The Times of India*, July 30, 2009, timesofindia.indiatimes.com.

27 July 2009

The indigenously developed Indian nuclear powered submarine, INS Arihant, which was launched for sea trials on July 26, and is expected to enter into service in the next few years, will be armed with the 700 km range nuclear capable K-15 ballistic missiles.

—T.S. Subramanian, "Nuclear-Powered Submarine To Be Fitted With Ballistic Missiles," *The Hindu*, July 27, 2009.

19 May 2009

The Indian Army successfully tested the 3000 km-range, nuclear capable Agni-II ballistic missile. Following three successful tests, the missile is ready for production.

—"India Successfully Tests Nuclear-Capable Missile," *Press Trust of India*, May 19, 2009, *BBC Monitoring South Asia Political*, Lexis-Nexis.

15 April 2009

The Indian Army has successfully tested an improved variant of its nuclear capable 350 km-range Prithvi-II ballistic missile. The army has already inducted this missile.

—"India Test-Fires Surface-to-Surface Missile," *Press Trust of India*, April 15, 2009, *BBC Monitoring South Asia Political*, Lexis-Nexis.

30 March 2009

The block II version of the land-attack variant of the BrahMos cruise missile was tested for the third time. The first test, in January, had been a failure. The second test, on March 5, and the most recent test, were both successful. According to the Defence Research and Development Organization (DRDO), the missile is now ready for induction into the army.

—T.S. Subramanian, "BrahMos Launch Successful," *The Hindu*, March 30, 2009.

7 March 2009

India successfully tested a missile interceptor over the Bay of Bengal in the Indian Ocean. A "hostile" missile was destroyed by the interceptor in the third successful trial of components of India's ballistic missile defense system since 2007.

—"India Tests Interceptor Missile," *The China Post*, March 7, 2009, www.chinapost.com.tw.

5 March 2009

The block II version of the land-attack version of the BrahMos cruise missile was successfully tested at Pokharan.

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The earlier test of this variant, in January, was a failure.

—T.S. Subramanian, "New BrahMos Test Successful," The Hindu, March 5, 2009.

21 January 2009

The January 20 test of the BrahMos cruise missile which had been termed as successful, in fact, resulted in the missile failing to hit the target, according to Indian defense scientists. The latest test was that of a block II version of the missile, which possesses advanced software that would allow the missile to select targets more efficiently. Older block I versions of the missile have already been deployed with the army.

—T.S. Subramanian, "BrahMos Missed the Target," The Hindu, January 22, 2009.

20 January 2009

India has tested its BrahMos supersonic cruise missile at Pokharan in the state of Rajasthan. The missile can carry conventional and nuclear warheads, and has a range of 290 km. The missile is being developed for launch from a range of platforms.

—"India Tests Missile Amid Tensions With Pakistan," Reuters, January 20, 2009, www.reuters.com.

8 January 2009

India has conducted talks with officials from the United States on the possibility of acquiring a missile defense system. The discussions were on a scientific and technical level and Indian officials also viewed computer simulations and attended live missile tests. According to a U.S. embassy official in New Delhi, "India is a partner of ours, and we want to provide it with whatever it needs to protect itself...This fits into the overall strategic partnership we are building."

—"India-US 'Missile-Shield Talks'," BBC News, January 8, 2009, news.bbc.co.uk.

2008

18 December 2008

The Indian Navy successfully tested the BrahMos cruise missile from a naval ship in the Bay of Bengal. This was the first test in a vertical launch configuration of the missile which can also be launched in an inclined configuration. The inclined variant has already been inducted into the navy.

—"India Test-Fires Supersonic Cruise Missile," Press Trust of India, December 18, 2008, BBC Monitoring South Asia - Political, Lexis-Nexis.

12 November 2008

India successfully test-fires a new surface-to-surface missile called "Shourya", which can carry both nuclear and conventional warheads. It is the land version of the underwater-launched missile K-15 (Sagarika). According to Dr. Selvamurthy, the Chief Controller of Defence Research and Development Organisation (DRDO), the missile cannot be detected by conventional satellite imaging, since it is fired from underground and is highly maneuverable.

—T.S. Subramanian, "Shourya test-fired successfully", The Hindu, 13 November 2008.

Related content is available on the website for the Nuclear Threat Initiative, www.nti.org.



14 September 2008

India holds flight trials of its first indigenously developed beyond-visual range (BVR) air-to-air missile, Astra. The BVR missile is integrated with Sukhoi-30 MKI and will be integrated with Mirage 2000 and the indigenous Light Combat Aircraft, once all tests are done to verify its accuracy in destroying maneuvering targets. Guided test firings are not expected until 2010, and service entry is still five years away.

—Neelam Mathews, "India test fires BVR missile Astra", Aerospace Daily & Defense Report, 16 September 2008; in Lexis-Nexis Academic Universe, 16 September 2008, <http://web.lexis-nexis.com>.

21 August 2008

The Russian-Indian joint company BrahMos is planning to put on the market a new generation hypersonic cruise missile, according to BrahMos executive director Sivathanu Pillai. The company is planning to agree the parameters of a cruise missile with the Russian and Indian defence departments within a year. A higher speed and being less visible will be the features of the BrahMos-2 missile. In addition, BrahMos-2 will be able to start from various platforms, such as sea, underwater, ground and air.

—"Russia and India developing new cruise missile", Interfax-AVN Military News Agency website (Moscow), 21 August 2008; in Lexis-Nexis Academic Universe, 24 August 2008, <http://web.lexis-nexis.com>.

8 August 2008

Country's first indigenously developed 3-D radar, "Rohini," is handed to the Indian Air Force (IAF) by the government-owned Bharat Electronics Ltd. The Multifunction Medium Range Surveillance Radar is capable of handling multiple targets simultaneously and also calculating the height at which projectiles are flying. The radar will give the IAF better air surveillance capabilities, particularly at low altitudes. Operating in a range of up to 170 kilometers and an altitude of 15 kilometers, the radar can track multiple targets like fighter jets and missile traveling at speeds of Mach 3.

—Neelam Mathews, "First unit of indigenous Indian radar delivered", Aerospace Daily and Defense Report, 8 August 2008; in Lexis-Nexis Academic Universe, 8 August 2008, <http://web.lexis-nexis.com>.

5-6 August 2008

The indigenously developed Nag missile, with an anti-tank tandem warhead and 4-kilometer range, is successfully fired on stationary and moving targets. According to the Indian Defense Research & Development Organization (DRDO), both targets are hit, confirming system capabilities.

—Neelam Mathews, "India's testing of Nag missile a success", Aerospace Daily & Defense Report, 7 August 2008; in Lexis-Nexis Academic Universe, 7 August 2008, <http://web.lexis-nexis.com>.

23 May 2008

India successfully test-fires its 150-250 km range surface-to-surface "Prithvi" missile, as part of a user's trial by the Indian Army. The indigenously built missile, developed by the Defence Research Development Organization (DRDO), is already inducted in the army.

—"India test-fires surface-to-surface missile", PTI News Agency (New Delhi), 23 May 2008; in Lexis-Nexis Academic Universe, 23 May 2008, <http://web.lexis-nexis.com>.

Related content is available on the website for the Nuclear Threat Initiative, www.nti.org.



14 May 2008

India successfully test-fires its nuclear-capable, intermediate-range ballistic missile Agni III. This firing is the second successful firing in three tests. Agni III's 3,000 km range puts Chinese cities such as Beijing and Shanghai within striking distance.

—"India conducts third test firing of Agni III", Jane's Defence Weekly, 14 May 2008; in Lexis-Nexis Academic Universe, 14 May 2008, <http://web.lexis-nexis.com>.

13 May 2008

The Defence Electronics Research Laboratory is developing a hi-tech decoy system which will be able to "seduce" missiles away from their legitimate targets. The decoy, meant for the Indian Navy, will be equipped with the most modern electronic warfare system and will protect aircraft, ships and other installations against radar-guided missiles. Being self-propelled, the decoys can fly freely too and can entice away a missile more easily than a towed decoy. The laboratory is planning to collaborate with international firms to develop the technology.

—"Indian lab developing new missile decoy system for navy", The Asian Age website (New Delhi), 13 May 2008; in Lexis-Nexis Academic Universe, 14 May 2008, <http://web.lexis-nexis.com>.

6 April 2008

According to the top Defence Research and Development Organization (DRDO) scientist S. Pahlada, India is ready to export missile to countries whose names are cleared by the government. Government is in favor of exports of missiles and DRDO is in a position to meet such sale orders. Though Pahlada does not name the missiles which can be offered in world market, some sources say that India can place Indo-Russian supersonic cruise missile BrahMos and recently tested surface-to-air Akash for sale.

—"Scientist says India ready to export missiles to short-listed countries", PTI News Agency (New Delhi), 6 April 2008; in Lexis-Nexis Academic Universe, 5 March 2008, <http://web.lexis-nexis.com>.

5 March 2008

India successfully test-fires indigenously developed, nuclear-capable submarine-launched cruise missile, Sagarika. The turbojet-powered missile has been under development by Aeronautical Development Establishment since early 1990s. It is said to have 700 km range with 500 kg payload, be capable of achieving high subsonic speeds and cruising at altitude of 15 m to 100 m.

—Rahul Bedi, "India test fires indigenously developed SLCM", Jane's Defence Weekly, 5 March 2008; in Lexis-Nexis Academic Universe, 5 March 2008, <http://web.lexis-nexis.com>.

26 February 2008

India successfully test-fires its first-ever undersea ballistic missile K-15 with a range of 700 km and joins a handful of countries, such as the US, Russia, France and China, to possess such a capability. The induction of K-15 missile into Indian armed forces will considerably enhance the country's nuclear deterrence as sea-launched missiles will form crucial part of the country's second strike nuclear capability.

—"India test-fires nuclear-capable undersea missile", BBC Monitoring South Asia, 26 February 2008; in Lexis-Nexis Academic Universe, 26 February 2008, <http://web.lexis-nexis.com>.

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9 January 2008

India scraps the Integrated Development of Guided Missile Programme (IDGMP) and announces the development and production of most futuristic weapons systems to take place with foreign collaboration. IDGMP was initiated in early 1980s and under it surface-to-surface longer range Agni group of missiles, shorter range tactical battlefield missiles Prithvi, surface-to-air Trishul and long-range multiple target surface-to-air Akash missiles have been developed. The only missile yet to be inducted is the fourth generation anti-tank missile Nag. The countries that already have expressed their readiness to work jointly with India include France, Israel, UK, Russia, Germany and Singapore. According to the India's top defence scientist Dr. S. Prahlada, longer range missiles, under-sea launched missiles and futuristic weapons systems like electronic counter-warfare measures would be "undertaken in-house".

—"India scraps strategic missile programme", BBC Monitoring South Asia, 9 January 2008; in Lexis-Nexis Academic Universe, 9 January 2008, <http://web.lexis-nexis.com>.

2007

22 December 2007

In a major technological breakthrough that will drastically reduce the weight of missiles and enable them to reach longer ranges with heavier payloads, Defence Research Development Organization (DRDO) scientists develop composite rocket motor casings (CRMC). Only the United States, Russia and a European consortium achieved a similar feat. CRMC will reduce the weight of a rocket casing by 40 per cent, enabling the missile to take heavier payloads or fly a longer range. In addition, the CRMC result in cost reduction by half compared to metallic casings, better performance and long storage due to non-corrosive nature of the material.

—"Indian defence organization achieves 'major breakthrough' in missile technology", The Hindu (Chennai), 22 December 2007; in Lexis-Nexis Academic Universe, 22 December 2007, <http://web.lexis-nexis.com>.

22 December 2007

A nine-day campaign, involving the surface-to-air Akash missile, radars, mobile launchers and support systems, concludes with a missile fired. Since the beginning of the campaign on December 13, a total of six missiles are fired on different days with the full Akash system working in tandem. The campaign is a fantastic success and it has international significance in both technology and operation.

—"India test fires surface-to-air missile", The Hindu (Chennai), 22 December 2007; in Lexis-Nexis Academic Universe, 22 December 2007, <http://web.lexis-nexis.com>.

2 December 2007

India tests a specially developed high-speed interceptor missile, Advanced Air Defence (AAD), to examine its capability to destroy a missile. The AAD is a new missile and not a derivative or an update of any existing missile. It is specially designed and developed by Defence Research and Development Organisation (DRDO) for its interceptor role.

—"India tests high-speed interceptor missile – defence source", BBC Monitoring South Asia, 2 December 2007; in Lexis-Nexis Academic Universe, 2 December 2007, <http://web.lexis-nexis.com>.

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25 October 2007

In a major breakthrough, India's indigenous Light Combat Aircraft (LCA) 'Tejas' successfully test-fires for the first time a close combat Russian R-73 air-to-air missile. Hailing it as a "milestone", a defence ministry spokesman says this heralds the start of the weaponisation of Tejas. The initial operational configuration for the fighter is expected between 2011 and 2012 and the aircraft will be fully operational by 2013.

—"Indian light combat aircraft test-fires Russian missile", PTI News Agency (New Delhi), 25 October 2007; in Lexis-Nexis Academic Universe, 26 October 2007, <http://web.lexis-nexis.com>.

5 October 2007

India test-fires its indigenously built short range variant of Agni ballistic missile, Agni-I. This is the fourth test firing of the surface-to-surface ballistic missile, which is capable of striking a target up to a distance of 700kms.

—"India test fires indigenous short range ballistic missile", BBC Monitoring South Asia, 5 October 2007; in Lexis-Nexis Academic Universe, 5 October 2007, <http://web.lexis-nexis.com>.

5 September 2007

According to the Defence Minister A.K. Antony, submarine launched version of BrahMos supersonic cruise missile is ready. The ship and land launched version of the missile are already cleared for induction in navy and army, after a series of successful flight trials launched from ships and from road mobile launchers. According to experts, the submarines in the armory of the Navy namely the German HDW series and the Russian Kilo class do not have the capability to launch such missiles.

—"India develops missile capable of launching from submarine", PTI News Agency (New Delhi), 5 September 2007; in Lexis-Nexis Academic Universe, 5 September 2007, <http://web.lexis-nexis.com>.

21 June 2007

President A.P.J. Abdul Kalam asks BrahMos team to work on developing "Mark-II" version of BrahMos hypersonic cruise missile system and also reusable class of cruise missiles. Fast deployment of hypersonic missile systems is necessary to maintain India's force level supremacy. The president also asks the BrahMos joint venture firm between India and Russia to aggressively market "world class" product with a market shelf life of not more than five years.

—"Indian president orders work on 'Mark-II' version of BrahMos cruise missile", PTI News Agency (New Delhi), 21 June 2007; in Lexis-Nexis Academic Universe, 21 June 2007, <http://web.lexis-nexis.com>.

21 June 2007

The Indian army becomes the first force in the world to be armed with supersonic surface-to-surface cruise missile, with the induction of 290 km range BrahMos missile. The US, French and Chinese forces have only subsonic cruise missiles in their armory. The actual delivery of the missile will commence next month, almost a year ahead of the scheduled induction fixed earlier for July, 2008.

—"Indian army inducts supersonic BrahMos cruise missile", PTI News Agency (New Delhi), 21 June 2007; in Lexis-Nexis Academic Universe, 21 June 2007, <http://web.lexis-nexis.com>.

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23 April 2007

A new regiment of the Indian Army that is being specially raised test-fires the BrahMos cruise missile, confirming that the artillery wing is being restructured and expanded. This is the third missile group that the army is raising. The first two - the 333 and the 444 - were raised for the Prithvi and the Agni II missiles. The BrahMos is a different class of missile - cruise, not ballistic - and calls for a special set of skills from the regiment that will be responsible for it.

—"India: Army sets up new regiment to handle supersonic missile", The Telegraph (Kolkata), 24 April 2007; in Lexis-Nexis Academic Universe, 24 April 2007, <http://web.lexis-nexis.com>.

30 March 2007

India successfully test-fires its indigenously developed beyond visual range (BVR) air-to-air Astra missile. The success is a relief for the scientists of the Defence Research Development Organization (DRDO) after the previous failure. The objective of the missile is to provide the Indian Air Force (IAF) with an indigenously-designed BVRAAM to equip the IAFs Mirage 2000, MiG-29, Su-30MKI and the Light Combat Aircraft (LCA).

—"Astra test-fire successful", The Statesman (India), 30 March 2007; in Lexis-Nexis Academic Universe, 30 March 2007, <http://web.lexis-nexis.com>.

9 February 2007

An Indian public sector undertaking (PSU) and a European defence conglomerate are in the process of jointly developing a missile warning system, based on a sensor called MILDS AN/AAR-60. The system will be integrated into the existing multi-sensor warning network of India's armed forces and its primary goal is to protect Indian Air Force (IAF) aircraft.

—"India to develop missile warning system with European company", PTI News Agency (New Delhi), 9 February 2007; in Lexis-Nexis Academic Universe, 9 February 2007, <http://web.lexis-nexis.com>.

5 February 2007

India successfully test-fires its supersonic cruise missile, BrahMos. The launch is successful, but data has to be analyzed before a final evaluation can be made.

—"Supersonic missile is tested by India", The Western Mail, 5 February 2007; in Lexis-Nexis Academic Universe, 5 February 2007, <http://web.lexis-nexis.com>.

2006

27 November 2006

In a major breakthrough, India's defence scientists successfully carry out a surface to surface missile interception over the Bay of Bengal brightening the prospects of development of an indigenous anti-missile shield. The supersonic missile, labelled only as AXO (Atmosphere Intercept System), successfully intercepts a surface-to-surface Prithvi target missile at an altitude of 40 to 50 km. According to the top Defence Research Development Organisation (DRDO) officials, this new missile is not part of country's Integrated Guided Missile programme. The missile has response time of 30 seconds and once it detects a target it can be launched in 50 seconds. It has high

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maneuverability, terminal homing with radar seekers and can operate independent of ground radar help.

—"India unveils new indigenous anti-missile system", "India acquires anti-missile capability", PTI News Agency (New Delhi), 27 November 2006; in Lexis-Nexis Academic Universe, 27 November 2006, <http://web.lexis-nexis.com>.

2 August 2006

According to Indian Defence Minister Pranab Mukherjee, the Prithvi and Agni strategic missile systems, as well as their variants, are inducted into the armed forces. The development of the Akash and Trishul surface-to-air missiles and Nag anti-tank missile is complete and the armed forces places production orders for these missiles, as well as for the BrahMos supersonic cruise missile.

—"India inducts Prithvi, Agni missiles into armed forces", PTI News Agency (New Delhi), 2 August 2006; in Lexis-Nexis Academic Universe, 2 August 2006, <http://web.lexis-nexis.com>.

9 July 2006

India test-fires its intermediate range ballistic missile Agni-III. The second stage of the nuclear-capable missile, designed to hit targets at a distance of 3,500 km, does not separate and it falls into the Bay of Bengal. The missile goes up to a height of about 12 km before the snag develops. The sources attribute the problem to a design failure. This is the first launch of the Agni-III, the most sophisticated product of the Integrated Guided Missile Development Programme that started in 1983. The testing of the missile was repeatedly put off since November 2004 for a variety of reasons, including once for technical problems.

—"Agni III test fails", The Statesman (India), 9 July 2006; in Lexis-Nexis Academic Universe, 9 July 2006, <http://web.lexis-nexis.com>.

6 July 2006

The Cabinet Committee on Security (CCS) approves the purchase of three more Russian stealth Krivak-class warships and 28 submarine-launched KLUK land attack cruise missiles. According to Prime Minister Manmohan Singh, the purchase of the three Russian frigates is a follow-up order to the purchase of three of the same type of warships in the late 1990s.

—"Indian cabinet approves purchase of Russian warships, missiles", PTI News Agency (New Delhi), 6 July 2006; in Lexis-Nexis Academic Universe, 6 July 2006, <http://web.lexis-nexis.com>.

11 June 2006

India successfully test-fires Prithvi, its most sophisticated surface-to-surface missile.

—"India successfully test-fires surface-to-surface missile", PTI News Agency (New Delhi); 11 June 2006; in Lexis-Nexis Academic Universe, 11 June 2006, <http://web.lexis-nexis.com>.

9 March 2006

According to Defence Minister Pranab Mukherjee, the Cabinet Committee on Security (CCS) clears proposal for procurement of 54 Prithvi missiles for the Indian Armed Forces from Defence Public Sector Unit Bharat Dynamics Limited. The CCS also approves the acquisition of 12 Intermediate Jet Trainers (IJTs) from Hindustan Aeronautics Limited, Bangalore and of 11 Interceptive Boats for the Coast Guard.

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—"Indian cabinet approves procurement of Prithvi missiles", PTI News Agency (New Delhi), 9 March 2006; in Lexis-Nexis Academic Universe, 9 March 2006, <http://web.lexis-nexis.com>.

6 February 2006

According to Defense News, Israel signs a secret \$350 million deal with India to develop and manufacture the long-range Barak anti-missile air defense system for both countries' militaries. The deal is signed between Israel Aircraft Industries (IAI) and the Indian Defense Research and Development Laboratory (DRDL). IAI will finance 50 percent of the project which is scheduled to be completed within five years. IAI officials refuse to confirm this information.

—Yaakov Katz, "Israel India sign a \$350 missile deal", The Jerusalem Post, 6 February 2006; in Lexis-Nexis Academic Universe, 6 February 2006, <http://web.lexis-nexis.com>.

30 January 2006

For the third time in as many days, the surface-to-air missile "Akash" is successfully test-fired.

—"India test fires surface-to-air missile again", PTI News agency (New Delhi), 30 January 2006; in Lexis-Nexis Academic Universe, 30 January 2006, <http://web.lexis-nexis.com>.

28 January 2006

India test-fires twice its surface-to-air missile Akash. The sleek 5.6 meter missiles with a range of 25 km are fired from a mobile launcher within a gap of 5 minutes, targeting a moving object attached to a pilotless target aircraft.

—"India tests surface-to-air missile Akash", BBC Monitoring South Asia, 28 January 2006; in Lexis-Nexis Academic Universe, 28 January 2006, <http://web.lexis-nexis.com>.

2005

21 December, 2005

India signs a contract worth \$400 million for purchase of 24 Russian Tunguska-M1 gun-missile air defence complexes. Each air defence complex is comprised of a tracked, armored vehicle carrying two automatic cannons, missiles and radar detection and targeting equipment. The Tunguska is capable of destroying enemy aircraft within a range of 18 km and can be used for defending military units on the march and in battle array from military aircraft and cruise missiles. According to Interfax, Self-propelled Tunguska gun-missile complex is the only air defence system with integrated gun and missile channels.

—" \$400 defence ware deal signed with Russia", The Statesman (India), 22 December 2005; in Lexis-Nexis Academic Universe, 22 December 2005, <http://web.lexis-nexis.com>.

8 December 2005

India successfully test-fires its short range surface-to-air missile Trishul. The solid fuel propelled missile is part of the Integrated Guided Missile Development Programme (IGMDP), has a range of 9 km and flies at supersonic speed.

—"Trishul test-fired", The Statesman (India), 9 December 2005; in Lexis-Nexis Academic Universe, 9 December 2005, <http://web.lexis-nexis.com>.

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1 December 2005

India test-fires the Army version of supersonic cruise missile BrahMos. This is the successful 11th flight of the missile, jointly developed by India and Russia. The Air Force version is to be developed soon following approval by both governments. The version will be integrated with the Sukhoi-30 MKI.

—T.S. Subramanian, "Army version of Brahmos test-fired", The Hindu, 1 December 2005; in Lexis-Nexis Academic Universe, 1 December 2005, <http://web.lexis-nexis.com>.

24 November 2005

According to the Scientific Adviser to the Defence Minister, M. Natarajan, a Rs. 300-crores facility will be set up by the Defence Development and Research Organization (DRDO) at Nashik to manufacture propellants for missiles and rockets. It would help in research on process engineering and production of propellants required for different programmes.

—"Nashik facility to make missile propellants", The Hindu, 24 November 2005; in Lexis-Nexis Academic Universe, 24 November 2005, <http://web.lexis-nexis.com>.

23 November 2005

According to Dr Prahalada, chief controller and director of India's Defence Research and Development Laboratories (DRDL), the Indian government agrees in principle to allow exports of Akash, Trishul, Naag, and BrahMos class of missiles. The clearances to which country they can be exported is yet to come. Besides earning foreign exchange, it would also mean better job opportunities for industries and employment opportunities for unemployed. Although there are several countries dealing in missiles, India should be able to capture some market as the cost structure for Indian missiles is competitive.

—"Indian government agrees "in principle" to allow missile export", PTI news agency, New Delhi, 23 November 2005; in Lexis-Nexis Academic Universe, 23 November 2005, <http://web.lexis-nexis.com>.

5 October 2005

India successfully test-fires short range surface-to-air missile "Trishul". Developed by the Defence Research and Development Organization (DRDO), "Trishul" has a triple battlefield role for the army, air force and navy. The solid fuel propelled missile has a range of 9 km and can be fitted with fragmented warhead.

—"India test fires "Trishul" surface-to-air missile", BBC Monitoring South Asia, 5 October 2005; in Lexis-Nexis Academic Universe, 5 October 2005, <http://web.lexis-nexis.com>.

4 October 2005

India and Pakistan sign accords on pre-notification of ballistic missile tests and setting up of a communication link between the Indian Coast Guard and the Pakistan Maritime Security Agency. The agreement on pre-notification of missile tests entails that both countries provide each other advance notification before undertaking any surface-to-surface ballistic missile test. An understanding on this was reached between the two countries at the third round of N-CBM talks on 5 and 6 August in Delhi.

—"Missiles on notice for peace route", The Statesman (India), 4 October 2005; in Lexis-Nexis Academic Universe, 4 October 2005, <http://web.lexis-nexis.com>.

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6 July 2005

The Russian-Indian joint venture BrahMos begins serial manufacture of its new cruise missile to order for the Indian navy. According to Aleksandr Maksichev, the acting general director of the Mashinostroyeniye association, the missile will not only be supplied to the Indian and Russian navies, but will be available to other countries as well.

—"Russian-Indian cruise missile goes into production", BBC Monitoring Former Soviet Union, 6 July 2005; in Lexis-Nexis Academic Universe, 6 July 2005, <http://web.lexis-nexis.com>.

28 June 2005

India and the United States sign a new framework for defence relationship for the next ten years, providing opportunities in areas such as technology transfer, co-production and research and development. Conducting joint exercises and exchanges; collaborating in multinational operations; strengthening the militaries' capabilities to defeat terrorism; enhancing the capabilities to combat proliferation of weapons of mass destruction; and expanding collaboration in missile defence are envisaged in the framework. It is also agreed upon that the Defence Policy Group shall continue to serve as the primary mechanism to guide the bilateral strategic defence relationship. A Defence Procurement and Production Group is also to be set up, to oversee defence trade and look at prospects for co-production and technology collaboration.

—Sridhar Krishnaswami, "India, U.S. sign framework for defence cooperation", The Hindu, 30 June 2005 ; in Lexis-Nexis Academic Universe, 20 June 2005, <http://web.lexis-nexis.com>.

13 May 2005

The Indian parliament approves a bill to prevent transfer of weapons of mass destruction and their technology from India. The government assures that this bill would in no way hinder development of defence capabilities in the country. According to the External Affairs Minister Natwar Singh, the Weapons of Mass Destruction and their Delivery Systems (Prohibition of Unlawful Activities) Bill, 2005, does not seek to check development of missile technology, but prevent leakage of this technology.

—"Indian parliament approves weapons of mass destruction bill", BBC Monitoring South Asia, 13 May 2005; in Lexis-Nexis Academic Universe, 13 May 2005, <http://web.lexis-nexis.com>.

12 May 2005

India test-fires Prithvi, its most sophisticated surface-to-surface medium range missile. Scientists of the Defence Research and Development Organization (DRDO) and army personnel, who conduct the test, describe it as a user's trial.

—"India test-fires nuclear-capable missile Prithvi", BBC Monitoring South Asia, 12 May 2005; in Lexis-Nexis Academic Universe, 12 May 2005, <http://web.lexis-nexis.com>.

11 May 2005

According to the Defence Research and Development Laboratory (DRDL) Director Prahlada, the indigenously built medium range surface-to-air missile Akash can be used for disaster management. Advanced computer software used for missile development can help coastal States predict natural calamities, like tsunami, and coordinate rescue operations.

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—"Akash can be used in disaster management", The Hindu, 11 May 2005; in Lexis-Nexis Academic Universe, 11 May 2005, <http://web.lexis-nexis.com>.

16 April 2005

BrahMos, the supersonic cruise missile jointly developed by India and Russia, scores a perfect ten out of ten. This is the first time that BrahMos is equipped with a live warhead and the flight takes place in the combat-mode of the Navy. The event signals that the production of the missile for the Navy has started. BrahMos is a versatile missile that can be launched from silos on land, big trucks, ships, aircraft and submarine. Work has started on developing the missile to be launched from aircraft.

—T.S. Subramanian, "Brahmos test-fired off West coast", The Hindu, 16 April 2005; in Lexis-Nexis Academic Universe, 16 April 2005, <http://web.lexis-nexis.com>.

24 March 2005

According to the Nag Project Director, S. S. Mishra, the aerial version of anti-tank Nag missile is under development. Nag, an all-weather, fire-and-forget anti-tank missile, is one of the five developed by the Defence Research and Development Organization (DRDO) under the Integrated Guided Missile Development Programme (IGMDP). The others are Akash, Trishul, Prithvi and Agni. In addition, India is also working on developing a third generation portable Nag missile. It is planned to develop the missile in four to five years. The U.S. and Israel already have such missiles.

—Y. Mallikarjun, "Aerial version of Nag is being developed", The Hindu, 24 March 2005; in Lexis-Nexis Academic Universe, 24 March 2005, <http://web.lexis-nexis.com>.

19 March 2005

The third generation anti-tank guided missile system "Nag" is successfully test-fired in western Indian state of Maharashtra. According to the director of Defence Research and Development Laboratory (DRDL) Prahlada, "Nag is an all-weather day and night weapon and its unique guidance system based on infra-red imaging ensures high accuracy and mainly targets a battle tank from the top."

—"India test fires anti-tank missile", BBC Monitoring South Asia, 20 March 2005; in Lexis-Nexis Academic Universe, 20 March 2005, <http://web.lexis-nexis.com>.

24 February 2005

For the second time in four days, India successfully test-fires its indigenously developed medium-range surface-to-air missile Akash.

—"India test-fires medium range surface-to-air missile", BBC Monitoring South Asia, 24 February 2005; in Lexis-Nexis Academic Universe, 24 February 2005, <http://web.lexis-nexis.com>.

21 February 2005

India successfully test-fires Akash, its surface-to-air missile. It is the third consecutive flight in which the missile showed total consistency. The problems encountered in the earlier flight are overcome and the missile travels its entire range of 25 km and hits the pilotless target aircraft "Lakshya."

Related content is available on the website for the Nuclear Threat Initiative, www.nti.org.



—T.S. Subramanian, "Akash test-fired successfully", *The Hindu*, 22 February 2005; in Lexis-Nexis Academic Universe, 22 February 2005, <http://web.lexis-nexis.com>.

12 February 2005

India continues work on its missile shield (a 200 sq km area defence system) that can protect big cities and strategic facilities like nuclear reactors and space launching sites against incoming missiles. The project began about two years ago and could be finished in the next five or six years. The system will comprise three parts. The first part will be a long-range tracking radar that will be able to pick up incoming missiles moving at supersonic speeds about 600 km away. The second part will be the creation of a C3I system that will allow the registering of information and decision-making leading to action. The third component will be the surface-to-air missile. In the past, India has been offered similar systems by Russia (the S-300) and Israel (the Arrow, which has American components), but neither has been agreed to by India as yet.

—"Missile shield heading for completion", *The Statesman (India)*, 12 February 2005; in Lexis-Nexis Academic Universe, 12 February 2005, <http://web.lexis-nexis.com>.

19 January 2005

India successfully tests Trishul, its most sophisticated short range surface-to-air missile. The missile flies at supersonic speed and can be used by the army, air force and navy.

—"India test-fires short-range surface-to-air missile", *BBC Monitoring South Asia*, 19 January 2005; in Lexis-Nexis Academic Universe, 19 January 2005, <http://web.lexis-nexis.com>.

2004

22 December 2004

During a visit to the Vellore Institute of Technology to inaugurate the 21st All-India Manufacturing Technology Design and Research Conference, the Director of India's premier missile development organization, Defense Research & Development Laboratory (DRDL) Dr. Prahlada states that his organization is working on the development of a hypersonic vehicle capable of flying at a speed 10 times the speed of sound; and development will be completed within three years. Prahlada also states that DRDL is also working on a beyond-the-visual-range air-to-air missile – Astra, which will be ready within five years.

—"Hypersonic air vehicle will be ready in three years," *Hindu*, www.hinduonnet.com, 22 December 2004.

22 December 2004

India tests a land-to-land or Army-version of the BrahMos supersonic cruise missile. The flight-tested missile successfully distinguishes and destroys a pre-determined building from within a cluster of buildings.

—T.S. Subramanian, "BrahMos-II bang on target," *Hindu*, www.hinduonnet.com, 22 December 2004.

13 December 2004

In an address to the 56th convention of the Aeronautical Society of India, the CEO and Managing Director of the Indo-Russian joint-venture company BrahMos Aerospace Pvt. Ltd. Dr. Sivathanu Pillai states that the first BrahMos supersonic cruise missile will be deployed on an Indian Navy warship in 2005. BrahMos Aerospace has already

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received a letter of intent and monetary advance from the Navy on the basis of which production of the missile has begun. Pillai also discloses that the Air Force version of the BrahMos will fly on the Sukhoi-30 and will require reconfiguration to "reduce the booster for the aircraft." Although the development time for the Air Force variant is expected to be about four to five years, Pillai expresses confidence that BrahMos Aerospace will be able to achieve the task within "three years." The BrahMos will be produced by a consortium of 20 Indian (seven public and 13 private sector) and 10 Russian companies. The Russian equity in BrahMos Aerospace has been financed through the diversion of Indian loan repayments to Russia.

—"IAF variant of BrahMos likely in three years," Times of India, 13 December 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 13 December 2004.

9 December 2004

In a written reply to parliament, Indian Defense Minister Pranab Mukherjee states that the indigenously developed Trishul and Akash surface-to-air missiles and the Nag anti-tank missiles will be ready for user-trials by December 2005. The Prithvi-I has already been inducted into the Army and development trials of the Air Force and Navy versions of the Prithvi – Prithvi-II and Dhanush – have been completed. The BrahMos, Agni-I, and –II are in the process of induction into the armed services. The Indian government, Mukherjee states, is not considering the export of the Prithvi and Agni ballistic missiles as both classes of missiles are subject to international nonproliferation restrictions. However, certain countries have shown interest in purchasing the Nag and the BrahMos.

—"Akash, Trishul, Nag missiles to user," Press Trust of India, 9 December 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 9 December 2004.

6 December 2004

India and Russia sign an agreement to protect intellectual property associated with Russian military technology transferred to India. Indian Defense Minister Pranab Mukherjee states that efforts to draft a formal agreement will commence in January 2005. Russian Defense Minister Sergei Ivanov indicates that Russia is ready to increase its investment in the BrahMos cruise missile project in which both countries hold 50 percent of the shares.

—"India-Russia will sign," Aviation Week & Space Technology, 6 December 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 9 December 2004.

6 December 2004

India and Russia plan on developing an air-version of the BrahMos cruise missile. The air-version will be integrated with Sukhoi-30MKI combat aircraft. The air-version of the missile will be developed in two years; it will be lighter than the naval version, but will have the same range. The air-version will also have an improved booster and a modified cap nose. The Defense Research & Development Organization (DRDO) is also planning to test a land- or Army-version of the missile from a mobile launch complex on ground towards a land-target.

—"India-Russia to develop air-launched version of BrahMos," Hindu, 6 December 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 5 February 2004.

6 December 2004

India's President Dr. A.P.J. Abdul Kalam visits the BrahMos Aerospace headquarters in New Delhi. In an address to

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the company's staff Kalam says that BrahMos is one of the most competitive missile systems and thrust should be given to marketing the missile to friendly Third World countries. If the missile is not marketed in time, it would face competition from other missiles in the market.

—"India-Russia to develop air-launched version BrahMos," Hindu, 6 December 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 5 December 2004.

6 December 2004

India indicates interest in purchasing the Arrow anti-ballistic missile system from Israel in talks with the Israeli defense ministry Director-General Amos Yaron and Israel Aircraft Industries CEO Moshe Qeret, who are on a visit to India as part of Industry and Trade Minister Ehud Qlmert's entourage.

—"India interested in buying Israel's anti-missile system," BBC Monitoring International Reports, 6 December 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 6 December 2004.

4 December 2004

Russian President Vladimir Putin inaugurates a joint Indo-Russian military venture in New Delhi to manufacture the BrahMos supersonic anti-ship cruise missile.

—"Putin inaugurates Indian-Russian missile manufacturing complex," DPA, 4 December 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 5 December 2004.

3 December 2004

India concedes Russia's two-year old request for a defense secrecy agreement to ensure that high-end defense equipment and technology received from Russia is not sold or transferred to another country. Indian Defense Minister Pranab Mukerhjee says that the agreement is likely to be negotiated within the next four or five months.

—Sandeep Dikshit, "India, Russia plan on fresh investment for developing BrahMos missile," Hindu, 3 December 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 3 December 2004.

3 December 2004

India and Russia agree to take their strategic partnership to a "higher" technological level, despite differences concerning the protection of intellectual property rights (IPR) and the maintenance and delivery schedules of weapon systems. Russia would like India to sign an IPR agreement immediately so that advanced weapon systems such as the BrahMos cruise missile jointly developed by both countries are not exported by India to third countries without Russia's consent. In turn India would like Russia to provide strong commitments on maintenance of delivery schedules on contracted weapon systems, uninterrupted supplies of spares, and lifetime product support. Russian Defense Minister Sergei Ivanov says that "we [Russian federation] are prepared to transfer frontier technology to India in a strategic tie-up based on a new pattern of defense cooperation."

—"India, Russia to make defense ties stronger," Times of India, 3 December 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 3 December 2004.

2 December 2004

Russia agrees to expand its role in the joint Indo-Russian BrahMos cruise missile project. Russian Defense Minister Sergei Ivanov says that "in the coming days executive orders will be passed so that the share of Russia's side in the

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project will be scaled up." He adds that the "India, Russia relationship has now moved from a buyer-seller relationship to joint technology development of new projects."

—"Russia to shore up support to India in cruise missile project," AFP, 2 December 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 3 December 2004.

2 December 2004

Russian Defense Minister Sergei Ivanov expresses skepticism about the export potential of the BrahMos supersonic missile project and tells reporters that he is "not enthusiastic about the project. So far it has been a stillborn baby." Ivanov further says, "The Russian side should sign a government resolution to increase the charter capital of the Russian company involved in the project. I will hope this will happen in the nearest future."

—"Russian minister skeptical about BrahMos missile project with India," BBC Monitoring International Reports, 2 December 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 2 December 2004.

2 December 2004

India agrees to participate in Russia's Global Navigation Satellite System (GLONASS). Under the terms of the agreement signed with Russia, India will participate in the program by launching Russian satellites and the two countries will jointly operate the system. India could also potentially gain access to the military applications of the GLONASS system, which could help improve the accuracy of Indian missiles.

—Vladimir Radyuhin, "India, Russia to build space navigation system," Hindu, 2 December 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 2 December 2004.

2 December 2004

India and Russia ink three protocols concerning fresh investments in the BrahMos supersonic cruise missile program after a meeting between the Indian and Russian defense ministers Pranab Mukherjee and Sergei Ivanov. Under the agreements Russia will take up a stake of 50 to 60 percent in the BrahMos project, which is expected to provide the project with an additional \$50 million. According to Russian officials, 360-370 BrahMos cruise missiles could be produced annually. India and Russia also agree to draft an intellectual property agreement in the next four or five months concerning intellectual property in collaborative defense projects.

—"India, Russia sign protocols for producing missiles," Press Trust of India, 2 December 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 2 December 2004.

1 December 2004

The Russian space agency says that it will continue cooperation with India in the development of an oxygen-hydrogen booster for space rockets. The agency's head Anatoly Perminov says, "In Russia, we are planning to install the booster in the new promising Angara rocket. The Indian project is already ahead of our own. In fact, both Russia and India benefit from that."

—"Russia, India to continue cooperation in developing space booster," BBC Monitoring International Reports, 1 December 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 1 December 2004.

30 November 2004

The Defense Research & Development Organization (DRDO) uses a live warhead during a test of the Akash surface-

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to-air missile. This is the first time the missile is tested with a live warhead and according to Dr. Prahlada, Director of DRDO's Defense Research & Development Laboratory (DRDL), the event represents "... a milestone in the history of India's defense research and development."

13 November 2004

The Defense Research & Development Laboratory (DRDL) plans to flight-test a ground-to-ground version of the BrahMos supersonic cruise missile in December 2004. It has also set up production facilities and can deliver one missile every month. The Director of DRDL Dr. Prahlada says, "the program [BrahMos] has matured and capability to test fire and manufacture them as per user demands has been achieved."

—"BrahMos, Akash, Trishul to be test fired soon," Business Insight, 13 November 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 16 November 2004; "BrahMos, Akash, Trishul to be test fired soon," Business Line, 13 November 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 14 November 2004.

7 November 2004

India's Defense Research & Development Organization (DRDO) conducts the third test of the Dhanush, the naval version of the Prithvi short-range ballistic missile. The missile is launched using a stabilized launcher on the naval ship INS Subhadra, anchored off Chandipur-at-sea on the Orissa coast. The head of the DRDO team Dr. Saraswat says that "all mission parameters in respect of accuracy and range were fully met."

—"Dhanush test fired from Orissa coast," Press Trust of India, 7 November 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 7 November 2004; "Dhanush missile successfully test fired," Hindu, 8 November 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 8 November 2004.

5 November 2004

In its annual report, India's Defense Ministry says that there is the 'threat of use of nuclear weapons against the country.' The report further states, "The Indian armed forces have to be prepared for the full spectrum of security challenges from terrorism, low intensity conflict, to conventional war and the possibility of the use of nuclear weapons and missiles." Along with a minimum deterrent, India also requires a balanced mix of land-based, maritime, and air capabilities.

—"India requires independent deterrent capability: Report," Press Trust of India, 5 November 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 5 November 2004.

3 November 2004

The naval version of the BrahMos supersonic cruise missile is tested in a ship-to-ship mode. The missile is fired from the naval destroyer Rajput and used to attack a decommissioned ship. This is the fourth test of the BrahMos and officials from the Defense Research and Development Organization (DRDO) report that the missile "had a perfect hit on the targeted ship." According to Dr. Sivathanu Pillai, Chief Executive Officer of the BrahMos project, "the major achievements of the tests were mid-course maneuverability of the missile and the advanced fire control systems, which functioned 100 percent."

—"Brahmos successfully tested," Press Trust of India, 3 November 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 3 November 2004; "Brahmos anti-ship missile tested," Business Line, 4 November 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 4 November 2004.

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27 October 2004

India tests a naval version of the Prithvi – dubbed Prithvi-III – from the Integrated Test Range (ITR) at Chandipur. The missile and its sub-systems are being developed under the project name K-15 and have been designated fast-track projects by the Defense Research & Development Organization (DRDO). The Prithvi-III can be launched from under water and this was the first test of the missile from a specially designed canister base inserted in an artificial water body.

—"Prithvi-III test fired," Press Trust of India, 27 October 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 28 October 2004.

22 October 2004

Russian Defense Minister Sergei Ivanov denies reports that Russia plans to lease nuclear submarines to India. Ivanov says that there were discussions with India concerning military deliveries earlier during 2004, but "there was no talk of leasing any submarines."

—"Russia denies reported lease of nuclear submarine to India," Xinhua General News Service, 22 October 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 23 October 2004.

22 October 2004

A Russian military industry source says that "Moscow and New Delhi have signed a contract under which the Indian Navy will get a Project 971 multi-role submarine on a 10-year lease." The submarine, which is believed to be 85 percent complete, is expected to be handed over to India by 2007. Other Russian media reports suggest that the construction of the two unfinished Project 971 nuclear submarines, which had earlier been suspended for the lack of funds, has resumed at the Amur Shipyards in Komsomolsk-on-the-Amur in the Russian Far East. India is reported to have made an advance payment of \$100 million towards the lease contract. The Project-971 submarines can be equipped with 28 nuclear-capable 3000km-range cruise missiles; and the Indian Navy versions of the submarine will likely be armed with the 300km-range nuclear capable Club cruise missiles.

—Vladimir Radyuhin, "Russia to lease nuclear submarine to India," Hindu, 22 October 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 22 October 2004.

18 October 2004

Indo-US negotiations on phase II of the 'Next Phase in Strategic Partnership' (NSSP) enters a critical stage. Indian officials say that "the US is looking to discuss changes in our domestic laws to tighten export controls" and wants to flag the issue of "human resources." The United States is concerned that Indian nuclear and missile scientists would be an invaluable source to potential proliferators because they are the only pool of talent familiar with the "start up stage" of nuclear and missile programs. The Indian government believes that the country's existing legal framework of export controls is robust. However, Indian officials admit that the whole framework can be "toughened" further.

—"Siddharth Varadarajan, "India-US negotiations entering crucial phase," Hindu, 18 October 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 18 October 2004.

10 October 2004

India plans on testing the Dhanush – the sea-version of the land-based Prithvi short-range ballistic missile – in the

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near future. At present the Indian Navy 's reservations about the Dhanush concern its size and the difficulties of launching the missile in rough sea conditions. A software problem that led the missile to loop after launch during an earlier test, has reportedly been resolved. The Defense Research & Development Organization (DRDO) is also working on a submarine-launched version of the BrahMos cruise missile and the Indian Navy has reportedly designated its Kilo class submarines as the likely platform for these missiles. The navy expects the submarine-version of the BrahMos to be developed within the next three years.

—"Dhanush to be put on trial soon," Statesman, 10 October 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 10 October 2004.

10 October 2004

According to the CEO and Managing Director of BrahMos Aerospace Dr. A. Sivathanu Pillai, the 'air launch' version of the cruise missile was in the design stage will be developed in another two to three years. Pillai says that BrahMos trials against sea-targets have been very successful.

—"Air launch versions of BrahMos in two to three years," Press Trust of India, 10 October 2004; in Lexis-Nexis-Academic Universe, <http://web.lexis-nexis.com>, 10 October 2004.

9 October 2004

The US Ambassador to India David Mulford says in a published interview that India and the United States have gone beyond mere discussions on the missile defense and the issue under discussion now is to "figure out which [ballistic missile] system is needed where."

—Amit Baruah, "US-India have gone beyond talking about ballistic missile defenses," Hindu, 9 October 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 9 October 2004.

5 October 2004

The Indian government floats a new approach to form partnerships between government owned defense laboratories and private companies to encourage the latter to develop defense products. Under the new approach – government-owned company-run (GoCo) – the Defense Research & Development Organization (DRDO) will enter into ventures with a small equity and guarantee private sector companies that undertake to manufacture the products with a buy back guarantee. One of the first proposals to be floated under the GoCo model is to develop servo valves uses in the control system of missiles.

—"Defense industry joint venture firms in offing," Business Insight, 5 October 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 7 October 2004.

2 October 2004

The Director of India's leading missile research and development laboratory – Research Center Imarat (RCI) -- Dr. V.K. Saraswat outlines the key priority areas for the laboratory in the future. According to Saraswat, Indian defense scientists aim at developing 'smart' missiles that are smaller, lighter, agile, and can home in on targets with great accuracy. The RCI's key focus areas include hypersonic vehicles, miniaturized missile systems, nanotechnology, very large systems integration (VLSI), and homing guidance. New miniaturization technologies of particular interest to RCI are miniaturized electro-mechanical systems (MEMS) and system on chip (SOP). In addition, the laboratory is also focusing on developing a new range of rugged materials such as ceramics and lightweight composites that

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can withstand temperatures of up to 4,000°C. Saraswat says that facilities at RCI are being expanded to facilitate development of technologies and products and that he hopes the projects will come to fruition during the next five to seven years.

—"Defense scientists embark on making 'smart' missiles," Business Line, 3 October 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 3 October 2004.

30 September 2004

According to the Deputy Program Director of the BrahMos cruise missile program, S. Sundararajan, it will take at least a decade before the ramjet technology developed for the BrahMos missile can be declared mature.

—"BrahMos will have to wait," Hindu, 30 September 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 30 September 2004.

18 September 2004

India will display the BrahMos cruise missile at the South African Defense Expo scheduled to begin on 21st September 2004 in Pretoria.

—"BrahMos to be put on display, sale at S. African defense expo," Press Trust of India, 18 September 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 19 September 2004.

9 September 2004

The Indian Air Force (IAF) is reportedly increasing its arsenal of Prithvi short-range ballistic missiles. The air force recently placed an order for 54 missiles. The IAF's two missile squadrons – one of which may be called the 2203 Squadron – are being raised in Hyderabad. However, the missiles will be moved closer to the border with Pakistan during a crisis or war.

—Srinjoy Chowdhury, "IAF increasing Prithvi arsenal," Statesman, 9 September 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 8 September 2004.

8 September 2004

According to the joint statement issued by the Indian and Pakistani foreign ministers at the conclusion of bilateral talks in New Delhi, the two countries will continue to hold expert level meetings to discuss the draft agreement on advance notification of missile tests.

—"Text of the joint statement issued at the conclusion of Indo-Pak talks at foreign ministers' level," Pakistan Press International Information Services Limited, 8 September 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 10 September 2004.

6 September 2004

In an address before the Delhi Policy Group (DPG) in New Delhi, India's Deputy National Security Advisor Satish Chandra criticizes the proliferation security initiative (PSI) and ballistic missile defense (BMD) -- two US initiatives designed to combat the proliferation of weapons of mass destruction. Chandra questions the legality of PSI and says that missile defense was "part of the paradigm shift where it [United States] could consider resorting to the use of nuclear weapons in a pre-emptive mode." Chandra also laments that instead of moving in the direction of nuclear disarmament, the United States has "been advocating new rationales for the retention of nuclear weapons

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and developing new types of nuclear weapons." Chandra describes measures such as PSI as "ad-hoc initiatives" and regrets that India has been "at the receiving end of existing export control regimes." He argues that the "US moves need to be analyzed closely with a view to ensuring that the new systems being contemplated do not hurt us...the US has announced several measures, most notably the PSI as well as the container security initiative to address this threat. Some of the measures contained in these proposals are commendable but some others could pose problems. Fore instance, there are obviously problems of legality in the interdictions envisaged under the PSI. There are also problems as to what would trigger these interdictions." Chandra emphasizes that the international community needs to undertake "concerted actions through universally negotiated programs and systems" rather than "ad-hoc, piecemeal measures."

—Siddharth Varadraj, "India signals wariness on missile defense," Hindu, 6 September 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 6 September 2004.

1 September 2004

The outgoing chief of India's Defense Research & Development Organization (DRDO) Dr. V.K. Aatre tells reporters that India will be collaborating with Israel and the United States to develop nano-materials and high-tech components needed for electronic warfare systems. Aatre says that India has decided to launch joint programs with Israel in the field of electronic warfare, where both countries are on an equal footing. "Israel is very strong in sensors and packaging," says Aatre, "...we would like to work on fibre-optic gyros and micro-electromechanical systems." Responding to questions on Indo-US defense cooperation, Aatre says that India and the United States have collaborated in the life sciences and would launch joint programs in the areas of nano-technology and nano-research.

—"India to tie up with Israel, US for e-warfare systems," Financial Express, 1 September 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 1 September 2004.

31 August 2004

The head of India's Defense Research & Development Organization (DRDO) Dr. V.K. Aatre tells reporters during his farewell press conference that DRDO is training the Indian Army's missile group in launch techniques, mounting warheads, and other technical parameters of surface-to-surface missiles. Aatre confirms that some Agni-I and II ballistic missiles have been delivered to the Army. "We have completely developed systems for these two missiles," says Aatre, "and a certain number of them have been delivered to the Army." Aatre also confirms that India will "soon go in for launch of the longer range 3,000km version of the missile Agni-III....the technique for longer-range missiles exists. We are in the process of putting it together," he says.

—"India deploying Agni missiles," Press Trust of India, 31 August 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 31 August 2004; "Agni-III launch soon, says outgoing DRDO chief," Economic Times, 1 September 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 1 September 2004.

31 August 2004

The head of India's Defense Research & Development Organization (DRDO) Dr. V.K. Aatre denies that Israel has already helped India build guided missiles. Aatre says Indo-Israeli defense cooperation was confined to research and development in the areas of sensors and fiber-optic gyroscopes for the military.

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—"India plans to build long-range missiles with Israel: Official," AFP, 31 August 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 1 September 2004.

29 August 2004

India flight-tests the Agni-II ballistic missile from Wheeler Island in the Bay of Bengal off the Orissa coast. This is the third test of the Agni-II. Project Chief R.N. Agarwal says, "The launch of the Agni-II from its rail mobile launcher met all the mission objectives, including achieving the high accuracy in guiding the payload to the designated target at a 1,200 kilometer range." Agarwal adds, "The white hot object (payload) was tracked by pre-positioned naval ships confirming the impact and success of the mission."

—"Agni-II test fired," Press Trust of India, 29 August 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 29 August 2004; "India tests nuclear-capable ballistic missile," AFP, 29 August 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 30 August 2004.

26 August 2004

Replying to a question raised in parliament, India's Defense Minister says that the "navy has placed a Letter of Interest for inducting BrahMos supersonic cruise missiles in certain types of ships and in-shore. Production has commenced for induction in 2005."

—"BrahMos supersonic cruise missile to be inducted in Navy next year," Press Trust of India, 26 August 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 26 August 2004.

20 August 2004

India's United Progressive Alliance (UPA) government indicates that it intends to continue with the preceding National Democratic Alliance (NDA) government's policies on missile defense. In a written response to a question raised in parliament whether the UPA government had formed an opinion on the US offer to include India in the missile defense program, the Minister of State for External Affairs E. Ahamed replies, "presentations and briefings by the US side on missile defense have been on the agenda of the India-US Defense Policy Group since 2001. The US side made a presentation on missile defense in Delhi on 1 June 2004. There is no change in the policy of the government under which it has held preliminary discussions and dialogue with the US on the subject of missile defense."

—Amit Baruah, "UPA continuing NDA policy on missile defense," Hindu, 20 April 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 20 April 2004.

19 August 2004

The Indian parliament's Standing Committee on Defense recommends that the Indian government should set up aerospace command to tap the potential for outer space in preparation for defense and future war scenarios. Despite appreciating the Indian government's concerns about a potential arms race in outer space, the committee in its report urges the government to prepare for any threat from outer space. The committee also urges the government to explore the possibility of exporting missiles built at Bharat Dynamics Ltd. in the international defense market.

—"India should go ahead with plans to tap potential space tech," Press Trust of India, 19 April 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 19 August 2004.

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19 August 2004

India's Defense Minister Pranab Mukherjee informs parliament that the Agni-I ballistic missile that was last tested on 4th July 2004 "is in production for induction into the Army."

—"India's Agni-I missile in production stage," Press Trust of India, 19 August 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 19 August 2004.

18 August 2004

The Scientific Advisor to India's Defense Minister Dr. V.K. Aatre says that the 3,000km-range Agni-III is in the final phase of integration, but indicates no time frame for flight-testing the missile. He also discloses that the Defense Research & Development Organization (DRDO) has begun developing the beyond-the-visual range Astra air-to-air missile; the latter will be integrated with the Light Combat Aircraft (LCA).

—"3,000km range Agni-III in final phase of integration: Aatre," Press Trust of India, 18 August 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 18 August 2004.

31 July 2004

India's new Chief of Naval Staff Admiral Arun Prakash says that the "navy needs nuclear submarines but it is up to the government to take a decision on the acquisition." Prakash says that his goal is to make the navy "network centric" by interlinking long-range missiles, radars, and sensors on the naval warships through satellite and information technology to deliver a lethal punch.

—"India needs nuclear submarines, says new naval chief," Press Trust of India, 31 July 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 1 August 2004.

31 July 2004

Addressing reporters at the Aeronautical Society of India meeting in Hyderabad, the Scientific Advisor to India's Defense Minister Dr. V.K. Aatre says that India is seeking collaboration with Israel in the development of long-range missiles. "Wherever they have strengths," says Aatre, "we want to jointly develop the missiles so that both the countries can benefit and share designs, costs, risk." Aatre also discloses that a ring-laser gyro indigenously developed by the Defense Research & Development Organization's (DRDO) laboratory at Imarat would find applications in the navigational systems of missiles and the Light Combat Aircraft (LCA).

—"Longer-range missiles in the offing: defense advisor," Press Trust of India, 31 July 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 1 August 2004.

21 July 2004

Indian Defense Minister Pranab Mukherjee informs parliament that the government has begun equipping the country's armed services with the BrahMos cruise missile. After a series of successful launches, the navy has decided to equip a number of its warships with the missile. Mukherjee also notes the good prospects of selling the BrahMos in the international defense market. However, he explains that marketing will require the joint consent of the Indian and Russian governments. Indian defense sources suggest that the five Rajput or Kashin-II class destroyers in the navy's fleet would be among the first to be equipped with the missile.

—Yuri Sidorov, "India equipping armed forces with BrahMos missile," ITAR-TASS, 21 July 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 22 July 2004; "Navy starts inducting BrahMos," Business Insight,

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23 July 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 10 August 2004; Rajat Pandit, "Navy begins to induct BrahMos," Times of India, 24 July 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 26 July 2004.

20 July 2004

An Israeli defense delegation holds high-level talks with India's Defense Research & Development Organization (DRDO) on a number of joint projects in high-technology areas including the development of unmanned aerial vehicles (UAV).

—"High-level Israeli defense delegation holds talks with DRDO," Press Trust of India, 20 July 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 20 July 2004.

4 July 2004

India tests its 700km-range Agni-I ballistic missile from a mobile launcher on Wheeler Island off eastern Orissa state. This is the third flight-test of the Agni-I. The Scientific Advisor to India's Defense Minister Dr. V.K. Aatre says the prime motive for this test was to reconfirm the technical parameters set for the user (Army) associated launch. Indian defense sources claim the test showed considerable improvements in the missile's re-entry and maneuverability; according to data obtained from ground radars, telemetry stations and visual observations, all objectives of the test were met. The Director of the Advanced Systems Laboratory Dr. R.N. Agarwal (Mission Director) calls the test a "text book" launch.

—Pratap Mohanty, "India tests nuclear capable missile," Agence France Presse, 4 July 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 5 July 2004; "India testfires upgraded Agni-I," Times of India, 5 July 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 5 July 2004; Sandeep Dikshit, "Army's missile group to maintain Agni A-1," Hindu, 5 July 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 5 July 2004.

23 June 2004

The Indian navy makes public India's naval doctrine and makes the case for a sea-based nuclear capability. The doctrine emphasizes that nuclear weapons have the potential to deliver unacceptable damage to any regime and urges the Indian government to invest in nuclear submarines capable of launching nuclear tipped missiles.

—"New Indian naval doctrine says nuclear submarines 'essential'," BBC Monitoring International Reports, 23 June 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 23 June 2004.

21 June 2004

According to the text of the joint statement issued by India and Pakistan after the expert-level talks on nuclear confidence building measures, both countries agree to "work towards concluding an agreement with technical parameters on pre-notification of flight testing of missiles, a draft of which was presented by the Indian side."

—Amit Baruah, "Text of joint statement," Hindu, 21 June 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 21 June 2004.

21 June 2004

In an address to Indian and American space scientists during a five-day conference in Bangalore the US

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Ambassador to India David C. Mulford says that the United States desires to "deepen" the ongoing dialogue with India on missile defense and engage it in a "more sophisticated" and advanced level. Mulford elaborates that "there is already conversation that is going on. The question is the degree of sophistication over confidentiality if you like..."

—"US desires to deepen missile defense dialogue with India," Press Trust of India, 21 June 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 21 June 2004.

19 June 2004

India's Defense Minister Pranab Mukherjee says that the Agni III ballistic missile was scheduled for a flight-test in November 2003; but the test was postponed. However, the missile will be tested in 2004. Without giving any precise time frame for the test, Mukherjee tells reporters, "you will get to know when we carry out the tests."

—"Agni III missile to be test-fired "when required" – Indian Defense Minister," BBC Monitoring International Reports, 20 June 2004; in Lexis-Academic Universe, <http://web.lexis-nexis.com>, 20 June 2004.

15 June 2004

The Defense Research & Development Organization (DRDO) plans on conducting one final demonstration test of the BrahMos cruise missile and is awaiting orders from the Indian government to commence mass production. Mass manufacture is expected to begin by the end of 2004. The DRDO's Defense Research & Defense Laboratory (DRDL) has the capacity to produce four to six BrahMos missiles annually.

—DRDL awaits orders to begin BrahMos production," Business Insight, 15 June 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 26 June 2004.

13 June 2004

India tests a surface-to-surface army version of the BrahMos supersonic cruise missile. This is the seventh test of the missile. The missile was launched vertically from a container using a mobile autonomous launcher. Of the seven flight tests conducted so far, two have been conducted from ships, three from land, and two from land-based TATRA mobile launchers. Although no missile has been flight tested using submarine platforms, a Defense Research & Development Organization (DRDO) source says that the submarine version is ready.

—"BrahMos test-fired successfully," Business Insight, 14 June 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 25 June 2004; T.S. Subramanian, "Kalam congratulates scientists," Hindu, 14 June 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 14 June 2004; T.S. Subramanian, "BrahMos launch successful," Hindu, 14 June 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 14 June 2004.

4 June 2004

The Scientific Advisor to India's Defense Minister V.K. Aatre says that India has begun integrating the 3,000km Agni-III ballistic missile with an aim to test it in 2004. However, Aatre says that it is difficult for him to predict precisely when the missile will be tested and the test is likely a few months away. Aatre also tells reporters that India has the technological capability to build inter-continental ballistic missiles (ICBM). "Once you have mastered the kind of technologies for Agni I, Agni II, and Agni III," Aatre says, "for longer range of missiles, there are no new technologies...we have all the technologies...it (ICBM) needs a larger engine, longer burning time, improvement in

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the guidance system, among others. However, Aatre cautions, "it's not a question of whether we can build an ICBM or not, but whether we want an ICBM, which I am not going to talk about."

—"India plans to test 3,000km Agni III missile this year: Aatre," Press Trust of India, 4 June 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 4 June 2004.

4 June 2004

US Undersecretary of Defense visits New Delhi to participate in the fourth meeting of the Indo-US defense policy group (DPG). After meeting members of the new government in New Delhi, Feith says that "we [US officials] discussed the issue [missile defense] with the new Indian leadership as both countries are facing serious missile threats. If India wants to go ahead with cooperation on missile defense, we will be happy to work with India."

—Siddharth Varadarajan, "Indo-US ties to face 'missile defense' test next week," Times of India, 30 May 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 31 May 2004; "US renews missile defense cooperation," Times of India, 4 June 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 4 June 2004.

26 May 2004

According to Dr. S. Sundararajan, a scientist at the Defense Research & Development Organization (DRDO), the BrahMos missile program has helped India develop several raw materials such as "high quality and strong materials and dyes," including several non-metallic materials such as radone. Sundararajan also singled out Indian private sector companies such as Larsen & Toubro and Godrej for speeding up advances in missile-related research and development, reducing costs, and optimizing the use of research facilities.

—"BrahMos has helped in developing raw materials: scientist," Press Trust of India, 26 May 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 26 May 2004.

25 May 2004

The Indo-Russian joint venture BrahMos Aerospace plans on becoming Asia's largest missile producer by 2007. According to the company's CEO Dr. A. Sivathanu Pillai, the company plans on achieving a \$1 billion annual turnover by that date.

—"BrahMos has big ambitions," Flight International, 25 May 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 2 June 2004.

26 April 2004

The Chief Controller (R&D) of the Defense Research & Development Organization (DRDO) Dr. A. Sivathanu Pillai praises the Kerela government owned Kerela High-Tech Industries Ltd. (KELTEC) for its success in manufacturing a range of defense and space-related products for the DRDO and Indian Space Research Organization (ISRO). Pillai says that KELTEC is able to manufacture products that require high-precision and work quality. It provides a one-stop shop for producing a range of products such as propellant tanks, liquid engines, control system components, nozzles, and other critical components for ISRO's polar satellite launch vehicle (PSLV) and geostationary satellite launch vehicle programs. Because of its unique strengths, DRDO and ISRO have extended financial support to the company and helped restore it to fiscal health.

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—Harsh Govind, "BrahMos will give navy a big advantage: expert," Hindu, 26 April 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 26 April 2004.

8 April 2004

The Indo-Russian BrahMos Aerospace Ltd. signs an agreement with Russia's main arms exporter Rosoboronexport and the NPP Mash missile company to jointly market the ship- and aircraft-borne versions of the BrahMos supersonic cruise missile. The missile is expected to enter production in 2004. According to the Dr. A. Sivathanu Pillai, CEO and MD of the company, the missile evoked a lot of interest when it was displayed at defense exhibitions at New Delhi, Singapore, and Sydney. The agreement with Rosoboronexport is also expected to speed up clearances for potential purchases of the missile by the Russian armed services. Despite many queries, the missile cannot yet be exported because the governments of Russia and India have not yet drawn up a list of friendly countries to whom the missile can be marketed.

—Vladimir Radyuhin, "India, Russia to market BrahMos," Hindu, 8 April 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 8 April 2004.

5 April 2004

Kerala Hightech Industries Ltd plans to expand its product range to include pressure transducers for the Indian Space Research Organization (ISRO) and the Defense Research & Development Organization (DRDO), as well as injection valves for ISRO's geo-stationary satellite launch vehicle (GSLV). The company already produces propellant tanks, liquid engines, control system components, nozzles and other important components for the polar satellite launch vehicle (PSLV) and GSLV programs. It has also supplied titanium gas bottles used in rockets and missiles and taken up manufacture of robots for the Bhabha Atomic Research Center (BARC).

—KELTEC set to expand product range," Business Insight, 5 April 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 7 April 2004.

29 March 2004

The Chief Executive Officer of India's BrahMos supersonic cruise missile project Dr. A. Sivathanu Pillai says that BrahMos aerospace will deliver the first of the anti-ship missile systems to the Indian navy by 2005; and production facilities for the missile are being established in both India and Russia. The anti-ship BrahMos that was first tested in 2001 is being made available to the user within a record four years. According to Pilla, trials of the missile from aboard a ship and from mobile launchers on shore produced "good results," ... and "almost all trials were successful." Encouraged by the success of the naval version of the missile, BrahMos aerospace is now undertaking the development of a ship-to-shore version and an air-to-ship version of the cruise missile. Pillai identifies the pooling of technological capabilities, sharing costs of setting up production and manufacture, and the combining of expertise during the development and trial phases as some of the advantages of the joint venture with Russia.

—"BrahMos missile for navy by next year," Business Line, 29 March 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 30 March 2004.

23 March 2004

The head of India's Defense Research & Development Organization Dr. V.K. Aatre says that India may test the Agni-III ballistic missile any time in 2004. According to Aatre, "we have put in operation elaborate plans that the test

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firing is successful...any failure in the launch would be a great setback to the defense scientists." Commenting on the recent test of the Air Force version of the Prithvi, Aatre says that these missiles were being tested with global positioning systems to give them greater accuracy. However, Aatre rules out a change in the Prithvi's propellants from liquid to solid fuel on grounds that shorter range missiles are more accurate with liquid fuel.

—"India may test-fire surface-to-surface Agni-III missiles," Press Trust of India, 23 March 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 24 March 2004.

19 March 2004

India successfully tests an Air Force version of its extended-range Prithvi short-range ballistic missile from the Interim Test Range (ITR) at Chandipur on the Orissa coast. The Air Force version of the missile is called P-II; it has been flight-tested many times and is in the final stages of operationalization. The Indian Defense Ministry says that the missile tested has improved accuracy and the test is part of a continuous effort to fine tune the missile.

—"Extended version of Prithvi missile test fired," Press Trust of India, 19 March 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 19 March 2004; "New improved Prithvi missile tested," Indian Express, 20 March 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 20 March 2004; T.S Subramaniam, "IAF version of Prithvi missile launched," Hindu, 20 March 2004, 20 March 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 20 March 2004.

4-5 March 2004

The Indo-US Joint Technical Group (JTG) approves a framework for exchanging information on defense research and development, including missile defense programs. This is the sixth meeting of the JTG and is co-chaired by Alfred Volkman, Director of International Cooperation in the Office of the US Undersecretary of Defense and Prada Rao, Chief Controller for research and development technology in India's Defense Research & Development Organization (DRDO).

—Bulbul Singh, "India, US agree on R&D cooperation," Aerospace Daily, 9 March 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 11 March 2004.

26 February 2004

The Indian Space Research Organization (ISRO) denies rumors that the test-rocket motor that caught fire at its Satish Dhawan Space Center was being developed for the Agni ballistic missile. ISRO Assistant Scientific Secretary Rajeev Lochan says, "this was a test development motor for a new motor. It is not yet connected with any particular launch vehicle, but is a new technology for a different design concept." The Hyderabad based Defense Research & Development Laboratory (DRDL) which designs solid rocket motors for the Agni project also denies reports that the motor that caught fire was designated for the Agni project. DRDL director Dr. Prahlada says that "ISRO keeps making segments of this motor depending on their needs. It is not a specifically designated module. The motor used in the PSLV is similar to the one used in the Agni; both have segments of the size of one meter."

—"Alarm on Agni is False," 26 February 2004, Economic Times, 26 February 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 25 February 2004.

24 February 2004

In a testimony to the US Senate Intelligence Committee, the US naval director of intelligence Lowell E. Jacoby says

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that that the US navy expects other countries such as India to join Russia, China, and France as major exporters of cruise missiles. India is expected to begin production of the P J10 anti-ship/land attack cruise missile in 2004 in partnership with Russia.

—"Prepared Statement of Lowell E. Jacoby US Navy Director Defense Intelligence Agency," Federal News Service, 24 February 2004; in Lexis-Nexis Academic Universe, 24 February 2004, <http://web.lexis-nexis.com>, 24 February 2004.

21 February 2004

According to Dr. Sivathanu Pillai, Chief Executive Officer and Managing Director of the BrahMos cruise missile program, India and Russia have agreed to develop and test an air-launched version of the missile for deployment aboard SU-30 combat aircraft during the next two to three years. Pillai says that while Hyderabad remains the technical center for the Brahmos program, New Delhi is the design and management headquarters for the project. On the question of exports, Pillai adds that the decision to export the missile will be made at the highest levels of both the Indian and Russian governments.

—"Second version of BrahMos to be tested in 2-3 years," Business Line, 21 February 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 22 February 2004.

20 February 2004

The Indian Space Research Organization announces plans to expand the annual production capacity of ammonium perchlorate (AP) at its Ammonium Perchlorate Experimental Plant from 300-tons to 800 tons. The expanded production facility is expected to be completed by early 2005. AP is an important constituent of solid propellants used to power rockets.

—T.S. Subramaniam, "A powder that will power the nation's strategic capability," Hindu, 20 February 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 20 February 2004.

20 February 2004

Raghavendra Singh of Foretek Marketing in Bangalore, the man suspected of trying to procure equipment illegally from the United States through Karni Singh, says the equipment was "for the space program, which is entirely civilian in nature."

—"Interview: Indian businessman named in US nuclear-related trial says material he got was not for a weapons program," AP, 20 February 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 21 February 2004.

19 February 2004

US federal investigators discover that Asher Karni, a South African businessman facing felony charges for exporting nuclear bomb triggers to Pakistan, also worked to supply India rocket related technologies. E-mail records of exchanges between Karni and an Indian businessman Raghavendra or Ragu Rao of Foretek Marketing (Pvt.) Ltd. indicate that the latter tried to procure high-tech equipment from the United States while concealing that the equipment was destined for the Liquid Propulsion Systems Center (LPSC) and the Vikram Sarabhai Space Center in India. An August 2002 e-mail from Rao to Karni warns the latter to conceal the final customer of an accelerometer to the LPSC, noting that its export to India is restricted due to concerns that it might be used in missile guidance systems.

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—Matt Kelley, Accused of aiding Pakistan nuclear program, trader also helped India, records indicate," AP, 19 February 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 20 February 2004.

17 February 2004

According to Larsen & Toubro's Senior Vice President Mr. P.M. Mehta, the company's heavy engineering department (HED) is placing increasing emphasis in the areas of nuclear power, defense, and aerospace, and will focus on high-end technology businesses in the future. Currently, these areas account for a fourth of the department's revenue stream; but that ratio will likely increase. The company has already produced missile launchers for the Defense Research & Development Organization (DRDO) and is pushing for increasing its contribution to the BrahMos cruise missile program.

—"L&T to focus on nuclear, defense, and aerospace sectors," Business Line, 17 February 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 17 February 2004.

15 February 2004

India's Defense Minister George Fernandes says that the Agni-III ballistic missile will be tested in 2004, but that no date has been fixed for a potential test so far. However, Fernandes refuses to comment on the missile's potential range or launch platform.

—"India all set to test-fire Agni-III this year: Fernandes," Press Trust of India, 15 February 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 15 February 2004.

11 February 2004

India's Chief of Naval Staff Madhavendra Singh says that the BrahMos cruise missile will become operational in at least one naval ship by the end of 2005. The Indian navy will conduct user trials of the BrahMos by the end of 2004.

—"Naval version of Brahmos will be ready by 2005," Business Insight, 11 February 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 12 February 2004.

6 February 2004

According to Dr. V.K. Saraswat, Director of the Research Center Imarat (RCI), India's missile program has come a long way since it was launched in 1982-83 and is set to enter an exciting phase. According to Saraswat, the Agni ballistic missile has been inducted into the armed forces and tactical missiles such as the surface-to-air Trishul and Akash and the anti-tank Nag missiles are ready for user trials and likely to enter production by 2005. Until the 1990s, the challenge for RCI was to meet "the range and warhead capacity for the missile." But from "2002-2010 the focus is on accuracy of hit or hit to kill," which "requires special technologies such as infrared and RF seekers embedded into the missiles with high precision homing devices." The RCI is also working on a beyond-the-visual-range missile Astra. One test-flight of the missile is expected to take place in 2004 and after the government grants formal sanction for the project in 2004, missile development will likely be accomplished in the next three or four years. Saraswat also provides details about Indian industry participation in the various missile projects.

—"India's Missile Program is Spurring Industries: Dr. V.K. Saraswat, Director, Research Center Imarat," Business Line, 6 February 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 6 February 2004.

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5 February 2004

According to the Defense Research & Development Organization (DRDO), the supersonic BrahMos cruise missile is ready for deployment at sea. DRDO chief Dr. V.K. Aatre claims that the missile's guidance system was developed by India entirely, with Russia carrying out systems integration. The land-based version of the 290km missile is capable of deploying both conventional and nuclear warheads. The DRDO is also developing an air-launched version of the missile with a reduced length and diameter to allow it to be fitted on the recently acquired Russian SU-30MK1 combat aircraft. DRDO officials claim that a number of tests of the land version of the solid-fuel BrahMos have been conducted at the Interim Test Range (ITR) in Balasore. The land-based version of the BrahMos is a "single vehicle weapon carrying three missiles in containers with launch readiness time of five minutes." The land-based missiles are capable of operation in a nuclear and biological environment and the carriers are fitted with hydraulic launcher control systems with the option for using remote instruments. Engineers at the DRDO's RDE facility in Pune have developed an indigenous heavy-duty tatra-based carrier to give the missiles all terrain mobility. —"Expo-BrahMos," Press Trust of India, 5 February 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 5 February 2004.

5 February 2004

Indian Defense Minister George Fernandes informs parliament that the Barak anti-missile system that India obtained from Israel, malfunctioned during trials. The malfunction was analyzed by the equipment manufacturer and rectified. Subsequently, the Barak system successfully engaged and destroyed a low-flying surface-to-surface missile in a test on 21 January. —"PAR-LS Questions," Press Trust of India, 5 February 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 5 February 2004.

4 February 2004

A group of 15 private US arms dealers begin talks with India on potential arms sales. A senior Vice President of the US Chambers of Commerce says that "over the next three days we will take a closer look at the potential for sales of sophisticated new technologies, shore our ideas about measures that can be taken by both governments to strengthen bilateral defense cooperation, explore potential modalities...for co-development of advanced technologies." Retired US General Daniel Christman tells reporters that "on missile defense, US corporations are looking at the supply of Patriot missiles...maybe there would be talks on that." Christman also dismisses fears in India concerning potential disruptions in the supply of critical components in the event of a US sanctions regime as happened in 1998; and says, "the pact between President Bush and Prime Minister Vajpayee has altered the strategic partnership and so there would be no light switch diplomacy." Major US companies participating in India's Defexpo 2004 exhibition include Raytheon, GE Aircraft Engines, General Dynamics, Honeywell, ATK Thiokol, and Northrop Grumman.

—US arms makers to offer high-tech military hardware to India," Agence France Presse, 4 February 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 5 February 2004; "DEFEXPO-US," Press Trust of India, 4 February 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 4 February 2004.

4 February 2004

According to Alexander Baskakov, Managing Director of the Russian side of the joint Russo-Indian BrahMos missile

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project, the BrahMos is a general purpose missile fit for any type of basing. The missile has a range of about 300km, its warhead weighs 200kg, and its velocity ranges from 160-800 meters per second. India and Russia only took one-and-a-half years to proceed to the development testing of the missile. Baskakov says that the missile is now ready for deployment on Indian navy surface and submarine platforms; plans are also afoot to produce a modified version of the missile for the air force. In addition, India and Russia, which are jointly co-producing the missile, plan to export it to countries in South-East and East Asia. However, the list of potential customers could be expanded in the future.

—Yuri Sidorov and Vladimir Shvarev, "Russo-Indian 'BrahMos' missiles proves its effectiveness," ITAR-TASS News Agency, 4 February 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 5 February 2004.

3 February 2004

India has begun research and development on a two-stage reusable space vehicle which will be capable of taking off and landing like an aircraft. The vehicle, which is named Avatar, would be able to deploy a 1,000kg payload into lower-earth orbit. The Avatar project is expected to cost about \$2 billion and development is likely to take a decade. An Indian defense ministry official says that the vehicle will be capable of performing at least 100 re-entries and is primarily intended as "a reusable missile launcher, one which can launch missiles, land,...and be loaded again for more missions." Vehicles sub-systems such as the Scramjet engine have already been tested at the Defense Research & Development Organization (DRDO) laboratories."

—Bulbul Singh, "India begins development work on Avatar space vehicle," Aerospace Daily, 3 February 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 5 February 2004.

23 January 2004

India flight-tests a short-range Prithvi ballistic missile to evaluate how quickly fuel can be loaded in the missile's fuel tanks as well to test a newly acquired simulator to train missile crews.

—"India tests Prithvi missile to study fuel loading," Aerospace Daily, 26 January 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 29 January 2004.

23 January 2004

The Defense Research & Development Organization (DRDO) flight-tests the short-range Prithvi ballistic missile from the Interim Test Range (ITR) at Chandipur in Orissa state. A DRDO press statement says that India's ballistic missile defense program has entered the flight evaluation phase with the firing of "its first missile" from the integrated test range. The statement further says "the missile and the ground elements such as multifunction surveillance radar, tracking, fire control radar, command, control and communication system and launch control systems performed to specification in real time meeting all mission objectives."

—"Prithvi," Press Trust of India, 23 January 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 23 January 2004.

13 January 2004

The Indian Army is reportedly raising two special missile groups – 444 and 555 – for the induction of the Agni-I and Agni-II ballistic missiles. The 555 Missile Group is responsible for the Agni-II. According to the Indian sources, the Defense Research & Development Organization (DRDO) has transferred technology related to the production of

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both missiles to Bharat Dynamics Limited, Hyderabad. However, the Army has still not gained possession of the Agni-I.

—"India's Agni-I missile yet to be handed over to Army," BBC Monitoring, 13 January 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 13 January 2004.

12 January 2004

The United States releases text of the "Next Steps in Strategic Partnership with India." Under the agreement, the United States and India agree to expand cooperation in the areas of nuclear activities, civilian space programs, and high-technology trade. The proposed cooperation will proceed through a series of mutually reinforcing reciprocal steps. Cooperation will involve nuclear safety and regulatory issues, missile defense, and enhanced cooperation in peaceful uses of space technology. The two countries will also undertake measures at the bilateral and multilateral levels to strengthen laws, regulations, and procedures to combat the spread of weapons of mass destruction.

—"Next Steps in Strategic Partnership with India," White House Press Releases, 12 January 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 13 January 2004.

6 January 2004

According Dr. V.K. Saraswat, Director of the Research Center Imarat (RCI), India's Scramjet engine should be ready by 2006 and will thereafter be integrated into an airframe capable of withstanding temperatures up to 3,000° Kelvin.

—"India's RCI airs new research information," Flight International, 6 January 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 13 January 2004.

2 January 2004

According to sources the Agni-III ballistic missile will be tested in the next three or four months. Further, India's Nuclear Command Authority chaired by the prime minister has issued directions for the operationalization of India's land-based Agni missile groups, fighter bombers, and sea-based platforms as soon as possible. A scheduled test of the Agni-III in late 2003 was delayed due to technical problems. Those problems have since been rectified.

—Rajat Pandit, "India to test-fire Agni-III soon," Times of India, 2 January 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 1 January 2004.

1 January 2004

According to the Director of India's Defense Research & Development Organization (DRDO) Dr. V.K. Aatre, India will test the 3,000km-range Agni-III ballistic missile in 2004. In addition, the BrahMos missile, which India has jointly developed with Russia, has been cleared for induction into the Indian Navy (IN). DRDO will also begin work on a version of the BrahMos for the Indian Air Force (IAF); and the air force version of the missile will likely be carried aboard the SU-30MK1 that the IAF has acquired from Russia. Aatre also says that the DRDO has explored possibilities for joint research and development with Israel for electronic warfare and sensors for the India's Light Combat Aircraft (LCA) and Unmanned Aerial Vehicles (UAV).

—"Govt. to testfire Agni this year," Indian Express, 1 January 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 1 January 2004.

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1 January 2004

India reportedly plans to fly a hypersonic plane in 2007. An eight-meter technology demonstrator is being built by the Defense Research & Development Laboratory (DRDL) in Hyderabad; and it will be powered by a "Scramjet" engine that takes in oxygen from the atmosphere and burns liquid hydrogen. According to DRDL sources India has made considerable progress in mastering air-breathing engine technology (ramjet) at sub-sonic speeds through its Akash surface-to-air missile program, but has yet to master technology at supersonic speed up to 7 mach. DRDL is closely collaborating with other institutions including the Indian Institute of Technology (IIT) and Indian Institute of Sciences (IISc) to develop nickel cobalt and carbon composite materials for the hypersonic plane project. The hypersonic prototype would be a precursor to the Defense Research & Development Organization's (DRDO) Aerobic Vehicle for Hypersonic Aerospace Transportation (AVATAR).

—"Hypersonic," Press Trust of India, 1 January 2004; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>, 1 January 2004.

2003

31 December 2003

The Scientific Advisor to the Defense Minister Dr. V.K. Aatre says that the 3,000 km range Agni III will be tested sometime during the next three months. Dr. Aatre denies any collaboration with Israel on missiles. Dr. Aatre also indicates that technical problems associated with the Akash missile system have been corrected and says that the missile will be tested in March 2004.

—"Agni III to be Test Fired in Three Months," *Press Trust of India*, 31 December 2003, Nationwide International News; in Lexis-Nexis Academic Universe, 1 January 2004, <http://web.lexis-nexis.com>.

27 December 2003

Dr. A. Sivathanu Pillai, the CEO and Managing Director of BrahMos Aerospace and the Chief Controller of Research & Development for the Defense Research and Development Organization (DRDO), says that the BrahMos supersonic cruise missile is ready for production and adds that the commercial production for the missile will begin in 2004. Dr. Pillai states that the joint Indo-Russian BrahMos cruise missile project represents the first project of its type and describes it as a symbol of true strategic partnership between India and Russia. Dr. Pillai adds that the top priority accorded for the project by the Indian government enabled the team to complete the project in half the projected time. He adds that the government will benefit greatly from its investment in the project. Dr. Pillai, without revealing the invested amount, says that the missile will provide great returns since it is cheap and has excellent quality. Dr. Pillai says that the two governments should arrive at a decision on prospective buyers since the missile is essentially a weapon.

—"Brahmos Missile Set for Production," *Business Line* (Chennai), 28 December 2003; in Lexis-Nexis Academic Universe, 29 December 2003, <http://web.lexis-nexis.com>.

25 December 2003

The Managing Director and CEO of Brahmos Aerospace Dr. A. Sivathanu Pillai says that the production of the naval version of the BrahMos supersonic cruise missile will begin in January 2004. Dr. Pillai says that the BrahMos missile

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is capable of hitting a target nine times more powerfully than a subsonic missile. According to Dr. Pillai, BrahMos Aerospace is planning to increase the capital of \$250 million in order to develop the land-based version of the BrahMos missile. Dr. Pillai says that the Air Force version of the missile will be developed after the completion of the development of the land-based Army version of the missile.

—"Brahmos Supersonic Cruise Missile Production in New Year," *Press Trust of India*, 25 December 2003, Nationwide International News; in Lexis-Nexis Academic Universe, 28 December 2003, <http://web.lexis-nexis.com>.

22 December 2003

India and Israel negotiate on developing closer relationships in defense production especially in the areas of missiles, surveillance, and anti-terrorism warfare technology. Major General Amos Yaron, Director General in Israel's Ministry of Defense, leads the 11-member Israeli delegation. Major General Yaron meets Defense Secretary Ajay Prasad in a one-on-one meeting and also holds delegation-level talks with the Indian delegation. Major General Yaron also meets India's Army Chief N.C. Vij, the Chief of Air Staff S. Krishnamurthy. According to sources in the defense ministry, the talks focused on several Indo-Israeli projects including the Phalcon Airborne Radar, missile development, radar avionics, and anti-terrorism warfare equipment. Defense sources also indicate that cooperation in the area of missiles only included missiles that do not fall under the purview of the Missile Technology Control Regime (MTCR).

—"India, Israel Discuss Defence Cooperation," *Press Trust of India*, 22 December 2003, Nationwide International News; in Lexis-Nexis Academic Universe, 22 December 2003, <http://web.lexis-nexis.com>.

22 December 2003

The Indian Defense Ministry says that the Trishul missile system was successfully test-fired with a new guidance system and states that it will not buy an equivalent foreign missile system. A series of tests for the Trishul missile are planned to fine-tune the guidance system. Earlier, India invited bids from foreign companies to supply short-range surface-to-air air defense systems. A Defense Research and Development Organization (DRDO) scientist says that the new guidance system has been developed since the announcement. According to officials, India will not procure foreign missile systems following the successful testing of the Trishul missile with the new guidance system. The recent tests for the Trishul missile included skimming tests for the Navy. The Army and the Air Force will also be provided with the missile. A DRDO scientist points out that compared to the existing Russian short-range surface-to-air missiles, the Trishul missile has a shorter reaction time and a superior control system. According to the scientist, the Trishul missile is capable of turning through 360 degrees in four seconds and its high-frequency and advanced guidance system makes it resistant to electronic countermeasures.

—Bulbul Singh, "Trishul's New Guidance System Passes Tests, India Claims," *Aerospace Daily*, 22 December 2003, Vol. 208, No. 57, p. 6; in Lexis-Nexis Academic Universe, 24 December 2003, <http://web.lexis-nexis.com>.

21 December 2003

India plans to conduct additional flight-tests for the Trishul missile system in the next two weeks. The tests will be witnessed by top officials from the Air Force who have expressed keen interest in the current series of tests. According to informed sources, the Air Force has not allocated funds to procure foreign short-range surface-to-air missile systems.

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—T.S. Subramanian, "Successful Trishul Tests Boost DRDO," *Hindu* (Chennai), 21 December 2003; in Lexis-Nexis Academic Universe, 20 December 2003, <http://web.lexis-nexis.com>.

21 December 2003

For the fourth time in three days, India test-fires the short-range surface-to-air Trishul missile at 1.00 PM IST from the Interim Test Range (ITR) at Chandipur-on-sea on India's eastern coast. The missile is fired from a mobile launcher at a moving target. Officials indicate that the current tests are aimed at testing the accuracy of the Trishul missile system.

—"India Tests Anti-Aircraft Missile Four Times in Three Days," Agence France Presse, 20 December 2003, International News; in Lexis-Nexis Academic Universe, 21 December 2003, <http://web.lexis-nexis.com>; "India Test Fires 4th Surface-to-Air Missile Trishul," Xinhua News Agency, 21 December 2003, World News; in Lexis-Nexis Academic Universe, 21 December 2003, <http://web.lexis-nexis.com>.

19 December 2003

India tests the short-range surface-to-air Trishul missile twice from the Interim Test Range (ITR) at Chandipur-on-sea on India's eastern coast. The first test is conducted at 11.20 AM IST and the second test is conducted at 2.45 PM IST. According to various sources, in one of the tests the missile was targeted at a moving object dropped from an AN-32 aircraft. According to sources, the trials are aimed at evaluating the accuracy and other parameters of the missile. The missile is three meters long and measures 200cm in width. The Trishul missile flies at supersonic speeds. Both the tests are declared as successful.

—"India Test-Fires Trishul Surface-to-Air Missile," BBC Monitoring International Reports, 19 December 2003; in Lexis-Nexis Academic Universe, 19 December 2003, <http://web.lexis-nexis.com>; "Trishul Test-Fired," *Hindu* (Chennai), 19 December 2003; in Lexis-Nexis Academic Universe, 19 December 2003, <http://web.lexis-nexis.com>; "India Tests Trishul Missile for Third Time in Two Days," Pakistan Newswire, 19 December 2003, Nationwide International News; in Lexis-Nexis Academic Universe, 21 December 2003, <http://web.lexis-nexis.com>.

18 December 2003

India test-fires the short-range surface-to-air Trishul missile from the Interim Test Range (ITR) at Chandipur-on-sea on India's eastern coast. Officials describe the test as a success. The missile is fired at a moving target.

—"India Tests Short-Range Surface-to-Air Missile," Deutsche Presse-Agentur, 18 December 2003, Politics; in Lexis-Nexis Academic Universe, 18 December 2003, <http://web.lexis-nexis.com>; "India Test-Fires Trishul Surface-to-Air Missile," BBC Monitoring International Reports, 19 December 2003; in Lexis-Nexis Academic Universe, 19 December 2003, <http://web.lexis-nexis.com>.

18 December 2003

The Indian government proceeds cautiously on acquiring Israeli Barak anti-missile system for the Indian Navy. According to an Indian Navy official, the failure of the Barak missile system during its trials has made it tougher for the missile system to be used on the Russian aircraft carrier Admiral Gorshkov that was recently purchased by India.

—Bulbul Singh, "India Postpones Contract for Barak Missile System," *Aerospace Daily*, 18 December 2003, Vol. 208, No. 55, p. 2; in Lexis-Nexis Academic Universe, 24 December 2003, <http://web.lexis-nexis.com>.

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17 December 2003

India's Defense Minister George Fernandes informs the upper house of parliament (Rajya Sabha) that the Israeli Barak missile system will undergo retrials since the previous round of trials were declared "unsatisfactory." Mr. Fernandes says that even though the missile hit the target successfully during the previous test, the test revealed certain technical malfunctions. According to Mr. Fernandes Israeli experts analyzed the failures and a new round of tests will be held shortly. Mr. Fernandes says that India is still importing surface-to-air missiles from Russia. He, however, refuses to divulge details about the current state of India's indigenous air defense system citing the sensitive nature of such information.

—"India to Conduct Retrial of Israeli Missile Defence System," BBC Monitoring International Reports, 17 December 2003; in Lexis-Nexis Academic Universe, 17 December 2003, <http://web.lexis-nexis.com>.

17 December 2003

The Director of Research Center Imarat (RCI) Dr. V.K. Saraswat, speaking at the inauguration of a seminar-cum-exhibition on "Aerospace Technologies - Challenges in the Millennium," says that India is focusing on developing re-usable rockets and precision strike weapons. Dr. Saraswat adds that the future trends in missile technology are in developing "hit-to-kill" missiles with a high degree of precision which do not damage surrounding buildings and kill civilians. He adds that several companies in Hyderabad possess the ability to make several precision components needed for aviation and aerospace industry.

—"Aerospace Research Focus on Reusable Rockets," *Economic Times* (Mumbai), 17 December 2003; in Lexis-Nexis Academic Universe, 17 December 2003, <http://web.lexis-nexis.com>.

15 December 2003

The Director of the Defense Research and Development Laboratory (DRDL) Dr. Prahlada says that the DRDO will test the surface-to-air Trishul missile system for the last phase of trials. He says that last year the missile had some problems with the guidance system which were corrected later. Dr. Prahlada indicates that the current tests are conducted to test the improved guidance system. According to Dr. Prahlada, the Air Force has shown interest in the planned missile tests which will involve live warheads. Dr. Prahlada indicates that the planned series of tests will be a week long exercise involving 4 tests. He also adds that the air defense project is progressing well.

—"DRDO to Conduct Trishul Missile Trials This Week," *Press Trust of India*, 15 December 2003, Nationwide International News; in Lexis-Nexis Academic Universe, 15 December 2003, <http://web.lexis-nexis.com>.

15 December 2003

Dr. V.K. Saraswat, the Director of Research Center Imarat (RCI), says that an air defense system, called Programme AD, with a centralized command, control, and communication structure and connected to several mission control units throughout the country to detect incoming enemy aircraft and missiles will become operational by the end of 2004. Dr. Saraswat discloses that a portion of the system is already operational and is currently undergoing tests with simulated batteries and radars. The RCI is developing the air defense system in conjunction with other defense laboratories including the Hindustan Aeronautics Limited (HAL) and Bharat Electronics Limited (BEL). Dr. Saraswat says that after all the control missions are connected to the central command, control, and communication, the interceptor missile can be fired from the missile batteries to meet the incoming missile or aircraft. Dr. Saraswat says that RCI has also developed the high-speed Scramjet engine which is currently

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undergoing tests. Dr. Saraswat projects that the engine will be operational in another two or three years. After the completion of tests on the engine, the RCI will develop an airframe for the aircraft that can withstand temperatures as high as 3000 degree calvin. Dr. Saraswat says that several defense laboratories including the Defense Materials Research Laboratory (DMRL) are engaged in developing the airframe using silicon carbide based composites. Dr. Saraswat indicates that the scramjet technology will be used to launch satellites into low earth orbits (LEO) which will result in a reduction in the cost for launching satellites. He says that the RCI is also working on developing an advanced accurate navigation and control system and terminal guidance system with imaging seekers that will allow air and land based missiles and aircraft to conduct precision strikes. He adds that the technology will allow missiles to have zero circular error probability (CEP) or zero miss-distance system. According to Dr. Saraswat, RCI is also working on a project to create a low cost navigation system for precision-guided sub-munitions which will allow a missile to carry 20 sub-munitions to be able to target 20 separate targets.

—Y. Mallikarjun, "Indigenous Air Defense System to be Operational Next Year," *Hindu* (Chennai), 15 December 2003; in Lexis-Nexis Academic Universe, 14 December 2003, <http://web.lexis-nexis.com>; "RCI Launches Defence System, Programme AD (Will Help to Intercept Incoming Aircraft or Missiles)," *India Business Insight* (Bangalore), 15 December 2003; in Lexis-Nexis Academic Universe, 18 December 2003, <http://web.lexis-nexis.com>.

11 December 2003

India's Defense Minister George Fernandes informs the lower house of parliament (Lok Sabha) that the flight tests for the BrahMos supersonic cruise missile met all the test objectives and states that the missile has proved its performance. An Indian official says that the production and induction of the missile will begin within six months.

—Rajat Pandit, "Brahmos on Deployment Track," *Times of India* (Mumbai), 14 December 2003; in Lexis-Nexis Academic Universe, 13 December 2003, <http://web.lexis-nexis.com>.

7 December 2003

The BrahMos supersonic cruise missile is ready for mass production and the BrahMos Aerospace Private Ltd. Awaits orders from the Indian Defense Ministry to commence production. Dr. A. Sivathanu Pillai, the CEO of BrahMos Aerospace Pvt. Ltd. and the Chief Controller for Research & Development at the Defense Research and Development Organization (DRDO), says that the BrahMos missile can be produced and sold to countries friendly to India and Russia. Dr. Pillai says that the Indian and Russian governments will identify the countries to which the missile can be sold.

—Ch. Sushil rao, "Brahmos Firm Waits for Orders," *Times of India* (Mumbai), 7 December 2003; in Lexis-Nexis Academic Universe, 9 December 2003, <http://web.lexis-nexis.com>.

5 December 2003

The Indian Space Research Organization (ISRO) says that it has tested a cryogenic engine by firing it for 1,000 seconds on the ground. The ISRO test exceeds the usual requirement of 721 seconds of firing time for such tests. The long-duration endurance test is conducted at ISRO's Liquid Propulsion Systems Center at Mahendragiri in Tamil Nadu in South India. An ISRO press release says that the 7.1 metric ton-thrust engine was fired simultaneously with two 400 kg thrust cryogenic engines that were mounted on a single-block. An ISRO press release says that the organization has obtained the technology to launch high-altitude satellites and undertake manned lunar missions.

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—"India Masters Rocket Technology to Send a Man to the Moon: Space Agency has 2015 Target Date After Successful Test of Cryogenic Engines," *Gazette* (Montreal, Quebec), 6 December 2003, News, p. A27; in Lexis-Nexis Academic Universe, 6 December 2003, <http://web.lexis-nexis.com>; Frank Moring Jr., "Indian Engine," *Aviation Week & Space Technology*, Vol. 159, No. 24, In Orbit, p. 17; in Lexis-Nexis Academic Universe, 6 December 2003, <http://web.lexis-nexis.com>.

4 December 2003

India's Defense Minister George Fernandes informs India's lower house of parliament (Lok Sabha) that the government has not decided to abandon the Akash surface-to-air missile project. Mr. Fernandes says that the missile faced some technical problems in the subsystems which have been corrected. Mr. Fernandes says that user trials are planned to be held next year.

—"India Conveys Concerns to Sri Lanka," *Press Trust of India*, 4 December 2003, Nationwide International News; in Lexis-Nexis Academic Universe, 4 December 2003, <http://web.lexis-nexis.com>.

3 December 2003

Indian Defense sources indicate that the BrahMos cruise missile can be launched from submarines. According to the sources, the ground-launched, the ship-launched, and the submarine-launched versions of the missile do not have the same design. According to the sources, the air-launched version of the missile needs additional development since the missile will be launched from a platform moving at great speeds and hence the missile should have less weight. Sources indicate that the development for the air-launched version of the missile will take about three years.

—T.S. Subramanian, "Anti-Ship Version of BrahMos Proves its Mettle," *Hindu* (Chennai), 3 December 2003; in Lexis-Nexis Academic Universe, 2 December 2003, <http://web.lexis-nexis.com>.

26 November 2003

India and Israel sign a \$100 million deal to transfer the third consignment of the Barak missile system. According to the Israeli newspaper Haaretz, the Barak missile system failed once in the tests conducted by the Indian Navy. According to the report, the back-up missile fired accurately and hit the target. Sources from the Israeli Aircraft Industries (IAI) say the failure was caused by a problem in the communication frequencies of the missile and the warship. The failure could also be attributed to a failure in the missiles guidance system. The radar for the Barak missile system is mounted on a ship's mast and it provides warning about cruise missiles, smart bombs, and helicopters. Each warship with a Barak missile system is equipped with 32 all-weather missiles and each missile weighs about 100kg.

—Atul Aneja, "India, Israel to Sign \$100 Million Missile Deal," *Hindu* (Chennai); in Lexis-Nexis Academic Universe, 26 November 2003, <http://web.lexis-nexis.com>.

23 November 2003

India successfully test-fires the BrahMos supersonic cruise missile for the sixth time. The missile is fired from a moving warship INS Rajput which was cruising at about 12 to 15 knots an hour in the Bay of Bengal towards a moving decommissioned ship at a distance of 290 km. Another warship INS Kalinga monitors the point of impact. Dr. A. Sivathanu Pillai, the Chief Controller of Research & Development at the Defense Research and Development

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Organization (DRDO) says that different versions of the BrahMos will be tested in the next few days following which the missile will be produced and inducted. The test involved two warships from the Eastern Naval Command. An Indian Navy official says that three more tests will be conducted against moving targets. The Indian Navy has estimated that it will require about 75 BrahMos cruise missiles and the Indian Army has estimated that it will require 50 BrahMos missiles.

—"Brahmos Test Fired Successfully," *Press Trust of India*, 23 November 2003, Nationwide International News; in Lexis-Nexis Academic Universe, 1 December 2003, <http://web.lexis-nexis.com>; Bulbul Singh, "BrahMos Cruise Missile Test-Fired from Destroyer," *Aerospace Daily*, 1 December 2003, Vol. 208, No. 42, News, p. 2; in Lexis-Nexis Academic Universe, 4 December 2003, <http://web.lexis-nexis.com>; T.S. Subramanian, "Anti-Ship Version of BrahMos Proves its Mettle," *Hindu* (Chennai), 3 December 2003; in Lexis-Nexis Academic Universe, 2 December 2003, <http://web.lexis-nexis.com>.

21 November 2003

Alexander Baskakov, the Managing Director for BrahMos Aerospace Ltd, says that India and Russia will finish testing the BrahMos cruise missile and initiate batch production of the missile. Mr. Baskakov says that the BrahMos will remain the best anti-ship missile for the next 10-15 years against which there is no defense. The missile assembly is ongoing at Hyderabad. The first batch of the BrahMos missiles will be available for sale in 2004. Countries in East and Southeast Asia have expressed interest in buying the missile.

—Yuri Sidorov, "Russia, India to Start BrahMos Missile Production in 2004," *Tass*, 21 November 2003; in Lexis-Nexis Academic Universe, 22 November 2003, <http://web.lexis-nexis.com>.

21 November 2003

US Under-Secretary for Department of Commerce Kenneth Juster and India's Foreign Secretary Kanwal Sibal discuss the "quartet issues" namely, civilian nuclear cooperation, civilian space cooperation, high-technology exports, and missile defense. The details of the discussions are not revealed. Mr. Juster says that the "framework" of nuclear and missile nonproliferation regimes is of interest to India even though India is not a signatory to the nuclear and missile treaties.

—"Hi-Tech Cooperation Group: Quartet Issues Discussed," *Indian Express* (Mumbai), 21 November 2003; in Lexis-Nexis Academic Universe, 21 November 2003, <http://web.lexis-nexis.com>.

19 November 2003

India and the United States agree to sign a Master Information Exchange Agreement (MIEA) that will allow the sharing of classified research data and increase technical cooperation between the two countries. Officials from the Pentagon and the Defense Research and Development Organization (DRDO) discuss the peaceful uses of nuclear energy and sharing of data on missiles, especially data on US experiments with anti-missile systems. The decision to sign the MIEA is taken during the third meeting of the Indo-US Joint Technical Group.

—"Classified Data Transfer Accord with US Soon," *Financial Express* (Mumbai), 19 November 2003; in Lexis-Nexis Academic Universe, 20 November 2003, <http://web.lexis-nexis.com>.

16 - 22 November 2003

The Barak anti-missile defense system fails to hit the target twice in the trials conducted off the coast of Mumbai.

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In both instances, the Barak missile interceptor fails to hit a Russian surface-to-surface missile with a deactivated warhead. The spokesperson from the Indian Navy refuses to comment on the incident. The Indian Navy plans to acquire at least eight Barak missile systems from Israel at an estimated cost of Rs. 1,000 crore. Officials from the Indian Navy, Rafael, and Israeli Aircraft Industries are working to fix the problem. Highly-placed Indian defense officials characterize the problem as "temporary" in nature.

— "Israeli Showpiece Anti-Missile System Fails Navy's Tests, Hard Work Ahead," *Indian Express* (Mumbai), 23 November 2003; in Lexis-Nexis Academic Universe, 24 November 2003, <http://web.lexis-nexis.com>.

11 November 2003

India plans to buy 100 BrahMos supersonic cruise missiles over the next decade and Russia plans to purchase 60 missiles.

— Bulbul Singh, "Firms Submit Bids to Supply Short-Range Missiles to India," *Aerospace Daily*, 11 November 2003, Vol. 208, No. 30, News, p. 5; in Lexis-Nexis Academic Universe, 22 January 2004, <http://web.lexis-nexis.com>.

11 November 2003

Seven international firms submit bids for the supply of short-range surface-to-air missiles for the Indian Air Force (IAF). The IAF requested the tenders from foreign suppliers following the poor results by the Trishul missile system. The foreign firms include France's MBDA and Thales, Russia's Rosoboronexport, Switzerland's Oerlikon Contraves, and South Africa's Denel. A senior Air Force official says that the government plans to procure missiles worth \$ 250 million within a year under a fast-track program. The Air Force plans to test the missile system during January and February next year and place orders by April 2004.

— Bulbul Singh, "Firms Submit Bids to Supply Short-Range Missiles to India," *Aerospace Daily*, 11 November 2003, Vol. 208, No. 30, News, p. 5; in Lexis-Nexis Academic Universe, 22 January 2004, <http://web.lexis-nexis.com>.

9 November 2003

India test-fires the BrahMos supersonic cruise missile for the fifth time around 12.30 PM (IST) at the Interim Test Range (ITR) at Chandipur-on-sea on India's eastern coast. The missile is fired from a mobile launcher. Following the test of the precision guidance capability in the previous test-launch on October 29, today's launch is aimed at testing other parameters.

— "India Test Fires Supersonic BrahMos Missile," Deutsche Presse-Agentur, 9 November 2003, Miscellaneous; in Lexis-Nexis Academic Universe, 10 November 2003, <http://web.lexis-nexis.com>; "'Brahmos' Successfully Test Fired," *Press Trust of India*, 9 November 2003, Nationwide International News; in Lexis-Nexis Academic Universe, 9 November 2003, <http://web.lexis-nexis.com>.

6 November 2003

Kerala Hitech Industries Ltd (Keltec), owned by the Government of Kerala, integrates the manufacture of titanium gas bottles and Secondary Injection Thrust Vector Control (SITVC) tanks which are used in the Polar Satellite Launch Vehicle (PSLV) as well as other satellite launch vehicles. The company has handed over the first batch of products to the Vikram Sarabhai Space Center (VSSC). Earlier, the production of titanium gas bottles was done at three different places. The hemisphere pressing was performed at Bharat Heavy Plate & Vessels (BHPV) in Hyderabad, the machining and welding was done at Keltec, and finally pressure testing was done at VSSC. The

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Managing Director for Keltec Mr. Johnson Peter says that Keltec has developed the technology to produce 600mm, 400mm, and 370mm diameter titanium gas bottles. Titanium gas bottles are used for storing high-pressure helium gas in satellite launch vehicles. In a similar fashion, the manufacture of SITVC tanks was performed at various facilities. The fabrication was done at VSSC, the aluminum coating was done at Bharat Heavy Electronics Ltd. (BHEL) in Hyderabad, and finally the pressure testing is done at VSSC. Mr. Peter says that the integration of the manufacturing process will result in a reduction of production costs and also ensure better delivery schedules. —"Keltec Integrates Titanium Gas Bottles Production," *Business Line* (Chennai), 6 November 2003; in Lexis-Nexis Academic Universe, 6 November 2003, <http://web.lexis-nexis.com>.

4 November 2003

P. Mohandas, the Chairman of Bharat Dynamics Ltd (BDL) says that even though the Defense Research and Development Organization (DRDO) undertakes development of missile systems, the BDL is engaged in concurrent engineering to produce the missiles quickly. Mr. Mohandas states that the surface-to-air Akash missile is at an advanced stage of development and also says that the surface-to-air Trishul missile is being tested. Mr. Mohandas says that BDL is planning to export missiles that are not part of the Integrated Guided Missile Development Program (IGMDP).

—"Company Asked to Refurbish Missiles to Enhance Reliability," *Press Trust of India*, 4 November 2003, *Nationwide International News*; in Lexis-Nexis Academic Universe, 4 November 2003, <http://web.lexis-nexis.com>; "Bharat Dynamics Aims to Double Turnover," *Business Line* (Chennai), 5 November 2003; in Lexis-Nexis Academic Universe, 5 November 2003, <http://web.lexis-nexis.com>.

29 October 2003

India test-fires the BrahMos supersonic cruise missile at 11.20 AM IST for the fourth time from the Interim Test Range (ITR) at Chandipur-on-sea on India's eastern coast. According to sources from the Defense Research and Development Organization (DRDO), the test was primarily conducted to establish the precision guidance capability in the surface-to-surface version. The sources indicate that the test achieved all the mission objectives. The ground range instrumentation at ITR and the ships located at the impact point tracked the missile's parameters. The missile was test-fired to a range of 290 km with precision impact on the target point. According to Dr. A. Sivathanu Pillai, the Chief Controller of Research & Development at DRDO and the Managing Director for the Indo-Russian joint venture, the test was aimed to verify the precision guidance system and the fire control system. The DRDO recently announced that the BrahMos missile will be ready for commercial production and induction into the armed forces within the next two years.

—"Brahmos Flight Tested," *Press Trust of India*, 29 October 2003, *Nationwide International News*; in Lexis-Nexis Academic Universe, 29 October 2003, <http://web.lexis-nexis.com>; "India Says World's First Supersonic Cruise Missile Test a Success," *Deutsche Presse-Agentur*, 29 October 2003, *Politics*; in Lexis-Nexis Academic Universe, 29 October 2003, <http://web.lexis-nexis.com>; Bulbul Singh, "India Conducts Flight Test of Supersonic BrahMos Missile," *Aerospace Daily*, 30 October 2003, Vol. 208, No. 22, *News*, p. 6; in Lexis-Nexis Academic Universe, 4 November 2003, <http://web.lexis-nexis.com>; "Brahmos Test-Fired Successfully," *Times of India* (Mumbai), 31 October 2003; in Lexis-Nexis Academic Universe, 31 October 2003, <http://web.lexis-nexis.com>.

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29 October 2003

The chief of the Defense Research and Development Organization (DRDO) Dr. V.K. Aatre says that the test of the 3,000km range Agni III has been postponed till January 2004. Dr. Aatre says that the preparations for the tests are "in full swing." Dr. Aatre indicates that the Trishul missile project will be revived after the completion of the user trials for the Akash missile.

—"India to Put Off Agni III Missile Till Next Year," Xinhua News Agency, 29 October 2003, World News, Political; in Lexis-Nexis Academic Universe, 30 October 2003, <http://web.lexis-nexis.com>.

17 October 2003

Indian police arrest Hans Raj Shiv, the Director of Indian NEC Engineers Private Ltd, for allegedly exporting banned chemicals to Iraq. Mr. Shiv is believed to have exported 10 shipments of equipment that included titanium vessels and centrifugal pumps. Titanium is often used to build the casings and warheads for missiles. The total worth of the equipment is estimated at \$ 800,000. Earlier in February 2003, the United States imposed sanctions on Hans Raj Shiv and his company for violating laws that prohibited trading chemical and biological weapons.

—"Indian Police Arrest Man for Alleged Export of Chemicals to Iraq," Agence France Presse, 18 October 2003, International News; in Lexis-Nexis Academic Universe, 19 October 2003, <http://web.lexis-nexis.com>.

15 October 2003

A spokesperson for India's Ministry of External Affairs criticizes US Department of State spokesperson Richard Boucher for including India in his comments on Pakistan's missile test. The spokesperson says "he [Richard Boucher] ought to have confined himself to reacting to that test rather than cluttering up what he had to say by thinly disguised, unwarranted references to India." Earlier on 14 October, Richard Boucher, in his comments on Pakistan's test-firing of the Shaheen-1 ballistic missile, asked India and Pakistan to restrain their missile programs.

—"India Blasts 'Cluttered' US Missile Reaction," *Times of India* (Mumbai), 17 October 2003; in Lexis-Nexis Academic Universe, 16 October 2003, <http://web.lexis-nexis.com>.

15 October 2003

A source in the Russian Defense Ministry says that preparations are being completed for testing the BrahMos supersonic cruise missile before the end of 2003.

—"Next Launch of Russian-Indian Cruise Missile Set for End of 2003," BBC Monitoring International Reports, 15 October 2003; in Lexis-Nexis Academic Universe, 15 October 2003, <http://web.lexis-nexis.com>.

7 October 2003

The Chief of Air Staff S. Krishnaswamy says that India has started efforts to build weapon platforms in space. Mr. Krishnaswamy says that India has to possess a space command since advanced countries are moving towards having laser weapon platforms in space. About six months back Indian parliamentarians expressed concern over the lack of efforts to build an aerospace command to manage space-based military assets. Mr. Krishnaswamy also acknowledges the presence of problems with the Integrated Guided Missile Development Program (IGMDP) and says that there are temporary delays in the development of quick reaction and medium-range missiles. According to Mr. Krishnaswamy, the surface-to-air Akash missile faced problems with its two-stage ramjet propulsion technology. He says that the Air Force plans to procure imported missiles as a makeshift solution.

Related content is available on the website for the Nuclear Threat Initiative, www.nti.org.



—"IAF Working on Weapon Platforms in Space," *Hindu* (Chennai), 7 October 2003; in Lexis-Nexis Academic Universe, 6 October 2003, <http://web.lexis-nexis.com>; Robert Wall, "India Eyes Weaponizing Space," *Aviation Week & Space Technology*, 13 October 2003, Vol. 159, No. 15, In Defense, p. 51; in Lexis-Nexis Academic Universe, 6 October 2003, <http://web.lexis-nexis.com>.

28 September 2003

The Vice-Chief of Army Staff Lieutenant General Shantonu Choudhary says that the Army will soon deploy the 700km range Agni I and the 1,500km range Agni II. Lt. Gen Choudhary says that the artillery regiment has already deployed the short-range Prithvi missile with a range of 225 km. He also says that the Army has created a separate missile regiment in the artillery which will be armed with the Agni I, Agni II, and the Prithvi missiles. Defense Ministry officials indicate that the 333 Prithvi missile group is armed with liquid-propelled missiles which can carry a payload of 1,000 kg over 150 km. Officials say that the 333 missile group has two independent sub-groups which can be deployed independently. Official sources also reveal that the 3,000 km range Agni III will be test-fired towards the end of 2003.

—"Agni Missiles Inducted into Army Soon," Press Trust of India, 28 September 2003, *Nationwide International News*; in Lexis-Nexis Academic Universe, 28 September 2003, <http://web.lexis-nexis.com>.

24 September 2003

India's Prime Minister Atal Behari Vajpayee plans to meet US President George Bush in New York and discuss cooperation in missile defense issues. According to senior Indian Defense Ministry officials, Prime Minister Vajpayee is expected to inform President Bush that the transfer of missile defense technology will lead to greater regional stability. According to the Defense Ministry officials, the initial disagreements within the government over the US missile defense system have given way to a consensus on the issue. Over the past two years, India and the United States have held four rounds of informal dialog on missile defense issues.

—Bulbul Singh, "Vajpayee to Promote Cooperation on Missile Defenses with US," *Aerospace Daily*, 24 September 2003, Vol. 207, No. 58, News, p. 2; in Lexis-Nexis Academic Universe, 2 October 2003, <http://web.lexis-nexis.com>.

23 September 2003

The Indian government sanctions the transfer of two new Agni missile groups to the Army in order to expedite the process of operationalizing the deployment of short- and medium- range Agni missiles. The new 334 missile group will be armed with the 700km range Agni I missile and the 335 missile group will be armed with the 1,500km Agni II missile. The new missile groups are expected to be raised near Secunderabad in Andhra Pradesh. Bharat Dynamics Ltd. (BDL), the organization which produces missiles is located in Secunderabad. The Army has already allocated manpower for the new missile groups even though the government is yet to release funds for the missile groups. Sources indicate that the new missile groups have been allocated to the Army since the newly formed Strategic Forces Command (SFC) is not yet operational. The government also approves the creation of two new Prithvi missile groups, named 444 and 555 missile groups. Currently, the Army has deployed two Prithvi missile groups, namely the 222 and the 333 missile groups. Officials indicate that the new Prithvi missile groups will become operational by 2005 and the missile groups will be raised in Secunderabad contingent on the funds allocated by the Ministry of Finance. Until now, only the 333 Prithvi missile group is complete and has been shifted along with the 40th artillery division to a permanent location in Madhya Pradesh. The 333 missile group is armed with liquid-

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propellant Prithvi missiles. The new Prithvi missile groups will have solid fuel motors, which will reduce the need for mobile fuel toppers, needed for liquid-fueled missiles, by one-third. According to highly placed sources, a large number of Navy and Air Force personnel, apart from the Army personnel, are undergoing training to use various surface-to-surface missiles. According to a forthcoming article in the defense magazine *Force*, the Indian government plans to use only conventional warheads on Prithvi missiles and use it to attack the enemy's strategic reserves and degrade the enemy theater. According to the article, the government plans to keep the Agni as the mainstay of its nuclear deterrence. The report says that the Defense Research and Development Organization (DRDO) has not equipped the Prithvi missile with incendiary warheads and blast-cum-earth shock submunitions. Moreover, the government has also not approved arming the missiles with fuel-air explosives.

—"Indian Govt. to Hand Over Agni Missiles to Army," *Press Trust of India*, 2 September 2003, Nationwide International News; in Lexis-Nexis Academic Universe, 23 September 2003, <http://web.lexis-nexis.com>.

21 September 2003

The chief of the Defense Research and Development Organization (DRDO) Dr. V.K. Aatre will lead a high-level delegation to Israel in early October. Senior officials in India's Ministry of Defense state that the visit is a follow-up to the negotiations held with the head of the Ministry of Defense Exports Maj. Gen. Amos Mayer. The negotiations were held during the visit of Israeli Prime Minister Ariel Sharon's visit to India. Officials indicate that India is seeking cooperation in developing the short-range sea-skimming missile and developing a new inertial navigation system. According to officials, the delegation will also seek cooperation in developing long-range missiles like the 3,000 km Agni III. The agenda for the meeting also includes collaboration to revive the surface-to-air Akash missile system and the Trishul missile system. The Ministry of Defense does not provide any official notice about the proposed trip.

—"Indian Defence Team to Visit Israel for Help on Missile Program: Report," *Agence France Presse*, 21 September 2003, International News; in Lexis-Nexis Academic Universe, 22 September 2003, <http://web.lexis-nexis.com>; "DRDO Team Visiting Israel to Explore Defence Collaboration," *Financial Express (Mumbai)*, 21 September 2003; in Lexis-Nexis Academic Universe, 21 September 2003, <http://web.lexis-nexis.com>.

12 September 2003

Indian officials indicate that the 700km Agni I and 1,500 km Agni II are being inducted into the military. Officials also indicate that the 3,000 km range Agni III will be tested at an appropriate time.

—"Agni Missiles Being Inducted into Armed Forces," *Press Trust of India*, 12 September 2003, Nationwide International News; in Lexis-Nexis Academic Universe, 12 September 2003, <http://web.lexis-nexis.com>.

10 September 2003

Israel's Deputy Prime Minister Yosef Lapid says that the United States is studying the proposal to sell the Arrow anti-missile system to India.

—"Israel Sale of "Arrow" Anti-Missiles Dependent on US Approval," *BBC Monitoring International Reports*, 10 September 2003; in Lexis-Nexis Academic Universe, 10 September 2003, <http://web.lexis-nexis.com>.

8 September 2003

According to the Israeli newspaper *Haaretz*, the United States has blocked discussions between India and Israel on

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the possible sale of the Arrow anti-missile system. According to the news report, the United States has advised Israel's Prime Minister Ariel Sharon not to offer the Arrow anti-missile system during his forthcoming visit to India. —Atul Aneja, "U.S. Objects to Sale of Arrow Missiles to India," *Hindu* (Chennai), 8 September 2003; in Lexis-Nexis Academic Universe, 8 September 2003, <http://web.lexis-nexis.com>.

7 September 2003

The Indian government approves the procurement of 30 additional nuclear-capable Prithvi missiles with 150-300 km range. The new Prithvi missiles will be propelled by solid fuel since the Army experts found solid propelled missiles to be more reliable and target oriented. The government also approves the purchase of additional missile launchers. Currently, each Army missile battalion has eight launchers. Defense officials also state that preparations are underway to test the 3,000 km Agni III and indicate that the missile will be tested in the first week of November. The government also approves the induction of the Agni I and Agni II missiles into the Strategic Forces Command (SFC). The location of headquarters, command structure, and location of alternate command are finalized and being implemented. The government also approves the transfer of the two Army missile battalions to the SFC. Officials indicate that these decisions were taken at the meeting of the Political Council last week. —"Government to Procure More Prithvi Missiles," *Press Trust of India*, 7 September 2003, Nationwide International News; in Lexis-Nexis Academic Universe, 8 September 2003, <http://web.lexis-nexis.com>.

5 September 2003

The Director of the Defense Research and Development Laboratory (DRDL) Dr. Prahlada says that the short-range surface-to-air Akash missile will be sent for user trials in 2004. Dr. Prahlada indicates that the Akash missile hit a flying target during the flight trials. He also says that the Trishul missile will also be tested and states that the dates for the test have not been finalized. Referring to the problems with the Trishul missile, Dr. Prahlada says that the missile faced a problem two years ago which was corrected subsequently. —K.R. Sreenivas, "Akash, Nag to be Sent for User Trials in 2004," *Times of India* (Mumbai), 6 September 2003; in Lexis-Nexis Academic Universe, 6 September 2003, <http://web.lexis-nexis.com>.

5 September 2003

The United States is undecided on whether to allow the sale of the Israeli Arrow anti-missile system to India. The United States has neither denied nor approved the sale. The Arrow anti-missile system is jointly developed by Israel and the United States. The sale of the Arrow anti-missile system requires the approval of the United States. The White House and the Pentagon are believed to support the sale whereas the Department of State and the non-proliferation lobby in Washington DC oppose the sale. Pakistan has also expressed its concerns over the possible sale of the anti-missile system to India. —C. Raja Mohan, "U.S. Holds Back Israeli Arrow," *Hindu* (Chennai), 5 September 2003; in Lexis-Nexis Academic Universe, 5 September 2003, <http://web.lexis-nexis.com>.

4 September 2003

India's Nuclear Command Authority (NCA) directs the military to transfer the control of the nuclear arsenal to the Strategic Forces Command (SFC) which was established in January 2003. The directive is issued after a meeting of the Political Council in which it is revealed that the command and control and warning systems and the

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infrastructure for the NCA are not operational. According to officials, the Indian armed forces are reluctant to transfer the nuclear arsenal to the SFC.

—Bulbul Singh, "Military Forces to Transfer Nuke Control to New Command," *Aerospace Daily*, 4 September 2003, Vol. 207, No. 46, p. 5; in Lexis-Nexis Academic Universe, 19 September 2003, <http://web.lexis-nexis.com>.

2 September 2003

India's Prime Minister Atal Behari Vajpayee chairs a two hour meeting of the Political Council of the Nuclear Command Authority (NCA). The meeting is also attended by Deputy Prime Minister L.K. Advani, Defense Minister George Fernandes, Finance Minister Jaswant Singh, and National Security Advisor Brajesh Mishra and other top government and defense officials. The Political Council reviews the steps undertaken to setup the Strategic Forces Command (SFC) with emphasis on instituting the chain of command, the transfer of nuclear assets from the three services to the Strategic Forces Command, and the implementation of the Chief of Integrated Defense Staff (CIDS). The meeting also reviews the preparedness of the SFC with respect to the nuclear delivery systems and the meeting also examines the doctrine of the SFC.

—"India Holds High-Powered Meeting to Review Nuclear Deterrence," Xinhua News Agency, 2 September 2003, World News, Political; in Lexis-Nexis Academic Universe, 3 September 2003, <http://web.lexis-nexis.com>.

September 2003

The Indian Air Force invites bids for the supply of short-range surface-to-air missiles following the poor test results shown by the Trishul missile system.

— Bulbul Singh, "Firms Submit Bids to Supply Short-Range Missiles to India," *Aerospace Daily*, 11 November 2003, Vol. 208, No. 30, News, p. 5; in Lexis-Nexis Academic Universe, 22 January 2004, <http://web.lexis-nexis.com>.

25 August 2003

Due to problems associated with the Trishul missile project, the Indian Navy decides to buy more Barak systems at an estimated cost of Rs. 100 crore for each missile system. The Navy plans to equip other warships including the Brahmaputra class frigates with the Barak missile system. Indian defense sources indicate that the Trishul missile system, despite undergoing 70 tests, is still facing problems with the guidance, control, and propulsion systems. Sources indicate that the Navy plans to standardize the anti-ship defenses on the Barak missile system. The Navy also plans to use the BrahMos supersonic cruise missile as its primary anti-ship weapon. The BrahMos cruise missile is believed to be more advanced than the anti-ship missiles currently possessed by China and Pakistan.

—Rajat Pandit, "Trishul is Blunt, SO Naval Forces Seek Barak," *Times of India* (Mumbai), 25 August 2003; in Lexis-Nexis Academic Universe, 26 August 2003, <http://web.lexis-nexis.com>.

20 August 2003

Russia displays the aerial variant of the BrahMos supersonic cruise missile at the International Aerospace Show (MAKS-2003) in Moscow. India and Russia are jointly developing the BrahMos cruise missile. Alexander Leonov, the Deputy Chief Designer of NPO Mashinostroyeniya says that flight-tests of the BrahMos will be completed in 2003 and serial production will begin simultaneously in India and Russia in 2004. The Indian and Russian production facilities can produce 100 BrahMos missiles annually. Mr. Leonov says that the BrahMos missile has been successfully tested in both inclined and vertical positions and also from the Indian warship INS Rajput. Mr. Leonov

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says that the displayed version of the missile is intended for the Sukhoi Su-30 MKI. The three Krivak class stealth frigates, which India recently acquired from Russia, can also be armed with BrahMos missiles. Mr. Leonov says that India and Russia plan to export the missile to some friendly countries; these countries have been indentified. Mr. Leonov, however, does not disclose the names of the countries.

—"Aerial Version of BrahMos on Display at Intl Aerospace Show," *Press Trust of India*, 20 August 2003, Nationwide International News; in Lexis-Nexis Academic Universe, 22 August 2003, <http://web.lexis-nexis.com>.

19 August 2003

An Indian Defense Ministry official says that the tests for the Akash surface-to-air missile will continue and adds that the government plans to invest \$500 million to procure other missile systems. The Akash missile system, based on the Russian SA-6 air defense system, is nearing completion. India is developing two versions of the Akash missile. One version has a range of 25 kilometers whereas the second version has a range of 60 kilometers.

—Bulbul Singh, "Indian Army Rejects Akash, Asks for Other Missiles," *Aerospace Daily*, 19 August 2003, Vol. 207, No. 35, News, p. 5; in Lexis-Nexis Academic Universe, 21 August 2003, <http://web.lexis-nexis.com>.

17 August 2003

India seeks information on the Patriot anti-missile system from the United States and also seeks US approval for India's participation in the Israeli Arrow anti-missile project. Indian Defense Ministry officials express confidence that the United States will provide an early response to India's requests. Indian officials state that the request is part of an action plan to build an anti-missile system along India's western border with Pakistan. The plan envisages at providing a rapid response capability to India's armed forces in the event of a nuclear or conventional missile attack. The plan also calls for linking existing systems like the Low Level Transportable Radars from Israel with the still-to-be inducted Airborne Warning and Air Control System. Another component of the plan involves the linking of ground components with an indigenous spy satellite system. Indian Defense ministry officials state that the request for technical information on the Patriot system is important since India is planning to restart trials for the Trishul missile which was shelved recently. The Trishul missile, originally intended for surface-to-air multi-target role was later adapted as an anti-missile system after some technical breakthroughs. The project faced some problems after the imposition of US sanctions following the nuclear tests in May 1998. Defense scientists are also attempting to adapt the Akash missile as an anti-missile system.

—"India Plans an Early Indigenous Anti-Missile System," *Press Trust of India*, 17 August 2003, Nationwide International News; in Lexis-Nexis Academic Universe, 18 August 2003, <http://web.lexis-nexis.com>.

17 August 2003

The *Hindustan Times* reports that India plans to shelve the surface-to-air Akash missile project. The Akash missile system was intended to provide air-defense capabilities for the Army and protect the vital assets of the Air Force. However, the delays in the development of the 25 kilometer range missile increased the cost for the missile and the Army initiated efforts to look for alternate foreign missile systems. According to the news report, one Akash missile system comprising of four missile batteries was estimated to cost \$187.5 million in 1985 and the cost escalated to \$416 million. Apart from the cost overruns, the Akash missile also faces technical problems. The radar for the missile system only scans a 90 degree swathe. Hence the missile system cannot track aircraft and missile approaching from different directions at the same time. The Akash missile can reach a maximum speed of Mach 3

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which is suitable to target aircraft but is insufficient to target missiles since they fly at more than Mach 6. The defense ministry states that the missile is capable of tracking several targets simultaneously. The new report, however, states that the missile's ability to respond to multiple unknown targets is doubtful since the missile tests only involved known single targets. According to the report, the Army is not confident that the Akash missile will be inducted even though a series of tests are planned for June 2004. The Army and the Air Force also found the BMP-II chassis unsuitable for mounting the missiles.

—"AFP Cites Hindustan Times Saying India to Shelve Second Anti-Aircraft Missile," *World News Connection*, 17 August 2003; in Lexis-Nexis Academic Universe, 19 August 2003, <http://web.lexis-nexis.com>; "India's Medium-Range Missile Akash Set Aside (After Both the Indian Army and Air Force Reject It)," *India Business Insight* (Bangalore), 30 September 2003; in Lexis-Nexis Academic Universe, 9 October 2003, <http://web.lexis-nexis.com>.

14 August 2003

As part of its efforts to acquire air defense capabilities, India requests "technical information" regarding the Patriot anti-missile system from the United States. India's Defense Minister George Fernandes informs the upper house of parliament (Rajya Sabha) that the Indian government has sent a request to the US Defense Cooperation Agency. India is also examining the Israeli Arrow anti-missile system. But Mr. Fernandes says that there is no proposal to acquire and upgrade the Arrow anti-missile system. Russia also renews its proposal to sell the long-range S-300V anti-missile system along with the shorter range Tor-M1 and Buk-M1 systems for theater missile defenses.

—Rajat Pandit, "India Wants Info on Patriot Missile System," *Times of India* (Mumbai), 14 August 2003; in Lexis-Nexis Academic Universe, 13 August 2003, <http://web.lexis-nexis.com>.

8 August 2003

The Director of the Vikram Sarabhai Space Center (VSSC) Dr. G. Madhavan Nair says that India will launch its first re-usable spacecraft by 2005 aboard the Polar Satellite Launch Vehicle (PSLV). After conducting experiments in materials processing and other areas, the spacecraft will be retrieved and re-used. According to Dr. Nair, the project will cost about Rs. 500 million. Dr. Nair also says that Indian Space Research Organization (ISRO) is developing the next variant of the Geo-Synchronous Satellite Launch Vehicle - Mark III (GSLV-Mark III), which will be able to deploy a 4 ton satellite into geo-synchronous orbit. Dr. V.K. Aatre, the scientific advisor to the Defense Minister, denies that the government is reviewing its decision to continue with certain guided missile projects. Acknowledging the existence of problems in certain projects, Dr. Aatre says that "no such program is being abandoned."

—"India to Launch Re-usable Spacecraft by 2005," *Press Trust of India*, 8 August 2003, Nationwide International News; in Lexis-Nexis Academic Universe, 8 August 2003, <http://web.lexis-nexis.com>.

8 August 2003

Dr. R.N. Agarwal, the former Director of the Agni missile project and currently the Director of Advanced Systems Laboratory (ASL), states that the carbon composite content of the new variants of Agni will be increased from 35 percent to 80 per cent making them lighter and hence travel longer ranges. Dr. Agarwal says that Agni's re-entry heat shield is entirely made up of carbon composite. Dr. Agarwal makes his remarks at the national symposium on "Strategic Materials and Technologies for Composites" organized by the ASL. Dr. Agarwal says that India developed the carbon composite technology completely indigenously since it was highly restricted. Dr. Agarwal adds that

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futuristic projects such as the reusable hyperplane will utilize composite materials extensively.

—"Lightweight Agni Variant on the Way," *Press Trust of India*, 8 August 2003, Nationwide International News; in Lexis-Nexis Academic Universe, 8 August 2003, <http://web.lexis-nexis.com>.

7 August 2003

Taiwan's customs officials board the North Korean container ship "Be Gae Dong" docked at Kaohsiung harbor and find 1,000 tons of aluminum oxide. The ship docked in the harbor to unload the 1,000 tons of aluminum oxide. The spokesperson from the Kaohsiung customs bureau Mr. Wong Yao-ming says that the aluminum oxide was made in India and was destined for Pyongyang, North Korea. Earlier, the United States informed the Taiwanese officials that the ship was carrying "missile-making material." Mr. Wong says that it is not possible to detain the ship since it had declared the aluminum oxide. According to Mr. Wong aluminum oxide alone does not present a danger. [Aluminum oxide when mixed with other chemicals produces aluminum salt which is used in producing missile shells.]

—"Taiwan Finds 'Missile-Making' Material on N. Korean Ship," *Deutsche Presse-Agentur*, 8 August 2003, Politics; in Lexis-Nexis Academic Universe, 8 August 2003, <http://web.lexis-nexis.com>.

6 August 2003

The Indian Navy plans to upgrade its Kilo-class submarines and convert them into missile capable submarines. The Indian Navy has 10 kilo-class submarines in its fleet of 16 submarines. According to the Navy's plans five Kilo-class submarines will be converted to carry missiles. After the transformation, the submarines will become capable of firing missiles with a range of 150-200 km. Currently, the Kilo-class submarines can only fire torpedoes. According to Commodore Uday Chitanavis the Kilo-class submarines "Sindhu Kesari" and "Sindhu Ratna" have already been upgraded. Currently the "Sindhu Ghosh" is undergoing transformation in Russia.

—"Indian Navy Submarines Undergoing Upgradation Programme," *Press Trust of India*, 6 August 2003, Nationwide International News; in Lexis-Nexis Academic Universe, 6 August 2003, <http://web.lexis-nexis.com>.

6 - 7 August 2003

The US-India Defense Policy Group (DPG) meets in Washington DC. India and the United States decide to hold a missile defense workshop in India within the next few months. The workshop is intended as a follow-up to the June 2003 Multinational Ballistic Missile Defense Conference in Kyoto, Japan and attended by India and the United States. India also agrees to participate in the July 2004 Multinational Ballistic Missile Defense Conference in Berlin and the Roving Sands Missile Defense Exercise in 2005. Both sides also agree that missile defense enhances cooperative security and stability.

—"US DOD: Joint Statement on U.S.-India Defense Policy Group," M2 Presswire, 11 August 2003; in Lexis-Nexis Academic Universe, 11 August 2003, <http://web.lexis-nexis.com>.

30 July 2003

India's Defense Minister George Fernandes informs parliament that the 700 km Agni I and the 2,000 km Agni II are in the induction phase. Mr. Fernandes says that the 200 km version of the Prithvi has been inducted into the Army whereas the Air Force version of the same missile is under induction.

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—"20 Missile Tests in India in First Half of 2003 at Cost of 16 Mln Dollars," Agence France Presse, 30 July 2003, International News; in Lexis-Nexis Academic Universe, 31 July 2003, <http://web.lexis-nexis.com>.

24 July 2003

The Defense Research and Development Organization (DRDO) decides to strengthen the security around the Interim Test Range (ITR) in Balasore district and Wheeler's Island in the nearby Bhadrak district. The DRDO plans to setup sophisticated radar stations along the coastline. The DRDO is increasing the security after Orissa's Chief Minister raised concerns about the presence of foreign nationals in the vicinity of the missile facilities. During the last two years, Orissa police nabbed Bangladeshi nationals for suspicious movements around the missile facilities. As a first step, the DRDO plans to setup a radar facility at Kendrappa district. The DRDO has also requested the Orissa State government to procure land for the radar facility.

—"Indian Defense Body to Strengthen Security Ring Around Missile Launching Centers," *World News Connection*, 24 July 2003; in Lexis-Nexis Academic Universe, 26 July 2003, <http://web.lexis-nexis.com>.

23 July 2003

India's Defense Minister George Fernandes informs the upper house of parliament (Rajya Sabha) that the defense Research and Development Organization (DRDO) is working to remove the problems associated with the Trishul missile project and convert it into an anti-missile system. Mr. Fernandes says that the project is currently de-linked from user service due to delays arising out of technical problems. Mr. Fernandes claims that the four tests for the Trishul missile conducted in June 2003 met all mission objectives like validating guidance system and operations. However, the Army, Navy, and the Air Force are allowed to import foreign missiles to meet their urgent demands while DRDO solves problems associated with the missile.

—"India's Home-Made SAM Not a DUD Missile: Defence Minister," Agence France Presse, 23 July 2003, International News; in Lexis-Nexis Academic Universe, 24 July 2003, <http://web.lexis-nexis.com>.

17 July 2003

The outgoing US Ambassador to India Ambassador Robert Blackwill states that the United States does not "fixate on India's nuclear weapons and missile program."

—Maseeh Rahman, "Outgoing Envoy Cites Shift in US Policy; Focus for Allies is Now on Civil Nuclear, Space, and Other High-Technology Areas," *South China Morning Post* (Hong Kong), 18 July 2003, News, p. 11; in Lexis-Nexis Academic Universe, 19 July 2003, <http://web.lexis-nexis.com>.

17 July 2003

India decides to increase the production of its missiles in order to counter Pakistan's Hatf, Shaheen, and Ghauri missiles. According to a senior defense official, the Defense ministry sanctioned \$500 million to Bharat Dynamics Limited (BDL) to produce six types of missiles. India plans to produce 50 Prithvi I missile for the Army, 50 Prithvi II missiles for the Air Force, 25 Prithvi Plus missiles for the Army, and 25 Dhanush missiles for the Navy. With the exception of Prithvi I which has a range of 150 kilometers, all the other missiles have a range of 250 km. The Army has also ordered 25 Agni I missiles and 25 Agni II missiles.

—Bulbul Singh, "India to Build Missile Stocks While Seeking Missile Defense," *Aerospace Daily*, 17 July 2003, Vol. 207, No. 12, News, p. 2; in Lexis-Nexis Academic Universe, 23 July 2003, <http://web.lexis-nexis.com>.

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16 July 2003

India and the representatives of Lockheed Martin discuss the pricing for the P3 B Orion multi-mission maritime aircraft. Indian defense officials indicate that India can fit the aircraft with BrahMos supersonic cruise missiles to provide strike capability for the aircraft.

—C.R. Jayachandran, "India Seeks More Naval Strike Capability," *Economic Times* (Mumbai), 16 July 2003; in Lexis-Nexis Academic Universe, 16 July 2003, <http://web.lexis-nexis.com>.

9 July 2003

A spokesperson for the Ministry of Defense rejects reports that the Trishul missile project is shelved and states that the missile subsystems, air frames, and controls worked as expected in missile tests conducted between June 22 and June 25. The spokesperson says that in future the Defense Research & Development Organization (DRDO) will conduct the tests in association with the user, i.e. the military. The spokesperson also states that the missile tests achieved better than specified results against moving targets. The spokesperson reveals that the missile tests before June 2003 were not meeting all the desired parameters and says that the problem was arising due to inconsistency of the guidance and control systems. According to the spokesperson, the DRDO conducted the tests last month after carrying out modifications to the guidance and subsystems and propellants. According to the spokesperson four missiles were launched from the Trishul Combat Vehicle in full combat configuration and the tests met all the flight objectives.

—"Further Tests of Trishul to be Carried Out With Users," *Press Trust of India*, 9 July 2003, Nationwide International News; in Lexis-Nexis Academic Universe, 12 July 2003, <http://web.lexis-nexis.com>.

7 July 2003

A senior scientist at the Defense Research and Development Organization (DRDO) denies reports that the Trishul missile project has been abandoned and says that the project is currently "not user-driven but R&D driven." The senior scientist says that the DRDO is examining problem areas and ensure consistency in performance in order to retain the customer confidence. The scientist denies news reports that the Trishul missile project is shelved and says that a project as complicated as a surface-to-air missile will involve some delays and setbacks prior to induction. The scientist promises that the DRDO will provide the Navy with the Trishul missile after correcting the problems in command guidance. Another scientist at the Defense Research and Development Laboratory (DRDL) says that the four tests of the Trishul missile conducted between June 22 to June 25 were conducted in the presence of Indian Air Force (IAF) officials and states that the results were satisfactory. The DRDL scientist adds that the missed distance was within the stipulated guidelines.

—Anantha Krishnan M., "Trishul Programme is Alive, Kicking: DRDO," *Economic Times* (Mumbai), 8 July 2003; in Lexis-Nexis Academic Universe, 8 July 2003, <http://web.lexis-nexis.com>.

5 July 2003

The scientific advisor to the Defense Minister Dr. V.K. Aatre says that the Trishul missile project has been converted into a research and development project since it did not meet the requirements of the armed services. Dr. Aatre says that the four tests of the missile system last month were conducted to solve the technical problems and says that the Defense Research & Development Organization (DRDO) will solve the problems associated with the missile system. Dr. Aatre does not provide details about the problems associated with the system. He says that

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the DRDO allowed the Navy to procure the Barak anti-missile system since the Navy wanted to have a system until the Trishul missile system is completed.

—"India Shelves Development of Short-Range Anti-Aircraft Missile," Agence France Presse, 6 July 2003, International News; in Lexis-Nexis Academic Universe, 7 July 2003, <http://web.lexis-nexis.com>.

25 June 2003

India test-fires the short-range surface-to-air Trishul ballistic missile at 1.20 PM IST for the fourth consecutive day from the Interim Test Range (ITR) at Chandipur-on-sea on India's eastern coast. According to sources, the test is conducted to verify the missile's accuracy and other parameters.

—"Trishul Test-Fired Again on the Fourth Consecutive Day at Chandipur," *Pakistan Newswire*, 25 June 2003, Nationwide International News; in Lexis-Nexis Academic Universe, 26 June 2003, <http://web.lexis-nexis.com>; "Another Test-Firing," *Hindu* (Chennai), 25 June 2003; in Lexis-Nexis Academic Universe, 25 June 2003, <http://web.lexis-nexis.com>.

24 June 2003

The Indian Express, quoting sources, says that all the four tests for the Trishul missile failed. The news report says that the first test occurred on June 20 in which the missile did not take-off from the missile launcher. In the second test on June 22, the missile was launched but it did not fly to its maximum range of 8-10 km. According to the news report, the third test on Monday also failed. The fourth test on June 24 failed as the missile did not hit the Lakshya micro-light aircraft and both the missile and the target fell into the sea. A spokesperson from the Defense Ministry denies that the fourth test failed to meet its specifications. Until last week the Defense Ministry planned to shelve the Trishul missile project. Last week, however, a decision was taken to test the missile.

—"Four Test-Firings Later, Trishul Yet to Find Its Target," *Indian Express* (Mumbai), 24 June 2003; in Lexis-Nexis Academic Universe, 25 June 2003, <http://web.lexis-nexis.com>.

24 June 2003

For the third time in three days India test-fires the short-range surface-to-air Trishul ballistic missile around 6.50 AM GMT from a mobile launcher at the Interim Test Range (ITR) at Chandipur-on-sea on India's eastern coast. The target is a micro-light unmanned aircraft.

—"Trishul Test-Fired for the Third Time," Press Trust of India, 24 June 2003, *Nationwide International News*; in Lexis-Nexis Academic Universe, 24 June 2003, <http://web.lexis-nexis.com>.

23 June 2003

India tests the short-range surface-to-air Trishul surface-to-air missile for the second time in two days. The missile is launched from a mobile launcher at the Interim Test Range (ITR) at Chandipur-on-sea on India's eastern coast. The missile successfully hit the micro-light unmanned aircraft target.

—"India Conducts Second Test of Trishul Surface-to-Air Missile," Deutsche Presse-Agentur, 23 June 2003, Politics; in Lexis-Nexis Academic Universe, 23 June 2003, <http://web.lexis-nexis.com>; "India Tests Short-range Missile Again," Agence France Presse, 23 June 2003, International News; in Lexis-Nexis Academic Universe, 24 June 2003, <http://web.lexis-nexis.com>; "India Successfully Test-Fires Short-Range Missile for Second Consecutive Day," BBC

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Monitoring International Reports, 23 June 2003; in Lexis-Nexis Academic Universe, 23 June 2003, <http://web.lexis-nexis.com>.

22 June 2003

India test-fires the short-range surface-to-air Trishul ballistic missile at 2.00 PM IST from the Interim Test Range (ITR) at Chandipur-on-sea on India's eastern coast. The scientists term the test as a success. The missile is tested to evaluate its accuracy and other parameters. The Indian government had earlier planned to shelve the Trishul missile project. The Trishul missile has a range between 500 meters to nine kilometers and can carry a 15 kg payload. The missile can also fly above the sea at a low altitude. The Army and the Air Force can also use the missile, originally intended for the Navy. The missile has a radar altimeter which allows the missile to fly above water at low altitudes.

—"India Tests Homegrown Short Range Surface-to-Air Missile," Agence France Presse, 22 June 2003, International News; in Lexis-Nexis Academic Universe, 23 June 2003, <http://web.lexis-nexis.com>; "India Conducts Second Test of Trishul Surface-to-Air Missile," Deutsche Presse-Agentur, 23 June 2003, Politics; in Lexis-Nexis Academic Universe, 23 June 2003, <http://web.lexis-nexis.com>; "India" Test Firing of Short Range Surface-to-Air Trishul Missile Detailed," *World News Connection*, 23 June 2003; in Lexis-Nexis Academic Universe, 25 June 2003, <http://web.lexis-nexis.com>.

21 June 2003

India acquires the absolute gravimeter at a cost of Rs. 2 crores. The device is capable of accurately measuring the gravitational pull "g" to parts per billion and the device can be used in developing missiles. Japan and China are the only other Asian countries possessing the equipment. India's National Geophysical Research Institute acquires the instrument and plans to use the device in Antarctica for research purposes. The Director of the Defense Research and Development Laboratory (DRDL) Dr. Prahlada says that the device can be useful for defense purposes. According to a senior scientist at DRDL, the gravitational force "g" is an important component in designing missile and delivery systems and adds that the accuracy and efficiency of a missile can be improved by knowing the accurate "g" value at its launching site and target site.

[1. The gravitational pull "g" is the force exerted by the earth towards an object. The gravitational pull varies across locations based on the density of the underground materials at a particular location. During the launch of a missile, "g" acts as a negative force pulling the missile back towards the earth. During the re-entry phase of a missile, "g" acts as a favorable force pulling the missile towards the target on earth. Usually, during the designing phase for a missile, "g" is assumed as constant. However, the ability to calculate the "g" at the launch site and the target site enables the design of missile with high accuracy.]

—Lison Joseph, "Gravimeter Gives India Strategic Edge," *Times of India* (Mumbai), 21 June 2003; in Lexis-Nexis Academic Universe, 20 June 2003, <http://web.lexis-nexis.com>.

20 June 2003

The scientific advisor to the Defense Minister Dr. V.K. Aatre says that India will conduct the next round of tests for the BrahMos supersonic cruise missile after the monsoon season.

—"Bangalore to Have 'Smart Materials' Center," *Hindu* (Chennai), 20 June 2003; in Lexis-Nexis Academic Universe, 19 June 2003, <http://web.lexis-nexis.com>.

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11 June 2003

India and the United States discuss the sale of high-technology military equipment and modules of the missile defense shield. The United States continues to provide information to India regarding the basic concepts of the missile defense system. India is also invited to attend a missile defense cooperation conference in Japan in July and to attend a missile defense exercise scheduled in July as well at the White Sands testing facility in California. The United States has not approved the sale of the Patriot anti-missile system and the issue has not progressed beyond India's request for information regarding the Patriot system. The delay is probably due to the restrictions imposed by the Missile Technology Control Regime (MTCR) regarding the export of missile and sensitive technologies. India and the United States are discussing this issue separately.

—Sandeep Dikshit, "India, US Discuss Sale of Hi-Tech Military Equipment," *Hindu* (Chennai), 11 June 2003; in Lexis-Nexis Academic Universe, 11 June 2003, <http://web.lexis-nexis.com>.

10 June 2003

India test-fires the short-range surface-to-air Akash ballistic missile from a mobile launcher at 11.40 AM IST at the Interim Test Range (ITR) at Chandipur-on-sea on India's eastern coast. An official at the test site describes the test as "a major milestone in the country's integrated guided missile development program."

—"India Test-Fires Akash Missile For 3rd Time in 2 Weeks," Japan Economic Newswire, 10 June 2003, International News; in Lexis-Nexis Academic Universe, 10 June 2003, <http://web.lexis-nexis.com>; "India Test Fires Surface-to-Air Missile Akash," Deutsche Presse-Agentur, 10 June 2003, Miscellaneous; in Lexis-Nexis Academic Universe, 18 June 2003, <http://web.lexis-nexis.com>.

2 June 2003

Scientists from the Defense Research and Development Organization (DRDO) indicate that the BrahMos supersonic cruise missile will be test-fired any time this week. According to the sources, two Indian warships INS Rajput and INS Nilgiri are stationed off the Paradip coast to conduct the test. Russia has already tested the missile from its warships. DRDO sources also suggest that India will carry out some more tests for the 800 km range Agni I ballistic missile. India is also planning to carry out the first test for its 3,000 km range Agni III.

—"Akash Successfully Test Fired," *Press Trust of India*, 2 June 2003, Nationwide International News; in Lexis-Nexis Academic Universe, 2 June 2003, <http://web.lexis-nexis.com>.

2 June 2003

India test-fires the short-range surface-to-air Akash missile from a mobile launcher at 1.15 PM IST at the Interim Test Range (ITR) at Chandipur-on-sea on India's eastern coast. India tests the missile with the Rajendra phased array radar system. Indian scientists had earlier attempted to use the short-range surface-to-air Trishul ballistic missile in conjunction with the Rajendra array radar. But the effort was shelved after several failures to integrate the Trishul missile with the Rajendra radar. Scientists from the Defense Research and Development Organization (DRDO) term the test as part of development trials and suggest that the missile could be modified as an anti-missile system. According to DRDO sources, the missile will be tested several times before its induction into the military. The Akash missile uses a second-stage ramjet motor and it is guided by a ground-based radar and an onboard homing system. According to an Indian military official, the Akash missile is based on the Russian SA-6 air defense missile and it could be modified to intercept short-range missiles such as Pakistan's Hatf-1. The Akash

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missile is also expected to be integrated with the Russian S-300V anti-missile system. Originally, the Akash missile was scheduled to begin user trials in 2003. However, the imposition of US sanctions following the nuclear tests in May 1998 delayed the project since critical technologies such as guidance systems became available only after the removed the sanctions in 2001.

—"Akash Successfully Test Fired," *Press Trust of India*, 2 June 2003, Nationwide International News; in Lexis-Nexis Academic Universe, 2 June 2003, <http://web.lexis-nexis.com>; Bulbul Singh, "India's Akash Missile Nearing User Trials," *Aerospace Daily*, 3 June 2003, Vol. 206, No. 45, News, p. 6; in Lexis-Nexis Academic Universe, 6 June 2003, <http://web.lexis-nexis.com>.

June 2003

The scientific advisor to the Defense Minister Dr. V.K. Aatre states that "the Trishul missile is a closed project. It is out of reckoning for induction. We have allowed the users (the three services) to import missiles of this class." Dr. Aatre states that the missile has a command and guidance problem. According to officials, the DRDO has spent about Rs. 300 crore on the Trishul missile project which was started in 1983. The Trishul missile was originally intended to replace the Russian made Geckos missile supplied for the Air Force and the Navy. The Army's version of the missile was called Trishul Combat Vehicle. The tests to integrate the missile, missile launcher, surveillance radar, and the fire control system failed. According to a DRDO official, the missile did not hit its intended target during its launch from the Interim Test Range (ITR) and the INS Dronacharya. The DRDO official cites the problem with the command-guidance system and says that the team was not able to guide the missile in the final stages of its flight towards the target. According to sources, the Trishul missile's design uses ground-based radars for guidance since using on-board sensors would have been expensive and would have required a sophisticated network on-board the missile as well as on the ground. The sources indicate that attempts to change the command-guidance mechanism were analyzed and rejected since it involved major changes to other parts of the missile.

—B.R. Srikanth, "A Cosmi-Comic Show:," *Outlook* (New Delhi), 30 June 2003.

30 May 2003

According to a Defense official, India is considering the purchase of the Russian S-300V anti-missile system. However, India is giving higher priority to the Israeli Arrow anti-missile system and the American Patriot Advanced Capability-3 (PAC-3) anti-missile system.

—Bulbul Singh, "India Seeks to Acquire PAC-3 Missiles from US," *Aerospace Daily*, 30 May 2003, Vol. 206, No. 43, p. 6; "India Hopes for a Patriot Nod," *Indian Express* (Mumbai), 24 May 2003; in Lexis-Nexis Academic Universe, 4 June 2003, <http://web.lexis-nexis.com>.

29 May 2003

An Indian Defense Ministry official says that India plans to buy at least 10 Barak missile systems from Israel. According to the official three systems will be acquired during the next two years and the remaining systems will be procured within five years. India already possesses seven Barak missile systems. The Barak missile system is designed to protect combat ships against sea-skimming missiles and aircraft. The decision to procure additional Barak systems was taken after India decided to shelve the Trishul missile project. According to the defense official India wants to buy the vertical launch missile systems that can launch missiles faster.

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—Bulbul Singh, "Indian Navy to Buy Additional Barak Missile Systems from Israel," *Aerospace Daily*, 29 May 2003, Vol. 206, No. 42, p. 6; in Lexis-Nexis Academic Universe, 3 June 2003, <http://web.lexis-nexis.com>.

29 May 2003

India test-fires the short-range surface-to-air Akash ballistic missile at 5.00 PM IST from a mobile launcher at the Interim Test Range (ITR) at Chandipur-on-sea on India's eastern coast. The missile weighs 650 kg and can carry a 50 kg payload. The missile utilizes a two-stage ramjet propulsion technology. According to a defense scientist, India is also building the Rajendra radar which can track 64 aircrafts up to a range of 60 km simultaneously.

—"Akash," Press Trust of India, 29 May 2003, Nationwide International News; "India Hopes for a Patriot Nod," *Indian Express* (Mumbai), 24 May 2003; in Lexis-Nexis Academic Universe, 29 May 2003, <http://web.lexis-nexis.com>.

27 May 2003

A source in the Russian Defense Ministry says that the BrahMos supersonic cruise missile will be tested between 1-5 June 2003. According to the source, a team of technical experts from the Mashinostroyeniye research and production association have left for New Delhi to attend the missile test. The mass production of the missile is expected to begin in India and Russia in 2004.

—"Next Test Launch of Russian-Indian Cruise Missile Set for Early June," BBC Monitoring International Reports, 27 May 2003; "India Hopes for a Patriot Nod," *Indian Express* (Mumbai), 24 May 2003; in Lexis-Nexis Academic Universe, 27 May 2003, <http://web.lexis-nexis.com>.

25 - 31 May 2003

According to a senior defense official Prime Minister Atal Behari Vajpayee will discuss the potential purchase of the S-300V anti-missile system when he meets with Russian President Vladimir Putin. India proposes making advance payment for the system. Upon successful completion of the discussions, Russia will supply four to six S-300V anti-missile systems until a new system is developed.

—Bulbul Singh, "India Proposes Buy of Russian Anti-Missile System," *Aerospace Daily*, 3 June 2003, Vol. 206, No. 45, News, p. 5; in Lexis-Nexis Academic Universe, 6 June 2003, <http://web.lexis-nexis.com>.

24 May 2003

India hopes that the United States will provide a positive response to India's request for the sale of the Patriot anti-missile system. India believes that a positive response will be given at the next meeting of the Defense Policy Group (DPG) to be held in Washington in late June or early July.

—"India Hopes for a Patriot Nod," *Indian Express* (Mumbai), 24 May 2003; in Lexis-Nexis Academic Universe, 24 May 2003, <http://web.lexis-nexis.com>.

21 May 2003

The Bush administration releases a fact sheet outlining the National Policy on Ballistic Missile Defense which states that the United States will review its current policies and practices governing technology sharing and cooperation on missile defense. The fact sheet states that such review will include existing export control regulations and statutes. A US administration official denies any steps to loosen existing export control regulations and asserts that

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the issue is still under study and "far from a decision."

—The White House, "National Policy on Ballistic Missile Defense Fact Sheet," www.whitehouse.gov; Tom Raum, "Administration Eyes Possible Easing of Missile-Export Rules," Associated Press, 21 May 2003, Washington Dateline; in Lexis-Nexis Academic Universe, 22 May 2003, <http://web.lexis-nexis.com>.

18 - 24 May 2003

India discusses the possible sale of the Patriot anti-missile system with the visiting US Assistant Secretary of State for Arms Control Stephen G. Rademaker.

—"India Hopes for a Patriot Nod," *Indian Express* (Mumbai), 24 May 2003; in Lexis-Nexis Academic Universe, 24 May 2003, <http://web.lexis-nexis.com>.

11 May 2003

The Scientific Advisor to the Defense Minister Dr. V.K. Aatre says that the 700 kilometer Agni I is ready for induction into the Army.

—"Agni Ready for Induction in Armed Forces," *Press Trust of India*, 11 May 2003, Nationwide International News; in Lexis-Nexis Academic Universe, 11 May 2003, <http://web.lexis-nexis.com>.

8 May 2003

The Indian Space Research Organization (ISRO) successfully launches the Geo-Synchronous Satellite Launch Vehicle (GSLV-D2) from the Satish Dhawan Space Center. The GSLV-D2 places a 1,800 kilogram experimental communication satellite in a geosynchronous transfer orbit. The Chairman of the ISRO Dr. K. Kasturirangan says that GSLV Mark II, which is the next version of GSLV, will carry a payload of 2,250 kilograms.

—"India Moves Closer to Global Major in Satellite Launch," *Press Trust of India*, 8 May 2003, Nationwide International News; in Lexis-Nexis Academic Universe, 8 May 2003, <http://web.lexis-nexis.com>; R.K. Radhakrishnan, "Next GSLV Version to Carry Heavier Satellite," *Hindu* (Chennai), 10 May 2003; in Lexis-Nexis Academic Universe, 10 May 2003, <http://web.lexis-nexis.com>.

7 May 2003

India's Defense Minister George Fernandes informs the upper house of parliament (Rajya Sabha) that Agni I and Agni II are under production and will be deployed in 2003. He also states that the government has approved the development of the 3,000 kilometer range Agni III in order to meet long-term security needs. Mr. Fernandes states that the missile will be tested in the near future but does not provide a specific date. Some sources indicate that the first test for Agni III is likely to occur in November or December 2003. Mr. Fernandes states that Prithvi I has been inducted into the Army and adds that the longer range Prithvi II is currently under production after completing flight tests. Mr. Fernandes says that Prithvi II will be deployed by the Army and the Air Force.

—"Agni I and Agni II Missiles to be Deployed During the Year," *Press Trust of India*, 7 May 2003, Nationwide International News; in Lexis-Nexis Academic Universe, 7 May 2003, <http://web.lexis-nexis.com>; "India Will Deploy Two Agni Versions This Year," *Economic Times* (Mumbai), 9 May 2003; in Lexis-Nexis Academic Universe, 9 May 2003, <http://web.lexis-nexis.com>.

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6 May 2003

The Indian government plans to encourage public sector undertakings (PSUs) to explore foreign markets to export missiles and their subsystems. The missiles considered for exports include anti-tank missiles and ballistic missiles. The Indian government is preparing plans to sell subsystems for the short-range Prithvi ballistic missile. Some countries are believed to have expressed interest in buying the entire missile. According to unconfirmed reports India might have exported some subsystems for the Prithvi missile. The PSUs are currently underutilized due to the long delays in getting clearance for the production of missiles and their subsystems. Such delays are produced since the military takes a long time to accept new missiles developed by the Defense Research and Development Organization (DRDO). As a result of such delays, the organizations charged with manufacturing missiles are producing pistols and small arms.

—"PSUs to be Encouraged to Export Missiles," *Hindu* (Chennai), 6 May 2003; in Lexis-Nexis Academic Universe, 6 May 2003, <http://web.lexis-nexis.com>.

4 May 2003

Japan's defense chief Shigeru Ishiba seeks India's understanding on the idea of creating a missile defense system. Mr. Ishiba informs India's Defense Minister George Fernandes that the proposed anti-missile system is entirely defensive in nature which does not threaten other countries.

—"Japan Seeks India's Understanding for Missile Defense," Jiji Press Ticker Service, 5 May 2003; in Lexis-Nexis Academic Universe, 5 May 2003, <http://web.lexis-nexis.com>.

2 May 2003

India is considering selling missiles to friendly countries in order to boost defense exports. The missiles earmarked for export range from anti-tank missiles to cruise missiles. Indian defense sources stress that such missile exports will not violate the Missile Technology Control Regime (MTCR) even though India does not belong to the MTCR. India and Russia plan to export the BrahMos supersonic cruise missile after the India and Russian armed forces have inducted the missile. India and Russia plan to induct the BrahMos cruise missile in the next six to seven months. Officials estimate a \$10 billion market for the BrahMos missile. According to the *Asian Age*, India is considering the possibility of exporting subsystems of the short-range surface-to-surface Prithvi ballistic missile. According to an official from Bharat Dynamics Ltd. (BDL) India is planning to sell only subsystems of the missile in order to ensure India's security.

—Rajat Pandit, "New Delhi Planning to Sell Missiles to Friends," *Times of India* (Mumbai), 2 May 2003; in Lexis-Nexis Academic Universe, 1 May 2003, <http://web.lexis-nexis.com>; "India to Export Missiles to Friendly Countries: Reports," *Agence France Presse*, 2 May 2003, International News; in Lexis-Nexis Academic Universe, 1 May 2003, <http://web.lexis-nexis.com>.

May 2003

India's National Security Advisor Brajesh Mishra discusses the possible sale of the Patriot anti-missile system with the US Deputy Secretary of State Richard Armitage.

—"India Hopes for a Patriot Nod," *Indian Express* (Mumbai), 24 May 2003; in Lexis-Nexis Academic Universe, 24 May 2003, <http://web.lexis-nexis.com>.

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29 April 2003

India test-fires Prithvi II, a modified version of the Prithvi ballistic missile, at 11.30 AM IST from a mobile Transporter Erector Launcher (TEL) at the Interim Test Range (ITR) at Chandipur-on-sea on India's eastern coast. A press release from the Defense Ministry states that all test objectives were achieved. The DRDO describes the test as part of user trials aimed at fine-tuning the missile. The missile weighs 4.6 tons at launch, which includes a one ton payload. The missile is capable of reaching 150 kilometers in 300 seconds and missile possesses an on-board computer and advanced inertial navigation system. The missile uses both solid and liquid propellants. Defense sources indicate that Prithvi II has a range higher than the version of the missile already inducted into the Army. According to a source, the military wants to increase the range of the missile to about 300-350 kilometers. According to an army official, India has deployed 80 Prithvi I missiles with a range of 150 kilometers. The Indian Army and the Indian Air Force need more than 100 missiles of Prithvi II. A spokesperson for Pakistan's Foreign Ministry states India provided advance notification for the test.

—"India Successfully Test Fires Prithvi Missile," BBC Worldwide Monitoring, 29 April 2003; in Lexis-Nexis Academic Universe, 29 April 2003, <http://web.lexis-nexis.com>; "Modified Version of Prithvi Missile Test-Fired," *Times of India* (Mumbai), 30 April 2003; in Lexis-Nexis Academic Universe, 30 April 2003, <http://web.lexis-nexis.com>; Bulbul Singh, "India Launches Prithvi-2 Missile to Test New Guidance System," *Aerospace Daily*, 30 April 2003, Vol. 206, No. 22, p. 7; in Lexis-Nexis Academic Universe, 5 May 2003, <http://web.lexis-nexis.com>; "Pakistan Spokesman Says India Informed in Advance of Missile Test," BBC Worldwide Monitoring, 29 April 2003; in Lexis-Nexis Academic Universe, 29 April 2003, <http://web.lexis-nexis.com>.

28 April 2003

In its 19th report, the Parliamentary Standing Committee on Defense states that the Defense Ministry has not initiated any steps to create an aerospace command. The Committee report observes that its earlier reports since 2000 have recommended the creation of an aerospace command. The report states that the Defense Ministry has not taken action for the past three years. Currently, the Indian Space Research Organization (ISRO) manages aerospace issues and foreign collaborations.

—"Indian Air Force Yet to Materialize Aerospace Command, Only Exploratory Work Done," *World News Connection*, 28 April 2003; in Lexis-Nexis Academic Universe, 30 April 2003, <http://web.lexis-nexis.com>.

27 April 2003

The Parliamentary Committee on Public Undertakings says that the government should provide early clearance for the indigenous production of missiles since long delays are forcing Bharat Dynamics Ltd. (BDL) to make losses. The report also points out that the employees BDL, the organization charged with manufacturing missiles, are turning to manufacturing pistols and rifles due to absence of orders to produce missiles. The committee report also recommends upgrading the technological capabilities for BDL in order to keep pace with current developments in modern weapons systems such as improved guidance capabilities.

—"Early Clearance of Indigenous Missiles Production by BDL," *Press Trust of India*, 27 April 2003, Nationwide International News; in Lexis-Nexis Academic Universe, 27 April 2003, <http://web.lexis-nexis.com>.

26 April 2003

India explores the option of creating an aerospace command. Currently, India does not possess important

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components such as dedicated military satellites or Airborne Warning and Control Systems (AWACS) that are necessary for an aerospace command. The Indian Air Force believes that an aerospace command, among several other uses, can be used in a ballistic missile defense system for India.

—Rajat Pandit, "Groundwork Begins for Aerospace Command," *Times of India* (Mumbai), 26 April 2003; in Lexis-Nexis Academic Universe, 26 April 2003, <http://web.lexis-nexis.com>.

6 April 2003

India's Defense Minister George Fernandes states that India is developing the nuclear-capable Agni III ballistic missile and adds that efforts are underway to test fire the missile in 2003. Without revealing the exact range of Agni III, Mr. Fernandes says that Agni III has a longer range than Agni II. Agni II has a range of more than 2,000 kilometers. Mr. Fernandes also says that Agni I and Agni II are available to the military for deployment and adds that the custodian of the missiles will either be the Strategic Forces Command or the Army based on the situational needs. Mr. Fernandes indicates that the Trishul project, despite being shelved, provided a lot of knowledge that will be used in other projects. Commenting on the BrahMos supersonic cruise missile, Mr. Fernandes says that it is ready for deployment since all testing for the missile is complete. Mr. Fernandes also indicates that several countries are interested in the missile and states that the range for the missile does not violate the Missile Technology Control Regime (MTCR).

—"India Making Efforts to Test Fire "Agni III": Fernandes," *Press Trust of India*, 6 April 2003, Nationwide International News; in Lexis-Nexis Academic Universe, 9 April 2003, <http://web.lexis-nexis.com>.

26 March 2003

India test-fires the short-range Prithvi ballistic missile at 11.30 AM IST from a mobile launcher at the Interim Test Range (ITR) at Chandipur-on-sea on India's eastern coast. Pakistan also tests a missile a few hours after India's test. The missile is 8.5 meters in length and weighs 4.6 tons including a one ton payload. The missile incorporates on-board computer and advanced inertial navigation system and can use both solid and liquid propellants. The missile can reach its target at a distance of 150 kilometers in 300 seconds. The missile can carry a nuclear payload or conventional incendiary and fragmentary munitions. India's Defense Ministry spokesperson Baljit Singh Menon describes the launch as a routine user test for the missile. According to Mr. Menon several senior Army officials witnessed the test. The Prithvi missile has been tested sixteen times since the first test on 22 February, 1988.

—"India Tests Nuclear-Capable Missile, Surprises Analysts," Agence France Presse, 26 March 2003, International News; in Lexis-Nexis Academic Universe, 27 March 2003, <http://web.lexis-nexis.com>; "Prithvi," *Press Trust of India*, 26 March 2003, Nationwide International News; in Lexis-Nexis Academic Universe, 26 March 2003, <http://web.lexis-nexis.com>; "Missile Tit-For-Tat: India Test-Fires Nuclear-Capable Rocket, Then Pakistan Launches a Short-Range One," *Gazette* (Montreal, Quebec), 27 March 2003; in Lexis-Nexis Academic Universe, 27 March 2003, <http://web.lexis-nexis.com>.

18 March 2003

The Indian government decides to establish structures for the Nuclear Command Authority (NCA) at Alwar, Jodhpur, and Pokhran in Rajasthan and also at a location in Delhi and at Kargil. The NCA structure, estimated to cost about Rs. 10,000 crores includes the procurement of anti-missile defenses, land and sea based nuclear delivery systems, command and control communications, computers and intelligence systems. The NCA

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components setup at Alwar, Jodhpur, and Pokhran are expected to be anti-ballistic missile defense centers. India is expected to seek Russian and Israeli assistance in creating the command and control centers.

—"India Moves Forward on Nuclear, ABM Command and Control Structures," *Defense & Foreign Affairs Daily*, 18 March 2003, Vol. XXI, No. 39; in Lexis-Nexis Academic Universe, 27 April 2003, <http://web.lexis-nexis.com>.

17 March 2003

India displays the BrahMos supersonic cruise missile at the International Defense Exhibition IDEX 2003 at Abu Dhabi. Dr. A. Sivathanu Pillai, the Chief Controller of Research & Development at DRDO says that India is looking at West Asian and Far East markets for exporting the BrahMos missile. The Chief of Staff of the United Arab Emirates (UAE) Armed Forces Lt. Gen. Sheikh Mohammed bin Zayed Al Nahyan visits the stand showing a video of the cruise missile's capabilities. The Vice Minister of Defense for Iran Hussain Alani also visits the Indian exhibit.

—"Brahmos to Enter West Asia, Far East," *Business Line* (Chennai), 18 March 2003; in Lexis-Nexis Academic Universe, 18 March 2003, <http://web.lexis-nexis.com>.

12 March 2003

India's Defense Minister George Fernandes informs the upper house of parliament (Rajya Sabha) that the short-range surface-to-air Trishul missile has been "de-linked from the user services" as a result of delay in achieving the "state-of-the-art three beam guidance system." Mr. Fernandes says that the project is currently being pursued as a "technology demonstrator." Mr. Fernandes adds that the project enabled scientists to establish several complex technologies and sea-skimming capabilities that can be used in other future missile projects. The Defense Research & Development Organization (DRDO) began the project about twenty years ago and has spent about \$62.5 million on the project. The project faced problems in developing the technology for the guidance and propulsion system. The Trishul missile system was designed to defend ships by intercepting low-flying objects with a response time of six seconds after identifying the object. Mr. Fernandes denies that US sanctions imposed after the nuclear tests in May 1998 affected the development of the missile. As a result of the decision to shelve the Trishul project, India might look for foreign anti-missile systems. India is likely to acquire the Israeli Barak anti-ship missile system which is currently used on the INS Viraat, INS Delhi, and INS Mysore.

—"Naval Version of Trishul, A 'Non-Starter'," *Statesman* (Kolkata), 13 March 2003; in Lexis-Nexis Academic Universe, 13 March 2003, <http://web.lexis-nexis.com>; V.K. Raghunathan, "India Scraps Surface-to-Surface Missile; The Trishul, for Targeting Low-Flying Objects, Faces Snags in Developing Guidance and Propulsion Technology," *Straits Times* (Singapore), 17 March 2003; in Lexis-Nexis Academic Universe, 16 March 2003, <http://web.lexis-nexis.com>; Patricia Parmalee, "India's Defense R&D Organization Scraps Trishul Surface-to-Air Missile," *Aviation Week & Space Technology*, 17 March 2003, Vol. 158, No. 11, p. 11, Industry Outlook; in Lexis-Nexis Academic Universe, 20 March 2003, <http://web.lexis-nexis.com>; Bulbul Singh, "Trishul Missile Back on Track, India's Defense Minister Says," *Aerospace Daily*, 30 July 2003, Vol. 207, No. 21, News, p. 5; in Lexis-Nexis Academic Universe, 6 August 2003, <http://web.lexis-nexis.com>.

7 March 2003

German prosecutors in the city of Dortmund order the arrest of two brothers, Peter L. and Michael L., for violating German export control laws by exporting high-precision hydraulic rams that were used in the mobile launchers for the Agni missiles. The two brothers are managers at Montanhydraulik, a company based at Holzwickede, Germany.

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The company has an office in Chennai, India. The two brothers exported nine consignments of hydraulic cylinders between 1997 and 2000 by declaring them as bridge-laying gear to the export authorities. The two brothers were aware of the use of the hydraulic cylinders in the Agni missile program. It is not known whether the equipment was used in the mobile launchers for Agni-I or Agni-II.

—"Two Arrested in Germany: Supplied Parts for Indian Missile Launcher," *Deutsche Presse-Agentur*, 8 March 2003, Miscellaneous; in Lexis-Nexis Academic Universe, 9 April 2003, <http://web.lexis-nexis.com>.

7 March 2003

A senior official in the Indian Ministry of Defense says that the BrahMos cruise missile will be ready for induction by the end of 2003 after completing flight trials. The official also states that an advanced version of the Akash air defense system with a range of 30 kilometers is under development.

—Bulbul Singh, "India Has Tested All Missiles Under Development, Minister Says," *Aerospace Daily*, 7 March 2003, Vol. 205, No. 44, p. 7; in Lexis-Nexis Academic Universe, 12 March 2003, <http://web.lexis-nexis.com>.

5 March 2003

In a written reply to the upper house of parliament (Rajya Sabha), India's Defense Minister George Fernandes states that Agni-I and Agni-II ballistic missiles are currently in the production and induction phase. Mr. Fernandes states that Prithvi-I has been inducted and that Prithvi-II and the ship-to-surface Dhanush missiles are being inducted into the armed forces.

—"Agni Missile System Under Production and Induction Phase," *Press Trust of India*, 5 March 2003, Nationwide International News; in Lexis-Nexis Academic Universe, 5 March 2003, <http://web.lexis-nexis.com>.

4 March 2003

India's Defense Research & Development Organization (DRDO) seeks assistance from foreign scientists especially from the former Soviet Union for developing millimeter range wave image sensors that could be used in developing precision targeting systems. The Research Center Imarat (RCI), charged with developing the technology indigenously, is facing problems since India does not possess many key components for the wave image sensors. India is developing wave image sensors since the precision guidance system based on India's satellites provides an accuracy of one kilometer. Also, India does not wish to depend on the highly accurate Global Positioning System (GPS) provided by the United States since the United States might not provide the technology. Therefore, India wishes to use the wave image sensors which could be used with satellite technology for obtaining less than a 10 meter resolution in cross and down range.

—"DRDO Seeks Foreign Help for Precise Target-Hitting Technology (Efforts to Develop Indigenous Technology are Facing Problems)," *India Business Insight* (Bangalore), 4 March 2003; in Lexis-Nexis Academic Universe, 5 March 2003, <http://web.lexis-nexis.com>.

3 March 2003

Pakistan's Defense Minister Rao Sikander Iqbal informs the Pakistani National Assembly that Pakistan has expressed its concern over the proposed sale of the Israeli Arrow anti-ballistic missile system to India. The US House of Representatives is informed that the State Department has not authorized the sale of the Arrow anti-ballistic missile system to India citing possible violation of the Missile Technology Control Regime (MTCR).

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—B. Muralidhar Reddy, "Pak Concerned Over Arrow Missile Sale," *Hindu* (Chennai), 5 March 2003; in Lexis-Nexis Academic Universe, 5 March 2003, <http://web.lexis-nexis.com>.

2 March 2003

In the defense budget for 2003-2004, the Indian government allocates separate funding for the Integrated Defense Staff (IDS) thereby enabling the IDS to invest in production lines for ballistic missiles.

—"Separate Funds for IDS, 50% of Total for DRDO (Capital Outlay to Purchase Naval Fleet Increased by Rs 3,300 Crore," *India Business Insight* (Bangalore), 2 March 2003; in Lexis-Nexis Academic Universe, 5 March 2003, <http://web.lexis-nexis.com>.

20 February 2003

India's Defense Minister George Fernandes informs the lower house of parliament (Lok Sabha) that the short-range surface-to-air Trishul missile needs to be tested and proven for all its capabilities. The missile's development is being pursued as part of a technology demonstration project. Mr. Fernandes observed that the missile's development has established several complex technologies and well as sea-skimming capability. Mr. Fernandes also says that the BrahMos supersonic cruise missile is being tested on several launch platforms.

—"Trishul Needs to be Proved For All Capabilities," *Press Trust of India*, 20 February 2003, Nationwide International News; in Lexis-Nexis Academic Universe, 20 February 2003, <http://web.lexis-nexis.com>.

20 February 2003

According to an official from India's Foreign Ministry, India has agreed to invest \$150 million in Israel's Arrow anti-ballistic missile system. The proposed investment, however, must be approved by the United States. India's efforts to develop an indigenous anti-missile system Akash have faced cost overruns and time delays. According to the foreign ministry official, India is also discussing the purchase of Russia's S-300V air defense system. But the discussions have become entangled in negotiations for the purchase of the aircraft carrier Admiral Gorshkov.

—Bulbul Singh, "Israel Invites India to Invest in Arrow-2," *Aerospace Daily*, 20 February 2003, Vol 205, No. 33, p. 5; in Lexis-Nexis Academic Universe, 25 February 2003, <http://web.lexis-nexis.com>.

20 February 2003

The Indian Space Research Organization (ISRO) is considering the development of re-usable and reconfigurable launch vehicles in order to reduce the high costs of manufacturing satellite launch vehicles.

—"ISRO Bid to Contain Cost of Launch Vehicles," *India Business Insight* (Bangalore), 20 February 2003; in Lexis-Nexis Academic Universe, 23 February 2003, <http://web.lexis-nexis.com>.

19 February 2003

The Chairman of the Space Research Organization (ISRO) lays the foundation stone for increasing the production capacity of Ammonium Perchlorate at the Ammonium Perchlorate Experimental Plant at Aluva from 300 tons to 800 tons. Ammonium Perchlorate is used in the manufacture of solid propellant for rockets.

—T.S. Subramanian, "A Powder that will Power the Nation's Strategic Capability," *Hindu* (Chennai), 20 February 2003; in Lexis-Nexis Academic Universe, 20 February 2003, <http://web.lexis-nexis.com>.

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15 February 2003

Israel reportedly asks India to invest \$100 million in the development of the Arrow anti-ballistic missile system. The Arrow anti-ballistic missile system is jointly developed by Israel and the United States; the United States has provided \$628 million for the project. The missile system, in which Turkey has already contributed \$100 million, revolves around the Green Pine Radar System that can track and intercept as many as 14 incoming tactical ballistic missiles at a height of 58km. The DRDO has already acquired one Green Pine Radar System from Israel and is planning to integrate it with the Akash missiles and the indigenously developed Rajendra radar. India also hopes to integrate Arrow interceptors with this system. Although any involvement in the missile defense system with Israel will require US approval, Pentagon officials have already stated that India's acquisition of Arrow interceptors would not violate the MTCR as the Arrow constitutes a defensive weapon system.

—Shishir Gupta, "Israel boosts Indian missile defence hope," *Indian Express* (New Delhi), 15 February 2003; in "Israel Invites India to Participate in Development of Anti-Missile Defense System, FBIS Document SAP20030216000029, 16 February 2003.

12 February 2003

The supersonic anti-ship cruise missile BrahMos/PJ-10 is successfully tested from the destroyer *INS Rajput* off the Orissa coast. The BrahMos, which combines aspects of Yakhont and Onyx SLCMs with Indian computer guidance systems, was first tested on 12 June 2001. The latest test constitutes the first BrahMos launch from a warship. About 40 Russian scientists and DRDO officials witness the test-firing.

—"BrahMos successfully flight-tested from Bay of Bengal," *Hindustan Times* (New Delhi), 12 February 2003, www.hindustantimes.com.

12 February 2003

India test-fires the BrahMos supersonic cruise missile from the ship *INS Rajput*. The missile is eight meters long, has a width of 670 mm, and weighs 3,000 kilograms. The missile uses the same propulsion system and homing device that is used in the 'Yakhont' or 'Onyx' anti-ship missile. Indian scientists developed the missile's on-board computer guidance system. After its launch from a ship, the missile can reach a maximum height of 14 kilometers at Mach 2 speed. The missile has a range of 185 miles and carries a payload of 440 pounds. The missile is not capable of carrying a nuclear warhead. The missile has a predetermined trajectory and can change course 20 kilometers from the target using a sensor. The missile is also capable of skimming the sea surface. Along with the Indian scientists, about 40 Russian scientists witnessed the test launch. The code name for the joint Indo-Russian project is PJ-10. A spokesperson for Pakistan's Foreign Ministry Kamran Niaz states that India is following a policy of massive militarization and refuses to indicate whether Pakistan might conduct a missile test in response.

—"BrahMos Flight Tested," *Press Trust of India*, 12 February 2003, *Nationwide International News*; in *Lexis-Nexis Academic Universe*, 12 February 2003, <http://web.lexis-nexis.com>; Neelesh Misra, "India Test Fires Cruise Missile Capable of Hitting Pakistan," *Associated Press*, 12 February 2003, *International News*; in *Lexis-Nexis Academic Universe*, 13 February 2003, <http://web.lexis-nexis.com>.

11 February 2003

The European Aeronautical Defense and Space Company (EADS) and Bharat Dynamics Limited (BDL) announce plans to jointly manufacture missiles for the export market. EADS, the parent company of MBDA, is the largest

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aerospace and defense firm in Europe.

—"Indian, French firms clinch deal to sell missiles," Defense-Aerospace Website, 11 February 2003, www.defense-aerospace.com.

10 February 2003

India's Defense Minister George Fernandes says that the BrahMos supersonic cruise missile will be added to the Indian Navy. Mr. Fernandes also says that the missile will be sold to countries friendly to India and Russia. A representative from the Indo-Russian joint venture company producing the BrahMos missile says that the missile will be test fired from a ship next month.

—"Russian-Indian Missile Brahmos to be Inducted into Indian Navy," BBC Monitoring International Reports, 10 February 2003; in Lexis-Nexis Academic Universe, 10 February 2003, <http://web.lexis-nexis.com>.

9 February 2003

A key official from the Defense Research Development Organization announces that India does not have an intercontinental ballistic missile program. The Director of the Research Center Imarat (RCI), Hyderabad, Dr. V.K. Saraswat, also claims that India has almost achieved its goal in offensive weaponry and is currently focusing on the development of a missile defense system using hypersonic-class missiles and long-range detection/tracking radars.

—"India Has No ICBM Programme, Defence Official Says," Yahoo Singapore Website, 10 February 2003, <http://sg.biz.yahoo.com>.

9 February 2003

The Director of Research Center Imarat (RCI) Dr. V. K. Saraswat says that India is concentrating on developing missile defense technologies like hypersonic class of missiles and long range detection and tracking radars. Dr. Saraswat, however, denies that India has a program to develop inter-continental ballistic missiles (ICBM) and states that India does not face any threat from ICBMs. Stating that India possesses the capability to build any offensive system, Dr. Saraswat states that India is looking to build a layered defense system. Dr. Saraswat adds that India gained valuable experience from building the Agni and the Prithvi series of missiles that would enable it to build any kind of offensive missiles. Describing the capabilities of the Akash surface-to-air missile, Dr. Saraswat says that the missile possesses multi-target capability, computerized operations for low action time, and a coded command guidance for secure and simultaneous multiple engagements. According to Dr. Saraswat, the Prithvi, Agni I, and Agni II missiles are under production. The former Chief Advisor to the Defense Research & Development Organization (DRDO), Dr. K.G. Narayanan states that India is likely to develop an unmanned aerial vehicle (UAV) that will be used in a ballistic missile launch warning platform.

—"India Developing Ballistic Missiles to Counter Missile Attacks," *Press Trust of India*, 9 February 2003, Nationwide International News; in Lexis-Nexis Academic Universe, 9 February 2003, <http://web.lexis-nexis.com>; "Plans for Missile Interceptors Unveiled," *Hindu* (Chennai), 9 February 2003; in Lexis-Nexis Academic Universe, 8 February 2003, <http://web.lexis-nexis.com>.

9 February 2003

The supersonic BrahMos cruise missile is ready for a test launch from a ship. Defense Research & Development Organization (DRDO) officials acknowledge that the version of the missile to be launched from a ship is identical in

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many aspects to the missile that was launched from land, but they also state the test launch from a ship is amore challenging due to the unstable nature of the launch platform as it moves and sways. The Air Force version of the missile, which could be fitted on the Sukhoi-30 and possibly the TU-22, is believed to more challenging to build since the missile has to be shorter and lighter than the versions launched from the sea and land. DRDO officials also indicate that the 150 kilometer-range Dhanush ballistic missile can be handed over to the Navy since the last test for the missile were completed successfully. The Dhanush can be launched from a ship and carry a one ton payload. According to officials, the DRDO corrected the missile's earlier problems with software configurations. —"Navy to Get More Teeth with Brahmos," *Statesman* (Kolkata), 9 February 2003; in Lexis-Nexis Academic Universe, 9 February 2003, <http://web.lexis-nexis.com>.

7 February 2003

Sources from the Defense Research & Development Organization (DRDO) indicate that India is preparing to test fire the 3,000 kilometer range Agni III ballistic missile. According to sources, the earliest date for the missile test is in September after the monsoon season. The sources state that the missile has a payload capacity of one ton without specifying the nature of the weapon or its yield. US State Department spokesperson Tara Riggler expresses disappointment over the plans to test the long-range missile and urges India and Pakistan to adopt restraint in their nuclear weapons and missile programs. The Chinese Foreign Ministry, without explicitly referring to the missile project, issues a statement urging all parties involved to work towards maintaining peace and stability in the region.

—"India Prepares to Test Long-Range Missile," *Agence France Presse*, 7 February 2003, International News; in Lexis-Nexis Academic Universe, 8 February 2003, <http://web.lexis-nexis.com>; "China Calls for Regional Stability Ahead of Indian Missile Tests," *Agence France Press*, 8 February 2003, International News; in Lexis-Nexis Academic Universe, 9 February 2003, <http://web.lexis-nexis.com>.

6 February 2003

The Indian aviation corporation Hindustan Aeronautics Limited (HAL) and Russian firm NPK Irkut sign a pre-contract agreement for producing Su-30MKI parts under license at HAL enterprises. Aircraft parts will include tail fins, canards, and stabilizers.

—Viktor Myasnikov, "Russian Assault on Bangalore," *Vremya MN* (Moscow), 7 February 2003; in "Indian Air Show in Bangalore Highlights Russian Arms Sales," FBIS Document CEP20030207000377, 7 February 2003.

6 February 2003

India's Bharat Dynamics Limited and the French company MBDA Missile Systems sign an agreement for future technical cooperation in the Indian manufacture of air-to-air and surface-to-air missile systems. The agreement also calls for the design of a new anti-tank missile. The French company may help India in its goal to produce advanced versions of Milan anti-tank missiles and Mica air-to-air missiles for Mirage 2000-5 fighters.

—Sandeep Dikshit, "Pact signed for designing new anti-tank missile," *Hindu* (Chennai), 7 February 2003; in "India, France Sign Accord for Technical Cooperation in Production of Missiles," FBIS Document SAP20030208000016, 8 February 2003.

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5 February 2003

Dr. V.K. Aatre says that the 3,000 kilometer Agni III might be tested before December 2003. Dr. Aatre also indicates that the Defense Research & Development Organization (DRDO) will soon initiate a subsonic project; but he does not provide any additional details. Dr. Aatre states that the range of the BrahMos cruise missile is limited to 290 kilometers due to the Missile Technology Control Regime (MTCR) and adds that the range of the BrahMos cruise missile might be increased beyond 290 kilometers.

—"India to Test 3000 kms Range Agni Missile This Year," *Press Trust of India*, 5 February 2003, Nationwide International News; in Lexis-Nexis Academic Universe, 5 February 2003, <http://web.lexis-nexis.com>; "Brahmos' Range Curtailed by MTCR," *India Business Insight* (Bangalore), 6 February 2003; in Lexis-Nexis Academic Universe, 8 February 2003, <http://web.lexis-nexis.com>.

3 February 2003

According to a Defense Research & Development Organization (DRDO) official, India has begun the development of a two-stage space vehicle called Avatar that can take-off and land like an aircraft and place a 1,000 kilogram payload into a low-earth orbit. The vehicle would be capable of performing about 100 re-entries into the atmosphere. According to the DRDO official, the primary function of the vehicle is to act as a "reusable missile launcher, one which can launch missiles, land ... and be loaded again for more missions." The official estimates the total cost for the project to be about \$2 billion with a developmental period of ten years. The DRDO official reveals that certain components such as the scramjet engine have already been tested.

—Bulbul Singh, "India Begins Development Work on Avatar Space Vehicle," *Aerospace Daily*, 3 February 2003, Vol. 209, No. 20, p. 3; in Lexis-Nexis Academic Universe, 3 February 2003, <http://web.lexis-nexis.com>.

29 January 2003

India's Prime Minister Atal Behari Vajpayee discloses that India has received several enquiries about the BrahMos supersonic cruise missile. Mr. Vajpayee says that India even received offers for collaboration on the project. Mr. Vajpayee, however, did not reveal the names of the enquirers.

—Arunkumar Bhatt, "Many Enquiries About BrahMos: PM," *Hindu* (Chennai), 29 January 2003; in Lexis-Nexis Academic Universe, 28 January 2003, <http://web.lexis-nexis.com>.

28 January 2003

The Indian Space Research Organization (ISRO) announces it will launch a remote sensing 100kg-class micro X-SAT satellite for Singapore. An official states that ISRO's Antrix Corporation and Singapore's Technological University (NTI) have signed an agreement. This will be the ISRO's fifth launch of a foreign satellite. The X-SAT satellite, which will be used for land and coastal imaging, will be launched on board a Polar Satellite Launch Vehicle.

—"ISRO to help launch Singapore's satellite," *Times of India* (Mumbai), 28 January 2003, www.timesofindia.indiatimes.com.

26 January 2003

The BrahMos/PJ-10 cruise missile is publicly displayed for the first time during the Republic Day parade.

—"Brahmos steals the show," *Hindu* (Chennai), 27 January 2003, www.hinduonnet.com.

Related content is available on the website for the Nuclear Threat Initiative, www.nti.org.



22 January 2003

Speaking before the 54th annual general meeting of the Aeronautical Society of India, President A.P.J. Abdul Kalam announces that flight trials of the supersonic BrahMos cruise missile have begun.

—"Supersonic missile system's trials begin: Kalam," *International News* (Islamabad), 22 January 2003, www.jang.com.pk.

21 January 2003

India's Defense Minister George Fernandes says that India's recent missile tests are not intended to send any message; instead they are conducted to strengthen defense preparedness and test the ability of the systems.

—"India's Missile Tests Did Not Send Signals to Anyone," Agence France Presse, 21 January 2003, *International News*; in Lexis-Nexis Academic Universe, 22 January 2003, <http://web.lexis-nexis.com>.

21 January 2003

India's President A.P.J. Abdul Kalam says that India has begun the flight trials for the BrahMos cruise missile. President Kalam also says that "while reusable missile configuration and technology has not yet emerged in the world, Indian technologists have started working on reusable hypersonic cruise missile system, an integrated design of multiple technologies derived from UAV, aircraft and missile systems."

—"Supersonic Missile System BrahMos Under Flight Trial," Press Trust of India, 21 January 2003; in Lexis-Nexis Academic Universe, 21 January 2003, <http://web.lexis-nexis.com>.

21 January 2003

India conducts its third missile test-firing in three days by launching an Akash surface-to-air missile. The missile is launched from a mobile launcher in Orissa at 0655 GMT. A senior official from the Defense Research and Development Organization says that "all the parameters of the test were achieved" and that this constituted one of the final tests before the Akash enters serial production.

—"India conducts another missile test," *International News* (Islamabad), 21 January 2003, www.jang.com.pk.

20 January 2003

India test-fires the Akash surface-to-air missile at 12.25 PM IST from a mobile launcher at the Interim Test Range (ITR) at Chandipur-on-sea. A senior DRDO official describing the test as one of the final tests before mass production says that the all the test parameters were achieved. Another defense scientist says that the missile requires additional user trials to test more than 100 parameters of the system. According to a defense official, the test achieved more than 80 percent of its test objectives. Ground radars and an on-board precision guidance system guide the missile. According to a senior military official, the missile can be used against Pakistan's Hatf-I missile with modifications to the warhead and guidance system. According to another defense ministry official the missile can be used to defend large installations like air fields against attack. India is also working on an advanced version of the Akash missile which will have a longer range. The missile under development is based on Russia's SA-6 and the Rajendra phased array radar is similar to the 30N6 'Flap-Lib B' radar used with the S-300 anti-missile system. Pakistan's Information Minister Sheikh Rashid condemns the test and states that Pakistan will not be provoked by the test. Indian sources deny that the tests are designed to send a political message and state that the testing of Akash missiles is to evaluate their launch efficacy from mobile launchers.

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—Pratap Chakravarty, "India Conducts Third Missile Test in 11 Days, Pakistan Protests," *Agence France Presse*, 20 January 2003, *International News*; in *Lexis-Nexis Academic Universe*, 21 January 2003, <http://web.lexis-nexis.com>; "India Test-Fires "Akash" for the Second Time in Three Days," *Xinhua News Agency*, 20 January 2003, *World News, Political*; in *Lexis-Nexis Academic Universe*, 21 January 2003, <http://web.lexis-nexis.com>; Sandeep Dikshit, "Testing Akash's Efficacy from Mobile Launchers," *Hindu (Chennai)*, 21 January 2003; in *Lexis-Nexis Academic Universe*, 20 January 2003, <http://web.lexis-nexis.com>; Bulbul Singh, "India's Akash Missile has Another Test Firing," *Aerospace Daily*, 22 January 2003, Vol. 205, No. 14, p. 7; in *Lexis-Nexis Academic Universe*, 27 January 2003, <http://web.lexis-nexis.com>; "India tests surface to air missile," *Channel NewsAsia*, 20 January 2003, in *Lexis-Nexis Academic Universe*, <http://web.lexis-nexis.com>, 20 January 2003.

19 January 2003

India and Russia agree on an arms deal in which Russia agreed to provide the aircraft carrier Admiral Gorshkov and lease long-range TU-22M3 strategic bombers and an Akula-class nuclear submarine. The BrahMos cruise missile is expected to be used in both the nuclear bomber and the nuclear submarine. The BrahMos cruise missile, even though claimed as an anti-ship weapon, is expected to be used in the future as a long-range nuclear weapon delivery system.

—Manoj Joshi, "Russia Gives Nuclear Edge to Indian Defence," *Times of India (Mumbai)*, 19 January 2003; in *Lexis-Nexis Academic Universe*, 19 January 2003, <http://web.lexis-nexis.com>.

18 January 2003

India test-fires the short-range surface-to-air Akash missile at 3.25 PM IST from a mobile launcher at the Interim Test Range (ITR) at Chandipur-on-sea on the eastern coast of India. The Akash missile is intended to be an anti-aircraft missile and is designed to be integrated with the Rajendra phased array radar. The missile weighs 650 kilograms and has a range of 25 kilometers with a payload capacity of 50 kilograms. The missile is capable of tracking 100 targets simultaneously and can fly at a maximum speed of twice the speed of sound. The missile uses an integrated two-stage RAMJET propulsion technology using a solid propellant. The test is intended to evaluate the performance of the guidance system. According to Indian sources, the user trials for the missile are scheduled to begin soon.

—"India Test Fires Medium Range Akash Missile," *Agence France Presse*, 18 January 2003, *International News*; in *Lexis-Nexis Academic Universe*, 19 January 2003, <http://web.lexis-nexis.com>; "Medium Range Surface-to-Air Missile Akash Test Fired," *Press Trust of India*, 18 January 2003, *Nationwide International News*; in *Lexis-Nexis Academic Universe*, 19 January 2003, <http://web.lexis-nexis.com>; Pratap Chakravarty, "India Conducts Third Missile Test in 11 Days, Pakistan Protests," *Agence France Presse*, 20 January 2003, *International News*; in *Lexis-Nexis Academic Universe*, 21 January 2003, <http://web.lexis-nexis.com>.

18 January 2003

India's Defense Minister George Fernandes announces that India and Russia have decided to increase the charter capital in the BrahMos joint venture from \$250 million to \$300 million in order to meet the production demands for the supersonic missile. Mr. Fernandes describes the BrahMos joint venture as a grand success and states that similar joint ventures in the research, development, and production of hi-tech weapon systems are under discussion.

Related content is available on the website for the Nuclear Threat Initiative, www.nti.org.



—"India, Russia to Make Further Investment in Joint Cruise Missile Venture," BBC Monitoring International Reports, 18 January 2003; in Lexis-Nexis Academic Universe, 18 January 2003, <http://web.lexis-nexis.com>.

16 January 2003

India and the United States conclude their two day discussions on missile defense and decide to continue discussions on the issue. According to an Indian External Affairs ministry spokesperson, "the two sides discussed security contributions that missile defense could make ... the meeting also provided an opportunity to review the latest developments in the US missile defense policy and programme." The talks also focused on the possibility of Israel's sale of the Arrow anti-ballistic missile system to India. India requires six to eight anti-missile systems. Indian defense officials, however, remain skeptical whether India can afford to pay \$3 billion to \$5 billion for the systems. Indian scientists are believed to be seeking other missile defense systems, even older systems, in order to re-engineer such systems and develop an indigenous missile defense system.

—"Indo-US Talks on Missile Defence to Continue," *Economic Times* (Mumbai), 18 January 2003; in Lexis-Nexis Academic Universe, 19 January 2003, <http://web.lexis-nexis.com>; Bulbul Singh, "India, US Wrap Up Missile Defense Talks," *Aerospace Daily*, 21 January 2003, Vol. 205, No. 13, p. 7; in Lexis-Nexis Academic Universe, 24 January 2003, <http://web.lexis-nexis.com>.

16 January 2003

India's defense ministry denies a television news report that a Prithvi missile was launched unsuccessfully and caught fire. The Defense Research and Development Organization claims there was no launch scheduled for any Prithvi missiles for 16 January 2003.

—"Prithvi launch report denied," *Hindu* (Chennai), 17 January 2003, www.hinduonnet.com.

15 January 2003

India and the United States begin the third round of talks on missile defense. The Indian side is led by the Joint Secretary for Disarmament Sheelkant Sharma and the US delegation is led by Principal Deputy Assistant Secretary of Defense David Trachtenberg. An Indian External Affairs Ministry spokesperson says the talks are "exploratory and conceptual in nature."

—"India, U.S. holds talks on Washington's missile defence," BBC Monitoring South Asia, 15 January 2003; in Lexis-Nexis Academic Universe, 15 January 2003, <http://web.lexis-nexis.com>.

15 January 2003

Indian Express reports that the process of raising the 334th Prithvi Missile Group has already begun. The 334th, like the 333rd Missile Group, will be stationed in Hyderabad and consists of 12 missile launchers. Both groups will be integrated into the Strategic Force Command at an unspecified date. The 334th Missile Group is expected to be ready by the end of 2003 and will include 300-400 personnel.

—Shishir Gupta, "Agni: sharpening our N-point," *Indian Express* (Mumbai), 15 January 2003, www.indianexpress.com.

12 January 2003

The Defense Research and Development Organization (DRDO) Chief V.K. Aatre confirms that an Agni-III ballistic

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missile will be tested by the end of 2003. Aatre states that the Agni-III is not much different from its Agni-I and Agni-II predecessors but will have an extended strike range of 3,500-4,000km. This range will give India the capability to strike targets deep within China.

—Rajat Pandit, "Agni-III Test Likely by Year-End," *Economic Times*, 12 January 2003; in Lexis-Nexus Academic Universe, 13 January 2003, <http://web.lexis-nexis.com>.

10 January 2003

Dr. V.K. Aatre says that India is developing the Agni-III missile with a range of more than 3,000 kilometers and expresses hope that it will be tested by the end of 2003. Dr. Aatre says that India possesses the technology to develop intercontinental ballistic missiles with ranges between 3,500 kilometers and 14,000 kilometers. He adds that India does not have a need to build intercontinental ballistic missiles. Dr. Aatre also states that the 600-800 kilometer range Agni-I is ready for induction into the armed services. Responding to a query whether the Agni-I is ready for induction after only two tests, Dr. Aatre replied that the missile belongs to the Agni series of missiles which have already been tested eight times. According to Dr. Aatre, the naval version of the BrahMos cruise missile will be tested in late January. According to him, the missile reaches a maximum height of 14 kilometers at twice the speed of sound. The missile can carry a 200-kilogram payload to a range of about 300 kilometers. The sensor on the missile head enables the missile to detect a target and change course 20 kilometers from the final objective.

—"India Developing New Variant of Nuclear-Capable Missile," Agence France Presse, 11 January 2003, International News; in Lexis-Nexus Academic Universe, 12 January 2003, <http://web.lexis-nexis.com>; "India Developing 'Agni II' Missile," *Press Trust of India*, 11 January 2003, Nationwide International News; in Lexis-Nexus Academic Universe, 12 January 2003, <http://web.lexis-nexis.com>.

10 January 2003

The Indian Air Force threatens to abandon the Trishul surface-to-air missile citing its poor performance. A senior Indian Air Force official informs Aerospace Daily that the missile had trouble detecting targets and maintaining accuracy. A senior official from India's Defense Research & Defense Organization (DRDO) says that the Trishul project has been scaled back owing to problems related to the guidance system. The DRDO official cites US sanctions imposed after the nuclear tests in May 1998 as having adversely affected the missile's development. [1.The Trishul missile system, intended to replace the OSA-AK air defense system, is a quick reaction air defense missile developed by the DRDO. The entire missile assembly includes a tracking radar, a fire control radar, and a missile battery on a chassis. The Army and the Air Force planned to use it against low-flying aircraft whereas the Navy intended to use it against sea-skimming missiles. In the Army version of the missile system, a tracked vehicle will carry three missiles and one radar surveillance and another radar for tracking and guidance. The air force version of the missile system uses two vehicles. The radar is located in a separate vehicle and the second vehicle can carry four missiles. The naval version of the missile system is expected to include an altimeter to enable it to skim waves. The radar for the naval version is under development. Indian military officials indicate that the Trishul does not incorporate revolutionary developments like vectoring capabilities. The Trishul project began in 1984 and the government has spent more than \$250 million on the project.]

—Bulbul Singh, "Indian Air Force Threatens to Abandon Trishul Missile," *Aerospace Daily*, 13 January 2003, Vol. 205, No. 8, p. 7; in Lexis-Nexus Academic Universe, 16 January 2003, <http://web.lexis-nexis.com>.

Related content is available on the website for the Nuclear Threat Initiative, www.nti.org.



10 January 2003

The Indian newspaper *Statesman* reports that the aircraft carrier Admiral Gorshkov, purchased from Russia, will be equipped with the BrahMos cruise missiles.

—"BrahMos Teeth for Gorshkov," *Statesman* (Kolkata), 11 January 2003; in Lexis-Nexis Academic Universe, 11 January 2003, www.hinduonnet.com.

9 January 2003

An 800km-range Agni missile is successfully test fired with a one-ton payload. This Agni variant is intended to fill the gap between short-range Prithvi missiles and the 2,500km range Agni-II missiles.

—Sandeep Dikshit, "Agni missile test-fired successfully," *Hindu* (Chennai), 9 January 2003, www.hinduonnet.com.

9 January 2003

India test-fires the Agni-I ballistic missile from a mobile launcher on Wheeler's Island. The test is witnessed by the Defense Minister George Fernandes, DRDO chief and scientific advisor to the defense minister Dr. V.K. Aatre, Chief of Integrated Defense Staff Lt. Gen. Pankaj Joshi, and Deputy Chief of Staff Lt. Gen. J.B.S. Yadava. The 15 meter long missile weighing 12 tons has a range between 600-800 kilometers. Indian defense sources indicate that the missile can be launched from a mobile launcher on a road as well as a rail platform. A press release issued by the Ministry of Defense indicates that the network of ground radar telemetry stations and visual observations from the impact point confirmed the successful completion of mission objectives. A senior official in the Defense Ministry says that the test is expected to validate certain critical technologies like guidance and telemetry systems. Indian sources indicate that a series of seven developmental flight tests are planned with payload capacities varying between one and three tons before the missile is handed over for user trials. Upon successful completion of the user trials, the missile will be handed over to the Army. The Army is also planning to conduct additional tests for the Prithvi missile which has already been inducted into the Army. Pakistan's Minister for Information Sheikh Rashid Ahmed says that the test demonstrates India's "war-mongering" attitude. India denies the accusation and says that the tests are part of a routine testing mechanism. India also says that it provided advance notification of the test to Pakistan. The spokesperson for the US State Department Richard Boucher expresses disappointment over the missile test and urges India and Pakistan to adopt restraint on their nuclear weapons and missile programs. The British Foreign Ministry also expresses regret over the missile test and says that the test sends wrong signals to the region and the world.

—"More Agni Missile Tests Planned," *Press Trust of India*, 9 January 2003, Nationwide International News; in Lexis-Nexis Academic Universe, 9 January 2003, <http://web.lexis-nexis.com>; "Agni Testfire Successful, More Trials to Follow Soon," *Indian Express* (Mumbai), 9 January 2003; in Lexis-Nexis Academic Universe, 10 January 2003, <http://web.lexis-nexis.com>; Palash Kumar, "India Tests Ballistic Missile," *Agence France Presse*, 9 January 2003, International News; in Lexis-Nexis Academic Universe, 10 January 2003, <http://web.lexis-nexis.com>; "Britain Says Indian Missile Test Sends "Wrong Signals"," *Deutsche Presse-Agentur*, 9 January 2003; "US "disappointed" at India's Missile Test," *Deutsche Presse-Agentur*, 9 January 2003, Politics; in Lexis-Nexis Academic Universe, 10 January 2003, <http://web.lexis-nexis.com>; Bulbul Singh, "India Tests Agni-1 from Mobile Launcher," *Aerospace Daily*, 10 January 2003, Vol. 205, No. 7, p. 7; in Lexis-Nexis Academic Universe, 15 January 2003, <http://web.lexis-nexis.com>.

Related content is available on the website for the Nuclear Threat Initiative, www.nti.org.



nexis.com; Sandeep Dikshit, "Agni Missile Test-Fired Successfully," *Hindu* (Chennai), 10 January 2003; in Lexis-Nexis Academic Universe, 9 January 2003, <http://web.lexis-nexis.com>.

8 January 2003

Canada's Foreign Minister Bill Graham expresses "deep concern" over India's planned missile tests and urges India not to conduct such tests. Mr. Graham also urges India to sign the Hague Code of Conduct against ballistic missile proliferation.

—"Canada Implores India to Quit Testing Ballistic Missiles," Agence France Presse, 9 January 2003, International News; in Lexis-Nexis Academic Universe, 9 January 2003, <http://web.lexis-nexis.com>.

5 January 2003

K. Kasturirangan, Chairman of the Indian Space Research Organization (ISRO) and Secretary of the Department of Space (DOS), declares that India is not planning on sending a manned mission to outer space in 2003. The DOS, however, is focusing on a mission to the moon involving an unmanned spacecraft.

—P. Sunderarajan, "No plan to send manned mission to outer space," *Hindu* (Chennai), 6 January 2003, www.hinduonnet.com.

4-5 January 2003

India places the two operational Army missile groups under the Strategic Forces Command (SFC). The two army missile groups possess the 150-250 kilometer Prithvi and the 2,500 kilometer Agni ballistic missiles. The SFC is also expected to have civilian nuclear experts from the Nuclear Energy Commission and missile experts from the DRDO.

—"Missile Groups to Form Nucleus of Indian Strategic Forces Command," BBC Monitoring International Reports, 6 January 2003; in Lexis-Nexis Academic Universe, 6 January 2003, <http://web.lexis-nexis.com>.

4 January 2003

The Cabinet Committee on Security (CCS) approves the creation of a Strategic Forces Command (SFC) to manage and administer all nuclear and strategic forces. India also creates a Nuclear Command Authority (NCA) comprising of a Political Council and an Executive Council. The Political Council, headed by the Prime Minister, has the sole authority to order the launch of nuclear weapons. The Political Council also includes the Deputy Prime Minister L.K. Advani, Foreign Minister Yashwant Sinha, and the Defense Minister George Fernandes. The nuclear doctrine released after the meeting says that India will continue to maintain strict control over the exports of nuclear and missile technologies.

—"India Establishes Strategic Forces Command," *Press Trust of India*, 4 January 2003, Nationwide International News; in Lexis-Nexis Academic Universe, 5 January 2003, <http://web.lexis-nexis.com>; Edna Fernandes, "India Sets Up Nuclear Arsenal Command Structure," *Financial Times* (London), 6 January 2003, World News, p. 6; in Lexis-Nexis Academic Universe, 5 January 2003, <http://web.lexis-nexis.com>.

3 January 2003

In an interview with the *Aerospace Daily*, Dr. V. K. Aatre, the chief of the DRDO, states that India will conduct tests for the shorter-range Agni-I missile, surface-to-air Prithvi-II missile, surface-to-air Akash missile, and the BrahMos cruise missile. Dr. Aatre states that each missile will be tested four or five times during the year. The Indian Army

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and the Indian Air Force are believed to have requested the purchase of about 200 Agni-I missiles. After the completion of user trials, Bharat Dynamics Ltd. will produce the missile. The Prithvi-II is designed for the Indian Air Force and is capable of carrying nuclear warheads and a cluster of submunition bomblets. The Akash surface-to-air missile is based on the Russian SA-6 air defense system and is integrated with the Rajendra phased array radar developed indigenously.

—Bulbul Singh, "India Plans Missile Tests in 2003, DRDO Chief Says," *Aerospace Daily*, 6 January 2003, Vol. 205, No. 3, p. 6; in Lexis-Nexis Academic Universe, 9 January 2003, <http://web.lexis-nexis.com>.

1 January 2003

The Defense Research and Development Organization (DRDO) Chief V.K. Aatre says the 600km-range Agni ballistic missile is "under the process of induction."

—"India to test indigenous missile soon," *Hindu* (Chennai), 1 January 2003, www.hinduonnet.com.

1 January 2003

India conducts 20 missile tests for seven types of missiles at an estimated cost of \$16 million. This figure also includes the cost of the flight-tested missiles. According to Defense Minister George Fernandes all the tests achieved their test objectives.

—"20 Missile Tests in India in First Half of 2003 at Cost of 16 Mln Dollars," *Agence France Presse*, 30 July 2003, *International News*; in Lexis-Nexis Academic Universe, 31 July 2003, www.hinduonnet.com.

2002

30 December 2002

According to Indian defense sources, the Cabinet Committee on Security (CCS) is planning on creating a Strategic Forces Command (SFC) in January 2003. The SFC commander will be under the authority of the Chiefs of Staff Committee (COSC) until a Chief of Defense Staff (CDS) is appointed by the government. In the future, the CDS will serve as a "single-point military adviser" to the civilian government in New Delhi.

—Rajat Pandit, "India All Set to Set up Nuclear Forces Command," *Times of India* (Mumbai), 31 December 2002, <http://timesofindia.indiatimes.com>.

28 December 2002

A Prithvi missile test is postponed for the second time in two days due to technical problems in the missile's sub-systems.

—"Prithvi Launch Put off Again," *Hindu* (Chennai), 29 December 2002, www.hinduonnet.com.

27 December 2002

A BrahMos supersonic cruise missile test is postponed due to problems in the missile's sub-systems.

—"BrahMos Missile Tests Rescheduled," *Times of India* (Mumbai), 27 December 2002, <http://timesofindia.indiatimes.com>.

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25 December 2002

India and the United States are set to begin a new round of missile defense talks in Washington on 15-16 January 2003. The talks will include an inter-agency team from India headed by the foreign ministry's Joint Secretary on Disarmament, Sheelkant Sharma.

—"India-U.S. Missile Defense Talks Ready to Take off," *Economic Times* (Mumbai), 25 December 2002; in Lexis-Nexis Academic Universe, 24 December 2002, web.lexis-nexis.com.

12 December 2002

Addressing the media at a conference on smart materials in Bangalore, Scientific Advisor to the Indian Defense Minister, V.K. Aatre, says that the BrahMos supersonic cruise missile will enter trials in two months.

—"Indo-Russian Missile to Go into Trials in Two Months," *Hindu* (Chennai), 13 December 2002, www.hinduonnet.com.

11 December 2002

In an address to the Rajya Sabha (India's upper house of parliament), Defense Minister George Fernandes says that India and Russia have signed a protocol regarding the export of Indian manufactured weapon systems manufactured under Russian license. According to the agreement, the export of armaments to third world countries will be made on a case-by-case basis. This protocol enables India to specifically export missiles and spare parts (for advanced fighter aircraft) in the future.

—"India, Russia Sign Protocol on Arms Exports," *Hindu* (Chennai), 12 December 2002, www.hinduonnet.com.

11 December 2002

A.S. Pillai, Chief Controller for Research and Development at the Defense Research and Development Organization (DRDO), says that India is "in the process of conducting developmental flights [of the BrahMos supersonic cruise missile] from various platforms." He adds that the cruise missile's induction into the armed services will commence in 2004.

—"BrahMos to Be Inducted by 2004," Press Trust of India, 11 December 2002; in Lexis-Nexis Academic Universe, 11 December 2002, web.lexis-nexis.com.

4 December 2002

Speaking at a banquet for Russian President Vladimir Putin, Indian President Dr. A.P.J. Abdul Kalam makes the case for marketing BrahMos supersonic cruise missiles to "friendly countries." He says that "the joint venture supersonic cruise missile is a unique example of the partnership between our two countries in critical areas of research and development.... Our cooperation in this area has solid foundations and will continue to serve our mutual needs."

—"Kalam for Sale of BrahMos Cruise missile to Friendly Countries," *Hindu* (Chennai), 5 December 2002, www.hinduonnet.com.

1 December 2002

Russian defense officials say that Russia has again offered India the opportunity to equip itself with integrated air and missile defense systems. Moscow is proposing the sale of long-range S-300V surface-to-air missile systems and

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the shorter-range "Tor-M1" and "Buk-M1" systems. According to media reports, the S-300V system can track and destroy aerial targets in all weather conditions. This enables the S-300V to protect vital installations from long distances. A Russian official states that the proposed air defense systems could protect India in its entirety and that "the Indian government is considering it."

—"Russia Missile Defense Offer Again," *Times of India* (Mumbai), 1 December 2002; in Lexis-Nexis Academic Universe, 30 November 2002, web.lexis-nexis.com.

28 November 2002

A.S. Pillai, the Chief Controller for Research and Development at the Defense Research and Development Organization (DRDO), says that the BrahMos supersonic cruise missile will be ready for serial production and introduction into the military services within the next two years.

—"BrahMos Induction in Two Years," *Hindu* (Chennai), 28 November 2002; in Lexis-Nexis Academic Universe, 27 November 2002, web.lexis-nexis.com.

19 November 2002

During a visit to NPO Mashinostroyeniya in Reutov (Moscow Region), Russian President Vladimir Putin says the Indo-Russian BrahMos project is a "successful venture with good prospects ahead." Putin adds that he is happy to see the "accurate and high-quality execution" of Indian defense contracts prior to his trip to India. Putin is scheduled to visit India in early December 2002.

—Vladimir Radyuhin, "Putin Praises BrahMos Project," *Hindu* (Chennai), 20 November 2002, www.hinduonnet.com.

16 November 2002

India declares that it will not be a signatory to the proposed international code of conduct (ICOC) against ballistic missile proliferation. New Delhi claims the ICOC is discriminatory as it fails to differentiate between missile development and space launch vehicles. The ICOC proposal will be considered for approval at a conference in The Hague on 25-26 November 2002.

—"India's No to Draft Missile Regime," *Economic Times* (Mumbai), 16 November 2002; in Lexis-Nexis Academic Universe, 16 November 2002, web.lexis-nexis.com; "India Will Not Be Party to Code against Missile Proliferation," *Hindu* (Chennai), 16 November 2002; in Lexis-Nexis Academic Universe, 15 November 2002, web.lexis-nexis.com.

26 October 2002

Defense Minister George Fernandes says that short- and medium-range versions of the Agni-II surface-to-surface missile have been deployed.

—"Agni Missiles Deployed, Says Fernandes," Global News Wire, 26 October 2002; in Lexis-Nexis Academic Universe, 31 October 2002, web.lexis-nexis.com.

22 October 2002

India inducts the 250km-range Prithvi II surface-to-surface ballistic missile into the Indian Air Force. However, a senior IAF official remarks that "operationally, Prithvi II makes no sense, especially when 2,500km Agni missile has been given to the Army.... It is a waste of manpower and money." According to Indian defense sources, the Prithvi

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is intended for "training and familiarization.... It is to supplement strike aircraft. It has a definite role in circumstances when strike aircraft cannot fly, but one needs to keep the pressure up."

—Vishal Thapar, "Prithvi-II Missile Inducted into IAF," *Hindustan Times* (New Delhi), 22 October 2002, www.hindustantimes.com.

14 October 2002

The Directorate of Revenue Intelligence reveals that the Indian company NEC Engineers Private Ltd. gave Iraq prohibited weapons of mass destruction-related materials and technical information. A report in *India Today* alleges that between September 1998 and February 2001, "the NEC shipped out 10 consignments of sensitive and prohibited materials worth \$791,343 to Iraq.... The exports included titanium vessels, spherical aluminum powder, titanium centrifugal pumps, and industrial cells with platinum anodes that may have been used in the manufacture of rocket propellant." As a result of these findings, the Indian government forms a coordination group to investigate the export activities of NEC Engineers Private Ltd. This coordination group is composed of senior officials from India's intelligence agencies and is directed by the Joint Secretary of the Ministry of External Affairs.

—Sheshir Gupta, "The Indian Connection," *India Today*, 14 October 2002, www.india-today.com.

4 October 2002

India successfully tests the medium-range Akash surface-to-air missile from the Intermediate Test Range (ITR) at Chandipur-on-sea near Balasore. The missile is fired from a mobile launcher. Akash has a range of 25km and can deliver a 55kg payload. The missile's Rajendra radar can engage four to six targets and track multiple enemy aircraft within a 40-60km range. According to DRDO officials, Akash has now entered user trials after completing its guidance test-flights. Reports indicate that India is now on the verge of completing its integrated guided missile program. This would include the successful production of its Agni, Prithvi, Trishul, Akash, and Nag missile series.

—"India Successfully Test Fires Multi-target Akash Missile," Press Trust of India, 4 October 2002; in Lexis-Nexis Academic Universe, 7 October 2002, web.lexis-nexis.com; "India Test Fires Missile," Agence France Presse, 4 October 2002; in Lexis-Nexis Academic Universe, 5 October 2002, web.lexis-nexis.com.

30 September 2002

The scientific adviser to the Indian defense minister, V.K. Aatre, says that "the naval version of Prithvi, christened Dhanush, is ready for induction after successful trials at sea." The Dhanush utilizes a single-stage, liquid-fueled twin engine with an inertial guidance system. The missile's on-board computers are enhanced by real-time software. According to Aatre, any "teething problems faced by DRDO scientists on the missile's launch stabilization system have been rectified."

—"Indian Missile Dhanush Ready for Navy," *Asia Pulse*, 30 September 2002; in Lexis-Nexis Academic Universe, 30 September 2002, web.lexis-nexis.com.

25 September 2002

India carries out another successful test of the Trishul surface-to-air missile. The missile is tested from a mobile launcher at the Intermediate Test Range (ITR) in Chandipur-on-sea near Balasore. According to ITR sources, the missile is tested to verify its accuracy and other parameters. Media reports suggest that the Trishul has a sensitive radar altimeter and height-lock-loop control. As a result, the naval version of the Trishul can skim over the sea at

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low altitudes.

—"Trishul Test Fired for Second Day," Press Trust of India, 25 September 2002; in Lexis-Nexis Academic Universe, 25 September 2002, web.lexis-nexis.com; "Trishul Test Fired Successfully," Press Trust of India, 24 September 2002; in Lexis-Nexis Academic Universe, 24 September 2002, web.lexis-nexis.com.

24 September 2002

Addressing the House of Commons, British Prime Minister Tony Blair states that the Indian chemical engineering firm NEC Engineers Private Limited provided assistance for the establishment of a chemical production facility in Al Mamoun, Iraq. The facility produces ammonium perchlorate, one of the key ingredients for producing solid fuel for missiles. Blair further alleges that the company has links to a chlorine production facility known as Fallujah-2. The Indian government finds Britain's "selective reference" to the Indian company "unfortunate."

—"Indian cos. Helping Iraq: Blair," *Hindu* (Chennai), 25 September 2002, www.hinduonnet.com; Shishir Gupta "The Indian Connection," *India Today*, 14 October 2002, www.india-today.com.

24 September 2002

India tests the Trishul short-range surface-to-air missile at the Interim Test Range (ITR) in Chandipur-on-sea, Orissa. The Trishul missile is about three meters long and has a range of nine kilometers. The missile uses a solid-fuel propellant and can deliver a 15kg warhead. The missile "carries a radio altimeter and an autopilot designed to allow the engagement of sea-skimming targets."

—"Trishul Test Fired," *Hindu* (Chennai), 25 September 2002, www.hinduonnet.com; David C. Isby "India Announces Successful Trishul Tests," *Jane's Missiles and Rockets* (Coulsdon, Surrey), 1 November 2002, www.janes.com.

22 September 2002

A.S. Pillai, Chief Controller of Research and Development for the Defense Research and Development Organization (DRDO), announces that serial production of the BrahMos supersonic cruise missile will begin in 2004. Pillai serves as the chief executive officer for the BrahMos project.

—David C. Isby, "BrahMos Production to Start in 2004," *Jane's Missiles and Rockets* (Coulsdon, Surrey), 1 November 2002, www.janes.com.

19 September 2002

In the latest issue of *India Report*, a Washington-based consultant John E. Carbaugh says "many US officials are keen to involve New Delhi in US plans for a multifaceted missile shield." He adds that senior Indian defense officials have traveled to the United States this year in order to discuss Indian participation in the missile shield. Carbaugh also writes that former US Assistant Secretary of State for South Asia Karl Inderfurth has warned of possible consequences if the United States were to pursue greater cooperation with India regarding missile defense.

—"U.S. Keen to Involve India in Missile Shield Program: Experts," *Hindustan Times* (New Delhi), 19 September 2002, www.hindustantimes.com.

12 September 2002

India's 1,060kg meteorological satellite (METCAT) is successfully launched from Sriharikota on board a Polar Satellite Launch Vehicle (PSLV). This is the first time that the Indian Space and Research Organization (ISRO) uses a

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PSLV to launch a meteorological satellite into a geo-synchronous transfer orbit (GTO). The METSAT, which was built by ISRO, "carries a very high resolution radiometer (VHRR) capable of imaging earth in the visible, thermal infrared, and water vapor bands. Its data relay transponder can collect data from unattended meteorological platforms and relay it to the New Delhi Met Data utilization center." The PSLV has four stages that alternate between solid- and liquid-fuel sources. According to Indian media reports, "the third stage solid propellant motor has been optimized and the liquid propellant in the fourth stage has been increased from two tons to two and a half tons." P.S. Goel, the Director of ISRO's satellite center, and Ramakrishnan, the Project Director of PSLV Missions, explain that the METSAT launch using the new PSLV series has "given room for optimism that ISRO will be able to further optimize the various stages to raise a payload up to 1,200kg for a variety of uses." They remark that the PSLV may be able to send payloads into numerous orbits, including the low earth orbit, polar orbit, and GTO.

—K. Ramachandran, "The PSLV Lift-off Successful, METSAT Put in Space," *Hindu* (Chennai), 13 September 2002, www.hinduonnet.com; K. Ramachandran "Moon Mission in Four Years," *Hindu* (Chennai), 13 September 2002, www.hinduonnet.com.

29 July 2002

An Indian defense ministry official says that an Indo-Israeli Joint Working Group will meet for the first time on 11 September 2002 in Tel Aviv to outline future military cooperation. The purchase of a US-Israeli Arrow-2 anti-missile system is on the top of India's wish list. India also hopes to procure the Phalcon airborne early warning and control system, unmanned aerial vehicles, naval surface-to-air missiles, and other military equipment. Israel will need US approval to sell the Arrow-2 system to India.

—Vivek Raghuvanshi, "Arrow Leads India's Wish List of Arms to Procure from Israel," *Defense News* (Springfield, VA), 5-11 August 2002, p. 18.

24 July 2002

Indian Defense Minister George Fernandes tells Rajya Sabha (India's upper house of parliament) that the government intends to conduct one more test of the 700km-range Agni before production begins. Fernandes says that development involving Trishul and Akash surface-to-air missiles should be completed by December 2003. The Nag anti-tank missile system will also be ready by December 2004. He further notes that India will begin producing the BrahMos supersonic cruise missile by late 2003 and induct it into the armed forces by 2004. Fernandes adds that all the objectives were met regarding recent test-firings of the Akash, Trishul, Nag, and BrahMos missiles.

—"Another Test of Short Range Agni Planned: Fernandes," *Rediff on the Net*, 24 July 2002, www.rediff.com.

15 July 2002

Indian Defense Secretary Yogendra Narain says that the deal on India's purchase of Green Pine radars from Israel was finalized in May 2002. India intends to integrate Green Pine radars with the indigenous Rajendra radar system, developed for the Akash and Trishul surface-to-air missiles.

—Vivek Raghuvanshi, "Arrow Leads India's Wish List of Arms to Procure from Israel," *Defense News* (Springfield, VA), 5-11 August 2002, p. 18.

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14 July 2002

The Chairman of the Indian Space and Research Organization (ISRO), Dr. K. Kasturirangan, says that India will undertake a lunar mission in 2007. He adds that a 2007 launch date would require a mission report from a scientific committee in 2002. Kasturirangan says the ISRO expects the report "any time now."

—"India to Undertake Lunar Mission in 2007: Kasturirangan," *Hindu* (Chennai), 15 July 2002, www.hinduonnet.com.

12 July 2002

According to *The Times of India*, a six-year-old letter written by Dr. A.P.J. Abdul Kalam was recently discovered in the files of the Defense Ministry. The letter suggests that the failures of India's Integrated Guided Missile Development Program outweighed its successes. The letter deals with program delays in the Trishul missile program that was to have been completed by 1992. In the letter, written in 1996, Dr. Kalam acknowledges delays in the Trishul program and permits the import of Israeli Barak-I missile systems for Indian Navy warships. On 29 February 1996, Kalam writes: "The type of immediate threat and proposed acquisition of Barak-I by Navy was presented. The Navy confirmed that these six Barak-I systems will be installed in the existing class 15 and 16 ships.... The above proposal by the Navy is agreed to..." The approval of Barak-I imports had two conditions. First, "the Navy monitors and ensures the performance of Barak-I systems, as claimed, and installs it at the earliest. [Second,] the Navy places the order immediately for Trishul missiles and systems to give production thrust." The proposal to purchase Barak-I was revived in June 1999. This resulted in an order for six missiles at the price of Rs 12 billion in the year 2000.

—Rajesh Ramachandran, "Kalam Had Agreed to Missile Import in 1996," *Times of India* (Mumbai), 12 July 2002, <http://timesofindia.indiatimes.com>.

8 July 2002

An senior Israeli government official says that Israel's planned purchase of Lakshya unmanned aerial vehicles (UAV) is aimed at exhibiting Israel's intention to develop mutual defense cooperation with India. Depending on the success of the Lakshya trials, the official claims that Israel "will purchase the Lakshya for purposes of anti-aircraft training." According to a *Defense News* report, the Indian armed forces have already ordered nearly 75 UAVs from Israel including 50 Searcher 2 mini-UAVs.

—Vivek Raghuvanshi, "Indian UAV to be Tested in Israel," *Defense News*, 15-21 July 2002, p. 18.

3 July 2002

According to the Director-General of Israel's Ministry of Defense, Amos Yaron, Israel may procure Indian Lakshya unmanned aerial vehicles (UAV) for use as targeting drones. However, procurement would be dependent on the success of the Lakshya trials currently being held in Israel.

—Vivek Raghuvanshi, "Indian UAV to be Tested in Israel," *Defense News* (Springfield, VA), 15-21 July 2002, p. 18.

29 June 2002

India tests the Russian rocket system, Smerch, from the Intermediate Test Range (ITR) in Chandipur-on-sea, Orissa. The rocket has a range of 70-90km and is part of an advanced weapons system that India is planning to purchase from Russia. India plans to conduct further Smerch trials in Ladakh and at the Ahmednagar Armor Range.

Related content is available on the website for the Nuclear Threat Initiative, www.nti.org.



—"Russian Rocket Test Fired from Indian Test Range," Deutsche Presse-Agentur, 30 June 2002; in Lexis-Nexis Academic Universe, web.lexis-nexis.com, 1 July 2002; "India Plans to Acquire Russian Rocket System," Global News Wire, 1 July 2002; in Lexis-Nexis Academic Universe, web.lexis-nexis.com.

28 June 2002

Indian Defense Secretary Yogendra Narain says that India has received an advanced Green Pine Radar system from Israel. He adds that the radar system, which is mainly used on an airborne platform as an early warning and control system, will be utilized for "advanced research purposes."

—"India Acquires Missile Tracing Green Pine Radar from Israel," Press Trust of India, 28 June 2002; in Lexis-Nexis Academic Universe, 29 June 2002, web.lexis-nexis.com.

22-24 June 2002

An Indian defense ministry official says that India's turbojet-powered unmanned aerial vehicle (UAV), the Lakshya, will be subjected to missile-launch trials and other tests during the next two months in Israel. The Lakshya, which is a reusable UAV that can be launched from land or ship, is designed to operate at a maximum altitude of 30,000 feet. Representatives from the Aeronautical Development Establishment in Bangalore will oversee these trials. Defense Research and Development Organization (DRDO) officials say that the testing of the supersonic Lakshya in Israel is a step towards advanced Indo-Israeli cooperation in UAV production. The Israeli defense ministry, in addition to hosting these trials, has apparently agreed to pay for them as well. While these trials proceed, India will continue to pursue the development of a cruise missile UAV that is capable of carrying a 350kg payload over a range of 600km. Although numerous payloads have already been developed for the Lakshya, the Indian Air Force is apparently dissatisfied with the UAV and is calling for a replacement.

—Vivek Raghuvanshi, "Indian UAV to Be Tested in Israel," *Defense News* (Springfield, VA), 15-21 July 2002, p. 18.

21 June 2002

India carries out two successful tests of the Nag anti-tank missiles within a three-hour time span. The third-generation guided missile is tested from the Interim Test Range (ITR) in Chandipur-on-sea near Balasore. The tests are conducted to determine the Nag's "advanced maneuverability and top-attack trajectory."

—"Nag Missile Test-Fired," Global News Wire, 22 June 2002; in Lexis-Nexis Academic Universe, 27 June 2002, web.lexis-nexis.com; "India Test Fires Anti-Tank Missile," Deutsche Presse-Agentur, 21 June 2002; in Lexis-Nexis Academic Universe, 21 June 2002, web.lexis-nexis.com.

17 June 2002

A media source reports that an explosion has occurred at Bharat Dynamics Limited (BDL), India's principal missile manufacturing facility. However, the Indian government does not confirm nor deny this report.

—"Confusion on Agni Factory Blast Report," *Dawn* (Karachi), 18 June 2002, www.dawn.com.

5 June 2002

A senior Navy official says that 12 Klub ZM-54 E anti-ship missiles, acquired from Russia for \$30 million in 2000, failed to reach the expected range of 100km during two undersea trials in May 2002 and hence will have to be replaced. According to the officials, India has sent requests for proposals to France, Israel, Italy, and the United

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States. He adds that the defense ministry has promised to provide adequate funds for the procurement of missiles.
—Vivek Raghuvanshi, "India Seeks Anti-Ship Missiles for Subs," *Defense News*, 10-16 June 2002.

23 May 2002

The *Hindu* reports that India's Strategic Nuclear Command (SNC) should be in place by June 2002. According to the report, the Indian Air Force will command the SNC that is to be headquartered in Thiruvananthapuram (currently the headquarters of the IAF's Southern Air Command). The SNC will operate within the confines of the newly created Integrated Defense Staff (IDS). The report also states that "a large portion of the SNC's air- and sea-based assets will eventually be based on the Andaman and Nicobar Islands in the Bay of Bengal." These island groupings house the headquarters of the Indian tri-service command that was established in October 2001.

—"Strategic N-Command to Be in Place Next Month," *Hindu* (Chennai), 24 May 2002, www.hinduonnet.com.

15 May 2002

In an address to the Rajya Sabha (India's upper house of parliament), Defense Minister George Fernandes says that the "government has approved in principle the raising of the Agni missile group for the Army. The DRDO has been working on the design and development of the Agni ballistic missile system based on the strategic requirements of the armed forces." He remarks that the medium-range surface-to-air Akash missile and the short-range Trishul are expected to enter service during 2003-2004. These missiles will be commissioned after additional flight-tests are completed.

—"Agni Missile Group for Army Cleared," *Hindu* (Chennai), 16 May 2002, www.hinduonnet.com.

9 May 2002

India carries out a second test of the "Lakshya" pilotless target aircraft (PTA) from the Interim Test Range (ITR) at Chandipur-on-sea, Orissa. The test vehicle is equipped with an upgraded engine.

—"Lakshya Successfully Test-Flown," *Rediff on the Net*, 9 May 2002, www.rediff.com.

8 May 2002

In a written reply to the Rajya Sabha (India's upper house of parliament), Defense Minister George Fernandes says that flight trials of the BrahMos will be conducted in 2002 and 2003. He also adds that serial production of the BrahMos will commence in 2003 so that the missile can be inducted into the armed forces by 2004. According to media reports, the Indian Air Force is examining the option of fitting the three-ton BrahMos cruise missiles on Su-30 fighters.

—"More Tests Planned for BrahMos Cruise Missile: Fernandes," *Hindustan Times* (New Delhi), 8 May 2002, www.hindustantimes.com.

2 May 2002

The Indian government informs the Indian parliament's Standing Committee on Defense that it has approved the creation of a Strategic Forces Command to control strategic missiles and space-based assets. The defense ministry also assures the committee that the Akash and Trishul surface-to-air missile programs, which are behind schedule, have been accelerated. In lieu of the delays, the government has approved a plan for the Air Force to upgrade their

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Pechora surface-to-air missiles.

—"First Strategic Forces Command on the Anvil," *Times of India* (Mumbai), 2 May 2002, www.hindustantimes.com.

28 April 2002

India carries out a second successful test of the BrahMos supersonic cruise missile from the Interim Test Range (ITR) at Chandipur-on-Sea, Orissa. In particular, the missile's autopilot and guidance systems are tested during the launch. The first sea-test of the BrahMos is planned for June 2002. According to Indian defense sources, the missile will be configured to carry a nuclear payload at a later date. Military officials believe that the BrahMos will not be inducted into the Indian Navy nor Air Force for several years. A senior navy officer says that the "BrahMos is a very versatile missile, especially if it is used with a sub-sea platform, like a submarine. It will become an important component of India's proposed nuclear deterrence based on a triad of sea, land, and aerial platforms." The BrahMos will apparently play a vital role in ensuring a second-strike capability for the Indian Navy.

—"BrahMos Gives India Lead over Pakistan, China," *Times of India* (Mumbai), 29 April 2002, <http://timesofindia.indiatimes.com>; "BrahMos Test-Fired," *Hindu* (Chennai), 29 April 2002, www.hinduonnet.com; "Indian, Russian Scientists Test Supersonic Cruise Missile 'BrahMos' in Balasore," *Times of India* (Mumbai), 28 April 2002; in FBIS Document SAP20020428000024, 28 April 2002; Rezaul Laskar "BrahMos Missile Years Away from Induction on Ships, Aircraft," *Hindustan Times* (New Delhi), 29 April 2002, www.hindustantimes.com; "Russia, India Stage 'Successful' Test of BrahMos Supersonic Cruise Missile," *Nezavisimaya Gazeta* (Moscow), 30 April 2002; in FBIS Document CEP20020501000095, 29 April 2002; "India: First Sea-Test of Supersonic Cruise Missile BrahMos Slated for June," *Indian Express* (Mumbai), 30 April 2002; in FBIS Document SAP200204300000066, 30 April 2002.

26 April 2002

A fire breaks out in the solid-rocket propellant section of the High Energy Materials Research Laboratory (HEMRL) in Pune. Six people are killed and one person is injured in the accident.

—"6 Killed in DRDO Lab Fire," *Hindu* (Chennai), 26 April 2002, www.hinduonnet.com.

25 April 2002

Hindustan Times reports that India's Strategic Nuclear Command (SNC) should be in place by June 2002. An integrated defense staff will command the SNC. According to the report, the Indian Air Force will likely provide the SNC with its first commander-in-chief. For the time being, the SNC chief will answer to the chairman of the Chiefs of Staff Committee (COSC). The Cabinet Committee on Security (CCS) headed by Prime Minister Vajpayee, however, will have final authority regarding India's nuclear weapons. All orders from the CCS will be conveyed to the chairman of the COSC.

—"India's Nuclear Command to Be in Place by June," *Daily Times* (Lahore), 26 April 2002, www.dailytimes.com.pk.

16 April 2002

The Indian Army begins preparations to induct the Agni-II intermediate-range ballistic missile. According to Indian defense sources, the Agni will arm a new missile regiment that is being raised by the Army. The induction schedule for the Agni is being discussed at an Army commanders' conference currently underway in New Delhi. The Agni-II system will give the armed forces the capability to deliver 1,000kg payloads to targets located outside the range of India's military aircraft. At the same time, Prithvi missiles will be used as "a battlefield support weapon."

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—Rajat Pandit, "Agni-II to Be Inducted into Army," *Times of India* (Mumbai), 16 April 2002, <http://timesofindia.indiatimes.com>.

10 April 2002

Defense Minister George Fernandes leaves for Moscow to discuss acquisition of the *Admiral Gorshkov* aircraft carrier and the lease of two nuclear submarines. Fernandes also intends to discuss a \$1 billion proposal to acquire six S-300 PMU-1 anti-tactical ballistic missile (ATBM) systems from Russia. India, which has been attempting to negotiate the sale of the ATBM system for five years, plans on integrating indigenous Akash surface-to-air missiles and Rajendra radar systems with the S-300 PMU-1s to reduce the sale price. According to Vladimir Simonov, head of the Russian government agency for defense control systems, "the integrated air defense proposal will certainly be on the table during Fernandes' visit."

—Rahul Bedi, "Politics-India: Russian Nuke Submarines High on Shopping List," Inter Press Service, 10 April 2002; in Lexis-Nexis Academic Universe, 11 April 2002, <http://web.lexis-nexis.com>.

10 April 2002

An Indian defense ministry official says that the BrahMos supersonic cruise missile will enter serial production phase by the end of 2003. This will begin after the completion of additional test launches. India and Russia are currently fine-tuning two basic BrahMos missile systems: a "'universal' version for submarines, warships, and shore-based platforms and a 'BrahMos-A' cruise missile for various aircraft." The naval version features a 200kg warhead while the airborne variant is armed with a 300kg payload. Indian government officials say that BrahMos exports will be restricted to "friendly third-world countries."

—Rajat Pandit, "'BrahMos' to Be Inducted Next Year," *Times of India* (Mumbai), 10 April 2002, <http://timesofindia.indiatimes.com>.

31 March 2002

India conducts a successful ground test of an optimized two-meter diameter solid motor at the Indian Space Research Organization's (ISRO) Sriharikota High Altitude Range (SHAR) in Sriharikota. This motor is earmarked as the new third-stage power source for the Polar Satellite Launch Vehicles (PSLV). According to press reports, the major improvements in the third-stage motor include the "optimization of the motor case and nozzle and increased propellant loading." The motor will likely be used for the next PSLV mission that is planned to enter a geo-synchronous orbit. In this orbit, the solid motor should increase the payload capabilities of PSLVs by 70kg. The Vikram Sarabhai Space Center (VSSC) in Thiruvananthapuram is responsible for the design and development of this new high-performance motor.

—"Solid Motor for PSLV Successfully Tested," *Hindu* (Chennai), 1 April 2002, www.hinduonnet.com.

30 March 2002

India carries out another test of the cryogenic engine for the Geosynchronous Satellite Launch Vehicle (GSLV). The successful test-firing lasts 12 minutes. An Indian Space Research Organization (ISRO) press release says that the test was carried out at the Liquid Propulsion Systems Center (LPSC) test complex at Mahendragiri, Tamil Nadu. According to the press release, the engine produced a nominal thrust of seven tons, and, that while the LPSC was accountable for the engine and testing facilities, the Vikram Sarabhai Space Center (VSSC) in Thiruvananthapuram

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was responsible for the production of pyrogen igniters, pyrotechnic devices and analysis software.

—"Indigenous Cryo Engine Successfully Test-Fired," *Hindu* (Chennai), 31 March 2002, www.hinduonnet.com.

25 March 2002

India's pilotless target aircraft (PTA) "Lakshya" is test-flown with a new engine at the Interim Test Range (ITR) at Chandipur, Orissa. Lakshya PTAs were originally inducted into the Indian Air Force in 2000.

—"Lakshya Test-Flown," *Hindu* (Chennai), 26 March 2002, www.hinduonnet.com; "UAV Lakshya Successfully Test-Flown with New Engine," *Hindustan Times* (New Delhi), 25 March 2002, www.hindustantimes.com.

18 March 2002

V.K. Aatre, scientific advisor to the defense minister, says that India will test the Agni-III [Agni-I] within the next three months. The nuclear-capable missile will have a range of 700km.

—"India to Test Agni III within Three Months," *Times of India* (Mumbai), 18 March 2002, <http://timesofindia.indiatimes.com>.

15 March 2002

India's Ministry of Defense announces that the 2000km-range Agni-II ballistic missile has entered into production and will soon be commissioned to the armed forces.

—"Agni-II Enters Production Phase," Global News Wire, 15 March 2002; in Lexis-Nexis Academic Universe, 18 March 2002, web.lexis-nexis.com.

5 March 2002

The Akash medium-range surface-to-air missile is tested from the Interim Test Range (ITR) in Chandipur, Orissa. Akash has a range of 25km.

—"Akash Test-Fired," *Hindu* (Chennai), 6 March 2002, www.hinduonnet.com; "India Test-Fires Akash Missile," Global News Wire, 5 March 2002; in Lexis-Nexis Academic Universe, 5 March 2002, web.lexis-nexis.com.

4 March 2002

The Deputy Chief Manager of the BrahMos Company, Alexander Maksichev, tells the Interfax News Agency that the second test of the BrahMos supersonic cruise missile is scheduled for June 2002. According to Maksichev, the BrahMos is "a multifunctional missile used to destroy a wide variety of sea-borne targets." He says that a ship-launched version is now under development. This variant will be 500kg light and have an altered launching device. Thereafter, the missile could reportedly be launched from ships and submarines without any adjustments or design alterations. The new missile will have a "flight range of 290km, supersonic speed of up to 2.8 Mach, a payload of up to 300kg and a low radar signature." Its operation mode will also allow for fire-and-forget capabilities. According to unofficial sources, the development of this missile will cost approximately \$240 million and be financed jointly by Russia and India.

—"Russian-Indian Supersonic Missile to Be Test Launched," *Agenstvo Voyennykh Novostey* (Moscow), 4 March 2002; in FBIS Document CET2002030400239, 4 March 2002.

2 March 2002

The Indian Space Research Organization (ISRO) conducts another test of the cryogenic rocket engine. The

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indigenously developed engine is fired for 40 seconds. According to ISRO officials, the next phase will include a prolonged testing time of 200 seconds.

—"India Tests Fire Rocket Engine," *Dawn* (Karachi), 3 March 2002, www.dawn.com.

28 February 2002

Budget proposals for the fiscal year 2002 allocate Rs 650 billion (\$13.5 billion), up 4.8% from the previous year. The Indian Army plans for upgrades in air defense and anti-missile systems. The Navy is negotiating the purchase of additional anti-missile systems, such as the Barak from Israel.

—Vivek Raghuvanshi, "Indian Budget Increase Tied to Unspent Funds," *Defense News*, 25-31 March 2002, p. 28.

27 February 2002

The Navy expects to begin user trials of the BrahMos cruise missiles soon. A Rajput-class destroyer will be utilized for the trials, which are set to begin in June or July 2002. According to Defense Research and Development Organization (DRDO) officials, the BrahMos "has several varieties of flight trajectories and uses the fire-and-forget principle." In addition to having a low radar signature, the DRDO claims that the BrahMos is an easy to operate cruise missile.

—Josy Joseph, "Navy to Test India's First Cruise Missile," *Rediff on the Net*, 27 February 2002, www.rediff.com.

19 February 2002

The Director of the Central Electrochemical Research Institute, M. Raghavan, tells the press that his institution has successfully developed special coatings to protect missiles from corrosion. In addition to increasing the service lives of missiles, some new coatings may add stealth capabilities to aircraft.

—"India Develops Novel Coatings for Missiles, Aircraft," Press Trust of India, 19 February 2002; in Lexis-Nexis Academic Universe, 19 February 2002, web.lexis-nexis.com.

9 February 2002

The Indian Space Research Organization (ISRO) successfully tests an indigenously developed cryogenic integrated engine at the Liquid Propulsion Systems Center (LPSC) in Mahendragiri, Tamil Nadu. The 7.5-ton engine, which utilizes liquid hydrogen and liquid oxygen as its fuel source, is tested for 10 seconds. A new cryogenic-powered rocket stage will reportedly replace the third stage of Geosynchronous Satellite Launch Vehicles (GSLV) in the future.

—Syed Muthahar, "ISRO Test Fires Cryogenic Engine," *Hindu* (Chennai), 10 February 2002, www.hinduonnet.com.

7 February 2002

Delegates from 78 nations meet in Paris to discuss an "international code of conduct" regarding ballistic missile proliferation. India sends a delegation to participate in the two-day conference.

—"78 Nations Meet on Ballistic Missile Proliferation in Paris," Xinhua News Agency, 7 February 2002; in Lexis-Nexis Academic Universe, 8 February 2002, web.lexis-nexis.com.

5 February 2002

V.K. Aatre, scientific advisor to Defense Minister George Fernandes, says that the government plans to improve the Agni ballistic missile by increasing its range, decreasing its weight, and introducing better systems. He also notes

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that India will embark on further trials of the BrahMos supersonic cruise missile that is being co-developed with Russia.

—"Agni Strike Range to Be Increased," *Rediff on the Net*, 5 February 2002, www.rediff.com.

January 2002

The Indian Army rejects the Nishant unmanned aerial vehicle (UAV) due to its poor high-altitude performance.

—Vivek Raghuvanshi, "India Shows Some Movement in Opening Industry," *Defense News* (Springfield, VA), 25-31 March 2002, p. 42.

31 January 2002

Media and official reports confirm that the Indian government has delegated control of front-line missiles to military forces. This turn-over was made on the condition that the missiles would only be armed with conventional warheads.

—Pratap Chakravarty, "India Ridicules Pakistan and Warns Troops, Missiles will Hold Border," *Agence France Presse*, 31 January 2002; in Lexis-Nexis Academic Universe, 31 January 2002, web.lexis-nexis.com.

30 January 2002

India announces the successful test of its Trishul surface-to-air missile at Cochin, Kerala. According to an official statement from the defense ministry, the missile was tested on 28 and 29 January in a "sea-skimming mode" in order to establish its capabilities in an "anti-sea skimmer role." The missile, which failed in its five previous tests, will undergo further testing before the Navy is allowed to conduct its own trials. For the time being, the Navy will continue to arm its vessels with Barak anti-missile systems, purchased from Israel.

—"India: Trishul Missile Test-Fired 28-29 January," *BBC Monitoring South Asia*, 30 January 2002; in Lexis-Nexis Academic Universe, 30 January 2002, <http://web.lexis-nexis.com>; "India Tests Naval Surface-to-Air Missile," *AFX-Asia*, 30 January 2002; in Lexis-Nexis Academic Universe, 31 January 2002, web.lexis-nexis.com.

29 January 2002

The Indian defense ministry speeds up plans to purchase S-300V anti-missile systems from Russia.

—Vivek Raghuvanshi, "India Moves Ahead to Fulfill \$2.5 Billion in Weapon Deals," *Defense News* (Springfield, VA), 11-17 February 2002, p. 34.

27 January 2002

According to the Director of the New Delhi-based IDSA, K. Santhanam, the development of an 800-900km-range variant of the Agni ballistic missile has been undertaken to address some of the shortcomings of the short-range Prithvi ballistic missile. The new road-mobile, solid-propellant Agni will fill the gap between the short-range Prithvi (150-250km-range) and the longer-range variants of the Agni (1,500-2,500km-range) and will allow missiles to be deployed and launched far away from India's western border. This factor will raise the nuclear threshold between India and Pakistan, as it will reduce the likelihood of nuclear war through miscalculation or misperceptions. The short-range variant of the Agni, which was developed within a span of 15 months, uses proven technologies and subsystems such as the first-stage and re-entry vehicle from the Agni II. However, the airframe and sub-systems in the new missile were reworked to account for the higher acceleration experienced during the boost phase of

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flight; in addition, the short-range variant incorporates a new closed-loop guidance system for the atmospheric phase of the missile's flight. Santhanam discloses that the Defense Research & Development Organization (DRDO) is working on a 3,500-4,000km-range Agni III. The Agni III will be rail mobile and could be tested in late 2003.

—K. Santhanam, "Agni-I: A short-range N-missile India urgently needs," *Times of India* (Mumbai), 27 January 2002, www.timesofindia.com in FBIS Document SAP20020127000025, 27 January 2002.

25 January 2002

India tests a short-range version of the Agni ballistic missile. The solid-propellant single-stage missile with a range of less than 700km was launched at 0850 IST from launch complex number four on Wheeler's Island, Interim Test Range (ITR) in Orissa. India's Defense Minister George Fernandes witnessed the test and described the missile's flight as "flawless." Fernandes said, the test enhanced India's capability to deploy surface-to-surface missile (SSM) systems. Commenting on the Agni test, Indian foreign ministry's spokesperson Nirupama Rao said the test was part of India's efforts to "guarantee credible nuclear deterrence." The short-range variant of the Agni as in the case of other missiles of the Agni family (Agni I and II) can carry a one-ton warhead. Rao told reporters the test was guided solely by technical considerations. India did not consider "...missile tests as sending a political message." The test, according to Rao, was undertaken in a predictable and transparent manner," and the five permanent members of the UN Security Council and Pakistan had been informed of the test.

—"Agni-3 successfully test fired," *Rediff on the Net*, 25 January 2002, www.rediff.com; "Missile flexing: Agni Tested," *Hindustan Times* (New Delhi), 26 January 2002, www.hindustantime.com; Atul Aneja & Sandeep Dikshit, "Short-range Agni test-fired," *Hindu* (Chennai), 26 January 2002, www.hinduonnet.com.

14 January 2002

A senior US government official says that an Israeli sale of Arrow anti-missile systems to India could violate the Missile Technology Control Regime (MTCR). Citing the US-Israeli developed Arrow system as a category one missile, he says that Israel "probably can't do it." Israel is India's second largest arms supplier after Russia.

—Janine Zacharia, "U.S. Trying to Stop Arrow Sale to India," *Jerusalem Post* (Jerusalem), 16 January 2002, www.jpost.com.

9 January 2002

The US intelligence community releases the National Intelligence Estimate (NIE), an unclassified summary of its 2001 report on foreign ballistic missile developments through 2015. The report indicates that India "is making progress toward its aim of achieving self-sufficiency for its missile programs, but it continues to rely on foreign assistance." The report states that the Prithvi-1 short-range ballistic missile (SRBM) (150km range) continues to be the only deployed ballistic missile in India. The longer-range Prithvi-2 SRBM (250km) is also addressed as a modified version of the Prithvi-1. While the Agni ballistic missile will become the new mainstay for India's nuclear-armed missile arsenal this decade, the Sagarika sea-launched ballistic missile (SLBM) is estimated to enter service in 2010 or later.

—"Foreign Missile Developments and the Ballistic Missile Threat Through 2015," Central Intelligence Agency, December 2001, www.cia.gov.

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7 January 2002

India tests the Nishant unmanned aerial vehicle (UAV) at the Kolar airfield near Bangalore.

—"Nishant Test Flown," *Hindu* (Chennai), 8 January 2002, www.hinduonnet.com.

2001

13 December 2001

The Indian Air Force tests a 250km-range Prithvi ballistic missile from the Interim Test Range (ITR) in Chandipur, Orissa. According to Indian defense ministry sources, the missile, which was launched by an Air Force team, "impacted at the intended target point accurately." The 8.56m tall Prithvi-250 has a launch weight of 4.6 tons, including a one-ton payload.

—"IAF version of Prithvi passes test," *Times of India* (Mumbai), 13 December 2001, <http://timesofindia.indiatimes.com>.

16 October 2001

Russia's Deputy Prime Minister Ilya Klebanov announces in New Delhi that India will lease four Tu-22M3 strategic bombers from Russia. Klebanov says, "We are concluding talks on the leasing of the Tu-22 bombers. We're looking forward to signing a contract for leasing four aircraft within the next month." The Tu-22 bombers can deliver 24 tons of bombs or missiles over a range of 6,800km. Indian officials suggest that the Indian Navy will use the Tu-22 for maritime reconnaissance purposes. However, the Tu-22 is designed as a bomber and one of its variants can carry nuclear weapons, including cruise missiles.

—Rezaul H. Laskar, "India to lease 4 strategic bombers from Russia," *Rediff on the Net*, 16 October 2001, www.rediff.com; Sandeep Dikshit, "India to acquire reconnaissance aircraft from Russia," *Hindu* (Chennai), 16 October 2001, www.hinduonnet.com.

21 September 2001

The Defense Research & Development Organization (DRDO) conducts the second test of the Dhanush, which is a Naval version of the Prithvi ballistic missile. The 250km-range Dhanush is flight-tested from a modified offshore patrol vehicle (*INS Subhadra*), near the Interim Test Range (ITR). An Indian defense ministry press release says, "the telemetry, electro-optic station, and tracking radar have tracked the entire mission right from take off to impact." Indian defense sources also claim that the "technology demonstrator met its entire mission objectives," and "the Navy will soon move towards operationalization of the system."

—"Sea-Launched Missile Dhanush Test-Fired," *Hindustan Times* (New Delhi), 21 September 2001, www.hindustantimes.com.

15 September 2001

A senior Indian defense official says that the Army will be the custodian of the Agni ballistic missile. The official explains, "the question whether the Agni should also be given to the IAF [Indian Air Force] is being considered. Whether the Agni missile systems should be placed under the newly evolving strategic command is another issue being decided." The Agni I will be inducted into the Army by December 2001, and the Agni II, which has "entered

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limited series production," will be inducted the following year. Other sources suggest that the Defense Research & Development Organization (DRDO) is also making headway in testing a ballistic missile from an underwater missile launcher, which simulates the conditions aboard a nuclear submarine.

—Rajat Pandit, "Army to induct Agni missiles," *Times of India* (Mumbai), 15 September 2001, <http://timesofindia.indiatimes.com>.

7 September 2001

Defense Research & Development Organization's (DRDO) Akash and Trishul surface-to-air missile (SAM) projects face further induction delays. These delays are attributed to problems in the "guidance" and "propulsion technologies." However, an Indian defense official claims that "both these missiles have entered the guided flight-trial phase...[and] problems during user-trials phase does not mean that there has been a major setback." Despite the schedule slippages in the Trishul and Akash programs, DRDO is contemplating "missiles of the future." The future systems are likely to incorporate ramjet technology. Meanwhile, DRDO has completed a feasibility study for a beyond-the-visual-range Astra air-to-air missile. The development of the Astra is likely to take a decade.

—"Snags in missile programme," *Times of India* (Mumbai), 7 September 2001, <http://timesofindia.indiatimes.com>.

5 September 2001

A senior Indian government official says that India is working to integrate the Akash surface-to-air missile (SAM) with Israel's Arrow 2 missile system to build an anti-ballistic missile (ATBM) architecture. The Arrow 2 can intercept missiles at an altitude of 48km; the Akash has a range of 27km. The ATBM project involves the networking of India's Rajendra phased array radar with Israel's Greenpine radar. Both the Air Force and the Defense Research & Development Organization (DRDO) are involved in the project.

—Atul Aneja, "Indo-Israeli partnership for new missile shield," *Hindu* (Chennai), 6 September 2001, www.thehindu.com.

4 September 2001

India's defense ministry quashes rumors in the press that the armed services have requested the defense ministry to stop further trials of the Trishul surface-to-air missile (SAM) project. A defense ministry official says, "there may be some inadequacies in the trials, but the project is on."

—"Trishul project not shelved," *Hindu* (Chennai), 5 September 2001, www.thehindu.com.

3 August 2001

The German paper *Die Woche* claims that a Bavaria-based German company is under investigation for supplying eight hydraulic cylinders for use in India's Agni ballistic missile. The cylinders are likely to be used to keep the missile in a vertical position during launch. According to Dieter Bauer, the state prosecutor in Wurzburg, the company obtained an export permit by making false declarations that the cylinders were meant for specialized vehicles used in bridge construction. The Indian government denies these reports. Indian Ministry of External Affairs spokesperson Nirupama Rao says, "we have seen these reports. None of the equipment supplied have been utilized in any missiles." However, Rao declines to explain the purpose of importing the cylinders.

—Manik Mehta, "German firm in dock for supplying technology for Agni," *Rediff on the Net*, 3 August 2001,

Related content is available on the website for the Nuclear Threat Initiative, www.nti.org.



www.rediff.com; P. Jayaram, "India denies German equipment was used in missiles," *Rediff on the Net*, 3 August 2001, www.rediff.com.

1 August 2001

The *Jane's Defence Weekly* reports that India has signed a contract with Russia's Rosoboronexport for the supply of a modified version of the Antey-2500 surface-to-air missile (SAM). The Antey-2500 is an export version of the S-300VM. The missile systems will be newly built and experts believe that they will be integrated with India's Akash and Trishul SAM systems to provide a layered defense against aircraft and ballistic missiles. [Note: The Soviet S-300VI entered service in the 1980s and was built to counter the US Pershing ballistic missiles in Europe. The S-300VM is an improved version of the S-300VI and was accepted for service by the Russian armed forces in 1996. The S-300VM uses "two vertically launched, two-stage, solid-fuel missiles; the 9M83 (SA-12a "Gladiator") with a maximum range of 75km and the 9M82 (SA-12b "Giant") with a maximum range of 100km." The new missiles use an "enhanced fire-control radar" and are believed to be "faster...and have a much higher kill probability." Both the 9M83 and 9M82 use "inertial guidance for the launch phase and semi-active radar homing for the terminal guidance and have a 150kg high-explosive warhead." The Antey-2500 can engage aircraft flying at altitudes from 25m to 30,000m. It is also designed to intercept ballistic missiles with a range of 2,500km and velocities up to 4,500m/s. The ballistic missiles can be intercepted at a maximum range of 40km at altitudes ranging from 1,000m to 30,000m.]

—Jim O'Halloran, "India Buys Antey-2500 SAM," *Jane's Defence Weekly*, (Coulsdon, Surrey), 1 August 2001, p. 15.

27 June 2001

Indian Foreign and Defense Minister Jaswant Singh comments on the Brahmos missile joint venture with Russia and says, "we are not coming out here as buyer and seller,...we are coming here together as both the producer and owner of the technology."

—Mikhail Kozyrev and Yelena Seregina, "Missile For Two: Russia and India Have Agreed to Make the PJ-10 Together," *Vedomosti* (Moscow), 27 June 2001, in FBIS Document: CEP20010627000374, 27 June 2001.

27 June 2001

The Director of NPO Mashinostroyeniye divulges that the Indo-Russian Brahmos missile project was conceived in 1998; the Brahmos is based on the technological specifications of the Indian Air Force. India's Defense Research & Development Organization (DRDO) and Russia's NPO Mashinostroyeniye are joint partners in the project. The joint venture's registered capital is divided evenly, although India has the controlling block of shares. Russia has contributed approximately \$122 million for the project and India's contribution is slightly larger. The Brahmos missile is based on the Russian Yakhont anti-ship missile. Although the joint venture will purchase the technology directly from Russia, India will contribute to the project in the form of electronic components. Further, contracts during the serial production of the missile will be divided equally among Indian and Russian contractors.

—Mikhail Kozyrev and Yelena Seregina, "Missile For Two: Russia and India Have Agreed to Make the PJ-10 Together," *Vedomosti* (Moscow), 27 June 2001, in FBIS Document: CEP20010627000374, 27 June 2001.

19 June 2001

India's National Security Advisor Brajesh Mishra writes to the chiefs of the armed services, urging them to expedite

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work on the \$3 billion effort to create a nuclear command and control system.

—Vivek Raghuvanshi, "Top Indian Defense Official Urges Better Nuclear Weapons Controls for Military," *Defense News* (Springfield, VA), 2-8 July, p. 19.

June 2001

According to media reports, the Indo-Russian joint venture to develop the Brahmos/PJ-10 cruise missile is just one of the products of a secret agreement reached between India and Russia in 1998. Apparently, India signed the agreement to develop technologies denied by other advanced industrialized countries. According to the Indian defense minister's scientific advisor and head of the Defense Research & Development Organization (DRDO), Dr. V.K. Aatre, "we have initiated joint research programs with Russia. We are not going to elaborate on what we are doing." Commenting on the Brahmos test, Taposh Banerjee, a former defense secretary says that India is looking for international partnerships in a specific defense program.

—Vivek Raghuvanshi, "Secret India-Russia Pact Produces Cruise Missile," *Defense News* (Springfield, VA), 18-24 June 2001, p. 3.

16 June 2001

Commenting on the successful test of the Brahmos/PJ-10 supersonic cruise missile with India, Russian Deputy Prime Minister Ilya Klebanov says that the Russian government aims at the "joint development, exploitation, and marketing of new weapons" in line with the Indo-Russian declaration on strategic partnership signed in the year 2000. Klebanov claims that India and Russia will "push the new cruise missile to the markets of third countries."

—Vladimir Radyuhin, "India, Russia to market missile," *Hindu* (Chennai), 16 June 2001, www.thehindu.com.

12 June 2001

India and Russia jointly test a ramjet-powered cruise missile at the Interim Test Range (ITR) in Chandipur (Orissa). The 280km-range cruise missile, which is christened Brahmos/PJ-10 (mnemonic for Brahmaputra-Moscow), is the result of a collaboration project between the Defense Research & Development Organization (DRDO) and Russia's NPO Maschinostroyeniya. The Indo-Russian joint venture apparently began in 1995. While the missile's propulsion system was developed in Russia, its guidance system was developed by DRDO. The missile weight is 3 tons, length is 6.9 meters, and diameter is 0.45 meters. A solid-propellant booster helps the missile achieve supersonic speeds, after which an air-breathing kerosene ramjet engine powers the missile in its six- to seven-minute trajectory to the target. The Brahmos/PJ-10 can be launched from a variety of platforms including ships, submarines, and aircraft. India hopes to begin manufacturing the missile in two years and offer it for sale in the international market. India's Defense Minister Jaswant Singh, who was present at the test, describes it as a "landmark in technology partnership" between India and Russia.

—Debabrata Mohanty and Chandan Nandy, "Birth in Russia, Blast-Off in India," *Telegraph* (Calcutta), 12 June 2001, www.telegraphindia.com; Atul Aneja, "Indo-Russian Missile Tested," *Hindu* (Chennai), 13 June 2001, www.thehindu.com.

31 May 2001

India's Defense Minister Jaswant Singh informs the parliament's consultative committee on defense that the Agni ballistic missile is likely to be "inducted" into the armed forces in 2001-2002. Singh tells members of parliament

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that "limited production" of the "operational missile system" has commenced and the missile forms the bedrock of India's minimum deterrent." According to Singh, "no constraints in funds will be allowed to come in the way of the indigenous development of the integrated missile program"...and the development of the Agni II is proof of the country's "determination to indigenize" defense production. Indian defense sources claim that the government is also considering approving the development of missiles with a longer range than the Agni II.

—"Long-range Agni missile gets go-ahead," *Times Of India* (New Delhi), 1 June 2001, www.timesofindia.com; "India to fine-tune n-delivery systems," *Hindu* (Chennai), 31 May 2001, www.thehindu.com.

2001

Expressing concerns at China's growing nuclear capabilities, the Indian defense ministry's annual report (2000-2001) says, "Every major Indian city is within reach of Chinese missiles and it is reported that this capability is being further augmented to include Submarine Launched Ballistic Missiles (SLBMs). The asymmetry in terms of nuclear forces is strongly in favor of China, which additionally has helped Pakistan to build missile and nuclear capability."

—"India's Security Environment," *Ministry of Defence Annual Report*, (New Delhi: Government of India, 2000-2001), p. 3.

May 2001

India's Minister of State for Science & Technology, B.S. Rawat, signs a memorandum of understanding on bilateral cooperation in with V.A. Tolokonsky, Governor of Russia's Novosibirsk region. According to Rawat, the MoU will provide additional mechanisms for cooperation between Indian and Russian scientists in Siberia and Bashkortastan in areas of industrial applications of "laser technology, catalysts, high-purity materials, accelerators, and heat physics." In Bashkortastan, the Indian delegation discussed the expansion of cooperation in aviation and composite material technologies.

—Vladimir Radyuhin, "India signs MoU with Russian regions on S&T," *Hindu* (Chennai), 23 May 2001, www.thehindu.com; Vinay Shukla, "India, Russia sign MoU on scientific cooperation," *Hindustan Times* (New Delhi), 16 May 2001, www.hindustantimes.com.

7 May 2001

The Indian parliament's Select Committee on Defense criticizes the Defense Research & Development Organization (DRDO) for poor management of the Lakshya unmanned aerial vehicle (UAV) project. A 42-page report issued by the committee says, "it is amply clear" that production of the UAV at Hindustan Aeronautics Limited (HAL) "cannot be anticipated with any degree of certainty," as production facilities have not been created. The report further adds that after 20 years of working on the project and expenditures totaling \$7.82 million, the goal of "providing the users with unmanned targets remains largely unfulfilled." According to a senior Indian defense official, DRDO was supposed to submit five UAVs to the Air Force in 1996 and another five were to be delivered to the Navy by 1997. However, the promised UAVs were only delivered to the Air Force in April 2001; meanwhile, the Navy has not received any of the promised vehicles. The official further said that Indian labs have been unable to develop an engine for the Lakshya. However, DRDO officials maintain that DRDO can meet the armed services' requirements for UAVs.

—Vivek Raghuvanshi, "Indian Unmanned Aerial Vehicle Quietly Fades Into the Distance: 20-Year Lakshya Program Fails to Yield an Engine," *Defense News* (Springfield, VA), 7 May 2001, p. 14.

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4 May 2001

Indian Foreign and Defense Minister Jaswant Singh denies reports that India is developing an intercontinental ballistic missile (ICBM). During a joint press conference with Russian Foreign Minister Igor Ivanov, Singh says, "the ICBM is neither our project nor our intention."

—"Report on ICBM denied," *Hindu* (Chennai), 5 May 2001, www.thehindu.com.

May 2001

India's defense ministry invites French, Israeli, and Russian companies to sign an agreement that will allow India to license-produce advanced air-to-air missiles. Under the Indian plan, the missiles will be produced at Bharat Dynamics Limited (BDL) in Hyderabad (Andhra Pradesh) in return for royalties and commitment not to export the missiles to other countries. The license-production agreement will also supplement India's plans to develop an indigenous advanced air-to-air missile (Astra). The Defense Research & Development Organization (DRDO) is working on a \$15 million project to develop the Astra; the first phase of trials is expected to be completed by 2003.

—Vivek Raghuvanshi, "India Seeks License To Build Missiles It Has Failed To Buy," *Defense News* (Springfield, VA), 18-24 June 2001, p. 60.

30 April 2001

According to *Defense News*, Indian defense scientists are planning to test an intercontinental ballistic missile (ICBM). The missile, which is called Surya, is based on a combination of solid motors and liquid-propellant engines and is a variant of India's Agni ballistic missile. However, the Surya's test-bed will be a single-stage liquid-fuel cryogenic engine. The development of the Surya, which is also known as Agni IV, began in 1994. It uses cryogenic engine technology developed at Indian Space Research Organization's (ISRO) Liquid Propulsion Systems Centre (LPSC) in Mahendragiri (Tamil Nadu) and guidance systems developed for the Geosynchronous Satellite Launch Vehicle (GSLV). According to a Defense Research & Development Organization (DRDO) scientist, the Surya will have a range of 5,000km. A follow-on version of the Surya known as Surya II (12,000km-range) will be tested in 2003 and thereafter the missile's range will be extended to 20,000km. The Surya I will be 40m in length and weigh 40 tons. DRDO has spent \$75 million on the Surya project so far and the government has allocated an additional \$100 million outside the regular 2001-2002 defense budget for the ICBM program. The defense ministry is now debating whether India should develop ICBMs or focus on building short- and intermediate-range ballistic missiles.

—Vivek Raghuvanshi, "Indian Scientists Poised to Test-Launch Country's First ICBM," *Defense News* (Springfield, VA), 30 April 2001, p. 26.

20 April 2001

The Geosynchronous Satellite Launch Vehicle (GSLV) appears to have underperformed as figures released by the Indian Space Research Organization (ISRO) show that the GSAT-1's apogee after launch was "32,051km as compared to the 35,975km, which should have been achieved. The shortfall of 3,900km is well beyond the launch vehicle's permissible orbital dispersion. In addition, the orbital inclination, the angle at which the satellite's orbit is inclined to the equator, is 19.2°, compared to the 19° degrees planned for."

—N. Gopal Raj, "ISRO hopes to overcome orbit shortfall," *Hindu* (Chennai), 20 April 2001, www.thehindu.com.

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19 April 2001

Defense Minister Jaswant Singh informs parliament that India conducted eight successful missile tests during 2000-2001. The tests included one test each of the Prithvi and the Agni-II ballistic missiles, and two each of the Trishul, Akash, and Nag missiles. Singh discloses that Prithvi missiles are being inducted into the Indian Air Force.

—"Singh says Prithvi missiles 'being inducted' into Indian Air Force," *Deccan Herald* (Bangalore), 19 April 2001, in FBIS Document SAP20010419000023, 19 April 2001.

18 April 2001

Successful launch of the Geosynchronous Satellite Launch Vehicle (GSLV) at 3:43 p.m.; the vehicle successfully deploys the 1.54-ton GSAT-1 satellite in a Geosynchronous Transfer Orbit (GTO) of 181km perigee and an apogee of 32,051km with the orbit inclination of 19.2° with respect to the equator. According to the Indian Space Research Organization (ISRO) sources, the first-stage 125-ton solid-propellant motor burned for 100 seconds and carried the vehicle to an altitude of 75km; the second stage, which carried 37.5 tons of liquid propellant, burned for 150 seconds, taking the vehicle to an altitude of 126km. After separation of the second stage, the cryogenic stage was ignited. The cryogenic stage, which carried 12.5 tons of liquid hydrogen and liquid oxygen, burned for 693 seconds, taking the satellite and equipment bay to an altitude of 195km. The cryogenic stage was obtained from Russia and successfully integrated with electronic systems developed by ISRO.

—ISRO Press Release, "GSLV Launched Successfully," 18 April 2001, Indian Space Research Organization, www.isro.org.

11 April 2001

A Trishul surface-to-air missile (SAM) explodes at the Naval Armament Depot at Cochin (Kerala). Indian officials say the explosion occurred when the Defense Research & Development Organization (DRDO) team was checking the continuity of the electrical circuit with a 28-volt current. The explosion took place in the propulsion system of the missile, which was to be tested by the Navy later during April. The missile was apparently not fitted with its warhead when the blast occurred.

—George Iype, "Missile blows up in Cochin arms depot," *Rediff on the Net*, 11 April 2001, www.rediff.com.

7 April 2001

The first launch of the GSLV-DI (Geosynchronous Satellite Launch Vehicle) is rescheduled for 18 April 2001; the window for the launch extends up to 25 April 2001. According to an Indian Space Research Organization (ISRO) press release, the 28 March 2001 mission was aborted after the automatic launch processing system detected that one of the strap-on boosters did not develop the required thrust. A detailed study of the data obtained during the five seconds of operation of the four strap-on motors during the countdown sequence showed that one of the strap-on boosters did not develop the required thrust due to a defective plumbing in the oxidizer flow line of the engine. This resulted in reduced flow of oxidizer to the engine. The anomalous engine is being replaced with a standby engine. A review of video and other data from the launch pad also reveals that the fire that spread from one of the strap-on boosters was due to the burning of foam insulation pads and was incidental; no permanent damage was caused to the vehicle.

—"GSLV-DI Launch Rescheduled for 18 April 2001," Indian Space Research Organization, 7 April 2001, www.isro.org.

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April 2001

According to *Defense News*, India is planning to lease two S-300PMU anti-missile systems from Russia to protect its nuclear command posts and other vital military installations. A team of senior Indian Army and air officials are currently undertaking a six-month training course to operate the missile system in Russia; the team will return to India in June 2001. India is expected to pay \$50 million for leasing the two S-300PMU systems, which will be delivered by December 2001. An agreement to lease the two missile systems will be signed during the meeting of the Indo-Russian Joint Commission on Military Cooperation in April 2001.

—Vivek Raghuvanshi, "India To Lease Antimissile Systems From Russia," *Defense News* (Springfield, VA), 2 April 2001, p. 4.

31 March 2001

India conducts 18th test of the Prithvi ballistic missile. The missile's flight from the "Chandipur-on-sea" test range is monitored and tracked by a network of radar, optical tracking telescope, three telemetry stations, and a naval ship deployed in the Bay of Bengal. According to Defense Research & Development Organization (DRDO) sources, the test was conducted to "gauge the propulsion parameters of the missile." The test is described as routine work and DRDO sources say that the results of the trial will be fully known after examining the data from the test.

—"India: Gauging propulsion parameters said main objective of 31 Mar missile test," *Times of India* (Mumbai), 31 March 2001, in FBIS Document: SAP20010331000069, 31 March 2001.

30 March 2001

Indian space officials trace the cause of the aborted Geosynchronous Satellite Launch Vehicle (GSLV) launch on 28 March 2001 to a malfunctioning gas injector in one of the rocket's four strap-on engines. The gas injector drives the turbine, which in turn activates the propellant pumps in liquid strap-on engines, did not develop enough pressure to drive the turbines. This prevented one of the strap-on from gaining the required more than 95% thrust. Although the thrust developed by that particular strap-on was only marginally low, the automatic launch sequence sensed the fault and ordered the shut down of all the four liquid strap-on engines. Indian Space Research Organization (ISRO) officials claim that since this is only a minor problem, the GSLV can be launched within a few weeks.

—"GSLV-D1 malfunctioning traced to gas injector," *Deccan Herald* (Bangalore), 30 March 2001, www.deccanherald.com.

20 March 2001

Defense News reports that India is seeking to purchase electro-optical seekers for ballistic missile warheads from the Moscow-based Central Scientific and Research Institute of Automatics and Hydraulics. The electro-optical seeker being sought was developed for Russia's 8K14 or Scud B ballistic missile; it is also deployed on Russia's Iskander E short-range ballistic missile. An optical seeker warhead compares imagery from the on-board target seeker with stored photographs of the target image in its guidance computer to achieve greater accuracy during the terminal stages of a warhead's flight. An Indian official confirms that India has sought Russian technical assistance to develop electro-optical seekers for ballistic missiles, but no assistance has been provided so far. The issue will be discussed during the next round of the Indo-Russian Joint Commission on Military Cooperation in New Delhi in April 2001.

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—Douglas Barrie and Simon Sardzhyan, "Arms Control in Crosshairs in Sensor Sale: System Would Improve Accuracy of Indian Missiles," *Defense News* (Springfield, VA), 26 March 2001, pp. 1, 28.

29 March 2001

India's Chief of Army Staff General S. Padmanabhan and National Security Advisor Brajesh Mishra meet to discuss defense reforms including the post of Chief of Defence Staff (CDS). The meeting follows directions from the Defense Minister Jaswant Singh for completing the preparatory work to implement the recommendations of the Group of Ministers on higher defense management. General Padmanabhan's meeting with Brajesh Mishra is followed by a meeting of the tri-service Chiefs of Staff Committee chaired by the Chief of the Naval Staff, Admiral Sushil Kumar. According to senior Indian government sources, the Chiefs of Staff Committee is preparing to make a detailed presentation on the formation of the CDS, and associated structures related to the national nuclear command before the Cabinet Committee on Security in early April 2001.

—"Army Chief, Brajesh discuss defence reforms," *Hindu* (Chennai), 29 March 2001, www.thehindu.com.

28 March 2001

The Indian Space Research Organization (ISRO) aborts mission to launch Geosynchronous Satellite Launch Vehicle (GSLV). According to ISRO Chairman Dr. Kasturirangan, on ignition of the strap-on motors, the insulation of one of the four motors caught fire. As a consequence, "one strap-on did not develop the expected level of thrust, so the computer ordered the shut down of the entire system." Although ISRO has not yet fixed a new launch date, the GSLV is expected to be launched sometime in May 2001.

—R.K. Radhakrishnan, "GSLV launch aborted," *Hindu* (Chennai), 29 March 2001, www.thehindu.com; "Relaunch in May?" *Hindu* (Chennai), 31 March 2001, www.thehindu.com.

27 March 2001

Prime Minister Atal Behari Vajpayee orders the Group of Ministers recommendations on "Reforming the National Security System" to be placed before the cabinet for formal approval. He also approves the creation of the post of Chief of Defence Staff (CDS). The CDS will be a single-point military advisor to the government and will also serve as the operational head of India's nuclear forces.

— "PM gives the green light for Chief of Defence Staff post," *Hindustan Times* (New Delhi), 28 March 2001, www.hindustantimes.com; "Army Chief, Brajesh discuss defence norms," *Hindu* (Chennai), 29 March 2001, www.thehindu.com.

20 March 2001

India has reportedly purchased parts of Israel's Green Pine radar system, which is capable of detecting ballistic missile attacks from hundreds of kilometers away. The Green Pine radar has been developed by Israel's Elta Electronic Industries. India decided to buy the radar in 1998; but the sale was delayed due to US pressure on Israel to delay the sale as a result of India's May 1998 nuclear tests.

—"Israel supplies radar to India," *Hindu* (Chennai), 21 March 2001, www.thehindu.com.

5 March 2001

Indian Space Research Organization (ISRO) Chairman Dr. Kasturirangan announces that India will launch the

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Geosynchronous Satellite Launch Vehicle (GSLV) sometime between 28 March and 3 April 2001. He attributes the delay in the GSLV's launch to extended "quantum-testing and simulation-testing" undertaken to reduce the chances of launch failure.

—"GSLV launch by April: ISRO chief," *Hindu* (Chennai), 6 March 2001, www.thehindu.com.

5 March 2001

The Indian government orders the chiefs of the Army, Air Force, and Navy to draw up a blueprint for operational command and control of India's nuclear forces. The government's decision is made on the basis of the recommendations of the Group of Minister (GOM) on national security. The GOM was appointed on 17 April 2000 to reappraise India's national security. The GOM submitted its 137-page report to Prime Minister Atal Behari Vajpayee in February 2001. The report recommends the Indian government to appoint a Chief of Defence Staff (CDS) to ensure "provision of single-point military advice to the civil political executive." The report further states, "As India is now a state with nuclear weapons, the highest importance must be attached to the creation of appropriate structures for the management and control of our nuclear weapons and strategic forces. The CDS should exercise administrative control, as distinct from operational military control over these strategic forces."

—"Reforming the National Security System: Recommendations of the Group of Ministers," *Government of India*, February 2001, pp. 100-101; "Service chiefs to plan on control of N-forces," *Times of India* (New Delhi), 5 March 2001, www.timesofindia.com.

28 February 2001

India offers to sell approximately 20 Lakshya unmanned aerial vehicles (UAVs) to Israel. The offer is made to the Israeli defense ministry team visiting the Bangalore air show. Israeli sources indicate that Israel has agreed to test the UAV in part to offset the costs of the sale of additional Israeli defense systems to India. India has also indicated that it would like defense cooperation between the two countries to be a two-way trade. An Israeli official says, "...we are talking about a low-cost and effective UAV that we can't find anywhere else and is not worth developing ourselves."

—"Israel Agrees to Test India's Lakshya UAV, India to Buy Israeli Sea Missile," *Middle East Newsline* (Jerusalem), 28 February 2001, in FBIS Document GMP20010228000065, 28 February 2001.

22 February 2001

According to the CIA, "India continues to rely on foreign assistance for key missile and dual-use technologies, where it still lacks engineering or production expertise in ballistic missile development. Entities in Russia and Western Europe remained the primary conduits of missile-related technology transfers during the first half of 2000." The report further says, "Russian entities during the reporting period continued to supply a variety of ballistic missile-related goods and technical know-how to countries such as ...India."

—"Unclassified Report to Congress on the Acquisition of Technology Relating to Weapons of Mass Destruction and Advanced Conventional Munitions: 1 January Through 30 June 2000," Central Intelligence Agency, 22 February 2001, www.cia.gov.

22 February 2001

Defense Minister George Fernandes informs parliament that limited production of the Agni II surface-to-surface

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missile (SSM) has begun and it will be inducted in 2001-2002. Test flights have also been planned for the Lakshya pilotless target aircraft (PTA), which has been inducted in the Air Force. User trials for the Nishant unmanned aerial vehicle (UAV) will begin later in February 2001 and production, induction, and operationalization will commence after completion of the trials.

—"Agni-II to be inducted by 2001-02: Fernandes," *Hindustan Times* (New Delhi), 22 February 2001, www.hindustantimes.com.

9 February 2001

Russian Air Chief General Anatoly Kornukov says that Russia is preparing to sign the lease of four Tu-22M3 long-range bombers armed with Kh-22 cruise missiles to India. The deal has been under negotiation between Russia and India since 1998. Earlier, the Yeltsin government put it on hold fearing "unwanted political consequences" from the United States. However, the Putin government has decided to proceed with the lease. Russia considers Kh-22 cruise missiles armed with conventional warheads sub-strategic weapons. However, the United States considers them strategic weapons. [Note: The Kh-22 is a "short-range, air-launched, liquid propellant, single warhead, air-to-surface missile." The Kh-22 is believed to have been designed by the Tupolev and Mikoyan (OKB 155) design bureaus and is produced at the Kharkov plant. The Kh-22 is now supported by Russia's Raduga NPO. The Kh-22 is "11.7m long, has a body diameter of 1.0m, a wingspan of 2.99m, and weighs 6,800kg. Guidance in mid-course is inertial. One version has no terminal guidance, one has a passive radar homing seeker, and a third version has an active radar seeker for terminal guidance." The missile can be armed with a nuclear or 1,000kg conventional high-explosive warhead. When released at high-altitude, the Kh-22 can achieve ranges of up to 400km.]

—"Russia to lease long-range bombers to India," *Hindustan Times* (New Delhi), 9 February 2001, www.hindustantimes.com; Duncan Lennox ed., "AS-4 'Kitchen' (Kh-22 Burya)," *Jane's Strategic Weapons Systems*, (Coulsdon, Surrey: Jane's Information Group, 1997).

8 February 2001

India's scientific advisor to the defense minister, Dr. V.K. Aatre, delivers a lecture at the Aero India international seminar and discloses that the Defense Research & Development Organization (DRDO) has established a silicon foundry in Bangalore (Karnataka) to manufacture VLSI chips using 0.8-micron technology. A 486-equivalent RISC processor has been developed and a signal-processor will be ready soon. DRDO has also set up a gallium-arsenide foundry in Hyderabad (Andhra Pradesh).

—"Nag, Trishul to be inducted in a year," *Hindu* (Chennai), 9 February 2001, www.thehindu.com.

8 February 2001

India is developing the Agni-III, the next in a series of long-range missiles. According to Dr. V.K. Aatre, scientific advisor to India's defense minister, "Agni-III is being planned and will have a better range and capability. I cannot disclose when it will be test-fired." However, Indian defense ministry sources say that the range of the new missile will exceed 5,000km. Aatre also discloses that the Electronic Research & Development Establishment (ERDE) has succeeded in integrating the Rajendra phased-array radar with the Akash surface-to-air missile (SAM). However, some "technical glitches" remain and the system will be inducted as soon as these problems are resolved. The system will replace the SA-6 SAM, which are in service with the Indian armed forces. The new radar will also be integrated with the S-300V air defense system, which is designed to counter aircraft as well as ballistic missiles.

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According to Indian defense sources the Rajendra is similar to the 30N6 Flap-Lid B engagement radar used in the S-300 anti-ballistic missile system.

—"India Developing Improved, Long-Range Agni III Missile," *Asian Age* (New Delhi), 8 February 2001, pp. 1, 2; in FBIS Document SAP20010208000044, 8 February 2001.

8 February 2001

According to Indian defense sources, the Indian Navy will soon receive the Barak missile-defense system from Israel in a deal valued at \$300 million. The Navy placed an order for the Barak system for its Brahmaputra-class destroyers after the Trishul, a similar system being developed by Defense Research & Development Organization (DRDO), was delayed.

—"Indian Navy to 'Soon' Receive Israeli Missile Defense System Worth \$300 Million," *Economic Times* (New Delhi), 8 February 2001, in FBIS Document SAP20010208000066, 8 February 2001.

7 February 2001

CIA Director George Tenet testifies before the US Senate Select Committee on Intelligence. Tenet tells committee members that "Russian state-run defense and nuclear industries are still strapped for funds, and Moscow looks to them to acquire badly needed foreign exchange through exports...Russian entities last year [2000] continued to supply a variety of ballistic missile-related goods and technical know-how to countries such as...India..." He warns, "...the missile and WMD proliferation problem continues to change in ways that make it harder to monitor and control, increasing the risk of substantial surprise. Among these developments are greater proficiency in the use of denial and deception and growing availability of dual-use technologies-not just for missiles...there is also great potential of 'secondary proliferation' from maturing state-sponsored programs such as those in...India. Add to this group the private companies, scientists, and engineers in Russia, China, and India who may be increasing their involvement in these activities, taking advantage of weak or unenforceable national export controls and the growing availability of technologies. These trends...have accelerated over the past year."

—Statement by Director of Central Intelligence George J. Tenet before the Senate Select Committee on Intelligence on the "Worldwide Threat 2001: National Security in a Changing World," 7 February 2001, www.cia.gov.

2 February 2001

The Nishant unmanned aerial vehicle (UAV) is successfully test-flown at the Yelahanka Air Force base in Bangalore (Karnataka). The scientific advisor to India's defense minister Dr. V. K. Aatre says, "we hope to induct it soon. It has to undergo several trials before its induction."

—"Nishant finally in the air," *Times of India* (New Delhi), 2 February 2001, www.timesofindia.com.

26 January 2001

Dr. Aatre announces that the Lakshya pilotless target aircraft (PTA) has been inducted in the Air Force. The Naval version will be ready by end of 2001, while the Army version will be developed by 2002. The PTA will be fitted with an indigenous engine in a couple of years.

—"Agni-II now ready for induction," *Hindu* (Chennai), 26 January 2001, www.thehindu.com.

Related content is available on the website for the Nuclear Threat Initiative, www.nti.org.



25 January 2001

Defense Research & Development Organization (DRDO) Director Dr. V. K. Aatre announces that, "the operational configuration of Agni II has been proven. It will be inducted sometime this year." The induction sequence and procedure have already been worked out. Aatre confirms that the Agni will carry nuclear warheads.

—"India to Introduce Nuclear-Capable Missile Soon," *New York Times*, 25 January 25, 2001, www.nytimes.com;
"Agni induction by year-end," *Hindustan Times* (New Delhi), 26 January 2001, www.hindustantimes.com; "Agni-II now ready for induction," *Hindu* (Chennai), 26 January 2001, www.thehindu.com.

24 January 2001

The Bangalore-based Hindustan Aeronautics Limited (HAL) announces the successful trial of the indigenously developed PTAE-7 jet engine. The PTAE-7 has been developed by the Engine and Test Bed Research and Design Centre, Engine Division, HAL. This is the first turbo jet engine developed in India; it will be used to power the Lakshya pilotless target aircraft (PTA), developed by Aeronautical Development Establishment (ADE). The Lakshya PTA is used for ground-air, air-air, and ship-air missile target practice. It is commanded from the ground by telemetry and can be recovered by a parachute, both in land and water. The PTA is provided with two targets on a 1.5km cable, and in the event of an emergency, auto recovery is possible. The Lakshya's maximum flight time is 50 minutes and it has a maximum life of 10 recoveries. [Note: PTAE-7 is "a single-shaft, lightweight, low-cost, short-life engine. It is comprised of a four-stage transonic axial compressor, a single-stage turbine, an annular flow combustion chamber, and 16 fuel flow burners...develops a thrust of 380kg.f at International Standard Atmosphere (ISA) sea level static conditions with specific fuel consumption of 1.15kg./kg.f/hr. It has a length of 1,270mm, and a maximum diameter of 330mm, and weighs 65kg." The engine is designed with material and features that protect it against seawater corrosion to enable reuse after recovery from the sea. Two engines were successfully tested three times in December 2000 at the Interim Test Range (ITR) (Orissa). Each time the engine was recovered from the sea, refurbished and re-run on the ground.]

—"PTAE-7 jet engine trial successful," *Hindu* (Chennai), 24 January 2001, www.thehindu.com.

19 January 2001

Despite the successful 17 January test of the Agni II, Indian Army and Air Force request at least four more user-trials, before the missile enters serial production. Reports suggest that the Air Force and Army have an immediate requirement for 20 Agni II ballistic missiles and might operate them jointly.

—Vivek Raghuvanshi, "As Arms Race in Asia Heats Up, India Tests New Ballistic Missile," *Defense News* (Springfield, VA), 29 January 2001, p. 17.

18 January 2001

An Indian newspaper reports that a draft nuclear doctrine prepared by the Chiefs of Staff Committee has recommended that India's nuclear forces be headed by a three-star general and that nuclear command and control rest with the civilian leadership. The draft also proposes that the nuclear force commander be responsible for India's land-, sea-, and air-based nuclear forces. The draft nuclear doctrine has been under consideration by the Cabinet Committee on Security for several months. Similarly, the Task Force on Higher Defense Management chaired by Arun Singh has also recommended that India's nuclear forces be placed under the proposed Chief of Defense Staff (CDS), who will be on par with the three service chiefs, and be the "single-point military advisor" to

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the civilian leadership. However, there are reports of differences between the Army, Navy, and Air Force over the custody and command and control arrangements over India's nuclear deterrent. The Army and Navy favor the creation of the post of CDS, while the Air Force is opposed to it. The Air Force's view is that whereas it is already a nuclear force, the Army was never meant to be a nuclear force, while the Navy neither has the platforms nor delivery systems to be a nuclear force.

—"Report Says Stage set for Command Structure of India's Nuclear Force," *Hindustan Times* (New Delhi), 18 January 2001, in FBIS Document SAP20010118000019, 18 January 2001.

17 January 2001

India conducts second test of the Agni II from the Interim Test Range (ITR) in Chandipur (Orissa) in its "final operational configuration." The Agni II is a mobile, two-stage, all solid-fuel missile with a range of "about 2,000km" and is capable of carrying a payload weight of one ton. The flight is monitored with shore and ship instrumentation facilities, which are networked in real-time. According to the Agni's program director R.N. Agarwal, the flight test results indicated that mission objectives were met successfully. Indian defense officials also claim that the missile, which uses an inertial navigation system and global positioning system (GPS), landed less than 100m from its target. Indian Defense Minister George Fernandes hints that the Agni will be inducted into the armed forces soon. —"Test Flight of Agni II," Press Information Bureau, Government of India, 17 January 2001, <http://pib.myiris.com>; "Fernandes: Agni Missiles Will Soon Be Inducted Into Indian Defence Set Up," All India Radio (New Delhi), 18 January 2001, in FBIS Document SAP20010118000073, 18 February 2001; Rahul Bedi, "India's second successful test of Agni II missile," *Jane's Defence Weekly* (Coulsdon, Surrey), 24 January 2001, in Lexis-Nexis Academic Universe, 24 January 2001, <http://web.lexis-nexis.com>.

4 January 2001

A Milan anti-tank missile is triggered accidentally during a demonstration before defense secretary Yogendra Narain. The accident at the Bharat Dynamics Limited (BDL) plant in Hyderabad leaves one person dead and five others injured. Indian experts speculate that the accident was most likely a systems failure and occurred because the standard operating procedure was probably not being followed.

—S. Nagesh Kumar, "BDL: a prime missile production agency," *Hindu* (Chennai), 5 January 2001, www.thehindu.com; T. Lalith Singh, "Doubts over BDL safety norms," *Hindu* (Chennai), 9 January 2001, www.thehindu.com.

2 January 2001

The Indian Air Force, in an internal document-Vision 2020-advocates the creation of a nuclear air command that would wield a "first-strike capability." The Air Force plan was presented to Prime Minister Vajpayee in November 2000. According to Rakesh Dhingra, an official spokesperson for the Air Force, the document contains details of future service plans, including the nuclear air command; but specific details of the plan are classified and cannot be made public. According to an Indian Air Force official, however, the document claims that the Air Force is best suited to run India's nuclear war machine and needs more money, aircraft, missiles, electronic warfare equipment, and communications equipment. It also lists the number of aircraft, missiles, and other assets needed to have a complete system for nuclear deterrence, as well as their management, location, and maintenance.

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—Mohammed Ahmedullah, "Indian Air Force Advocates First Strike Capability," *Defense Week* (Washington, DC), 2 January 2001, in Lexis-Nexis, 16 January 2001, www.lexis-nexis.com.

January 2001

A US Department of Defense report on global proliferation trends states, "India probably has a small pile of nuclear weapon components and could assemble and deploy a few nuclear weapons within a few days to a week. The most likely delivery platforms are fighter-bomber aircraft. New Delhi is also developing ballistic missiles that will be capable of delivering a nuclear payload in the future...India has development and production infrastructures for both solid- and liquid-fuel missiles. By striving to achieve independence from foreign suppliers, India may be able to avoid restrictions imposed by the MTCR [Missile Technology Control Regime]. Nevertheless, India's ballistic missile programs have benefited from the acquisition of foreign equipment and technology, which India has continued to seek, primarily from Russia."

In the section on Indian ballistic missiles, the report claims, "An Indian submarine-launched missile, called the Sagarika, also is under development with Russian assistance. Its intended platform is the 'Advanced Technology Vessel' nuclear submarine." Commenting on India's cruise missile inventories and capabilities, the report says, "India possesses ship-launched and airborne short-range anti-ship cruise missiles and a variety of short-range air-launched tactical missiles, which are potential means of delivery for NBC [nuclear, biological, and chemical] weapons. All were purchased from foreign sources, including Russia and the United Kingdom. In the future, India may try to purchase more modern anti-ship cruise missiles, or try to develop the missiles themselves. However, funding priorities for such efforts will be well below that for ballistic missiles." The report also notes that Libya has successfully obtained ballistic missile-related goods and technologies from Indian and Serbian companies.

—Office of the Secretary of Defense, "Proliferation: Threat and Response," *US Department of Defense*, January 2001.

2000

December 2000

The defense ministry informs the parliament's Standing Committee on Defense that there will be "considerable delay" in the induction of the Akash and Trishul surface-to-air missile (SAM) systems into the armed forces.

—"LCA, Akash, Trishul facing slippages," *Hindu* (Chennai), 18 December 2001, www.thehindu.com.

2 November 2000

The Defense Research & Development Organization (DRDO) conducts a successful test of the Lakshya unmanned aerial vehicle (UAV) from Interim Test Range (ITR) in Chandipur (Orissa). [Note: Lakshya was developed as an unmanned target drone, but speculation persists that it may be employed as a weapons-carrying cruise missile or UAV.]

—"Lakshya test-fired," *Hindu* (Chennai), 2 November 2000, www.thehindu.com.

22 October 2000

The Defense Research & Development Organization (DRDO) says that it is "fine-tuning" a supersonic missile

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obtained from Russia to carry nuclear warheads. A senior official says that the "missile is in the final stages of development and could be handed over to the Navy soon." Russian scientists have met with DRDO officials during the past several months for technical consultations. Indian officials refuse to confirm if the missile has an Indian name, but an Indian news media report suggests that the top-secret missile is called Brahmos. Indian officials claim that the new missile can deliver a 500kg-payload over a 300km-range and that it is a "supersonic weapon that can't be shot down. It requires a lot of electronic countermeasures to ensure protection against it." The missile is likely to be fitted on the Indian Navy's Project 17 (Stealth) warship and will also be modified for deployments on aircraft and submarines. The Indian Navy has plans to acquire three Project 17 warships and the first ship is expected to join the Navy in 2007.

— Srinjoy Chowdhury "India Reworks Russian Missile to Make It N-Capable," *Statesman* (Calcutta), 21 October 2000, www.thestatesman.net; Srinivas Laxman, "Building of stealth warship begins," *Times of India* (New Delhi), 19 December 2000, www.timesofindia.com.

9 October 2000

Addressing a seminar on air power sponsored by the Institute of Defense Studies & Analyses (New Delhi), defense minister George Fernandes says that India's military modernization program is "running parallel" to that of China and in the coming years the defense budget could be hiked to 3% of the GDP.

—"Military modernisation programme 'running parallel' with China," *Hindu* (Chennai), 10 October 2000, www.thehindu.com.

8 October 2000

The Indian Air Force's Chief of Air Staff, Air Marshall Anil Yashwant Tipnis, says that his organization has finalized its doctrine for responding to a nuclear threat. According to Tipnis, "India is committed to a no-first-use policy for nuclear weapons. The only option then is to develop a second-strike capability."

—"IAF draws up nuclear strategy," *Times of India* (New Delhi), 8 October 2000, www.timesofindia.com.

5 October 2000

India and Russia agree to a news blackout on sensitive information exchanges in the areas of defense and nuclear cooperation. Under the proposed agreement, Russia and India will appoint watchdogs to enforce compliance with the new agreement. The need for tighter secrecy is linked to the growing defense cooperation as India makes a transition from purchasing Russian defense technology to co-developing new weapon systems with Russian defense entities. According to Russian daily *Vremya Novostei*, the Russian defense industry is negotiating "far more intriguing contracts with India."

—Vladimir Radyuhin, "Secrecy on defense, nuclear deals," *Hindu* (Chennai), 6 October 2000, www.thehindu.com.

2 October 2000

Russian defense officials indicate that the Indian Navy has begun taking delivery of the 3M-54E-class of anti-ship cruise missiles. A Kilo-class submarine fitted with the missiles set sail for India in late August 2000 and two successful missile tests were conducted in the Baltic Sea earlier in June 2000. Officials from the Novator Experimental Machine Bureau have also disclosed that flight-tests of a vertically launched frigate-version of the 3M-54 for the Indian Navy will commence in 2001. Novator has also offered India a subsonic variant of the 3M-54

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missile. [Note: Speculation persists that India might try and purchase the 3M-14 variant of the 3M-54. The 3M-14 is a subsonic variant of the 3M-54E; it is equipped with a seeker, which gives it a land attack capability.]

—Douglas Barrie, "India Begins to Receive Russian Missiles for Subs to Equip Latest Kilo-Class Vessels," *Defense News* (Springfield, VA), 23 October 2000, p. 60.

17 September 2000

According to Dr. A. P. J. Abdul Kalam, principal scientific advisor to the government of India, India is on the threshold of becoming an intercontinental ballistic missile (ICBM) power. According to Kalam, "today we have the capability to design and develop any type of missile including the ICBM. Now, it's for the country to decide." He also discounts speculation that the ICBM will be a derivative of the Indian Space Research Organization's (ISRO) Geosynchronous Satellite Launch Vehicle (GSLV).

—Vishal Thapar, "ICBMs any day, says Kalam," *Hindustan Times* (New Delhi), 18 September 2000, www.hindustantimes.com.

September 2000

Indian government allegedly decides to proceed with the production of 300 Prithvi ballistic missiles for all three branches of India's armed forces at a cost of approximately \$200 million. Senior Indian defense ministry officials say that the 150 missiles will be produced for the Army, 100 for the Navy, and 50 for the Air Force. All missiles will be produced at Bharat Dynamics Limited (BDL) in Hyderabad (Andhra Pradesh), which will invest \$100 million to expand production. Indian scientists claim that the Naval and Air Force versions of the Prithvi will go into production in April and June 2001, respectively.

—Vivek Raghuvanshi, "India Moves Prithvi Missile Toward Serial Production," *Defense News* (Springfield, VA), 11 September 2000, p. 11.

29 August 2000

According to a senior Defense Research & Development Organization (DRDO) scientist, the Agni missile is ready for serial production and deployment. Although he refuses to specify the number of missiles that will be manufactured, he admits that two variants of the missile—Agni I (1,500km) and Agni II (2,500km)—are now fully operational. Both versions can carry nuclear warheads and are designed for rapid deployment. The scientist claims that at present, India has 10 Agni I missiles and two prototypes of the Agni II, and that DRDO's missile research labs could produce 18 missiles annually in collaboration with Bharat Dynamics Limited (BDL) in Hyderabad (Andhra Pradesh). The unit cost for Agni I and II is \$5 and \$8 million, respectively. The NDA government has increased funding for India's missile programs from \$500 million in 1999 to \$800 million in the year 2000.

—"Agni ready for serial production and deployment," *Rediff on the Net*, 29 August 2000, www.rediff.com.

18 August 2000

India's Defense Minister George Fernandes informs parliament that India has reached the point where the Agni ballistic missile could be made operational. According to Fernandes, "India's IRBM [intermediate-range ballistic missile] program is progressing satisfactorily."

—"Longer range Agni now Operational: Fernandes," *Times of India* (New Delhi), 18 August 2000, www.timesofindia.com.

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11 August 2000

According to Defense Research & Development Organization (DRDO) Director Dr. V. K. Aatre, the Dhanush missile will be flight-tested after modifications sometime "this year end." Indian defense scientists are working on rectifying the problems Dhanush faced during its 11 April 2000 flight. DRDO sources say that the test will most probably occur in October 2000 and a ship is being readied for it.

—Josy Joseph, "Dhanush may be test-fired this year-end," *Rediff on the Net*, 11 August 2000, www.rediff.com.

19 July 2000

India's Chief of Naval Staff, Admiral Sushil Kumar, commissions the *INS Sindhushastra* in St. Petersburg; the Kilo-class submarine is armed with the supersonic Club-S anti-ship missiles.

—Atul Aneja, "New missile-firing sub being commissioned," *Hindu* (Chennai), 19 July 2000, www.thehindu.com.

16 June 2000

India conducts 17th test of the Prithvi from the Interim Test Range (ITR) in Chandipur (Orissa).

—"Prithvi Test-Fire Successful," *Hindu* (Chennai), 17 June 2000, www.thehindu.com.

26 April 2000

The Defense Research & Development Organization (DRDO) tests the Nishant unmanned aerial vehicle (UAV), which is designed to perform discreet aerial reconnaissance of battlefields, including target acquisition. According to DRDO sources, the Nishant is "unique in its category." It is capable of accurate navigation to designated target points and can fly on extended missions lasting for several hours with an electro-optical and photographic payload.

—"Nishant test-flown," *Hindu* (Chennai), 27 April 2000, www.thehindu.com.

20 April 2000

The Defense Research & Development Organization (DRDO) is reported to be developing a 500km-range version of the Dhanush. According to Indian government sources, the acquisition of a 500km-range missile would fit into the Navy's plans to acquire a ship- or submarine-based stand-off land-attack capability. The 500km-range Dhanush will use the same propulsion fuel as used in the 250km-range version. Indian news media sources report that although Dhanush is still in the experimental stage, a debate on cruise vs. ballistic missiles has revived within the top echelons of the Indian Navy.

—"Dhanush variant for land targets sought," *Hindustan Times* (New Delhi), 20 April 2000, www.hindustantimes.com.

11 April 2000

India flight-tests the 250km-range Dhanush from the *INS Subhadra* off the Interim Test Range (ITR) in Chandipur (Orissa) at 1:35 p.m.; the test is unsuccessful. The missile breaks up within four seconds of launch.

—"Dhanush variant for land targets sought," *Hindustan Times* (New Delhi), 20 April 2000, www.hindustantimes.com; Rahul Bedi, "Missile Test is 'Partial Success', says India," *Jane's Defence Weekly* (Coulsdon, Surrey), 19 April 2000, p. 14.

8 March 2000

According to Indian foreign ministry spokesperson R. S. Jassal, Chinese assistance to Pakistan's nuclear and missile

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program is threatening regional stability. Jassal says that India conveyed its concerns to China during the two-day Sino-Indian security dialogue held in Beijing on 6-7 March 2000.

—"India conveys concern to China," *Dawn* (Karachi), 9 March 2000, www.dawn.com.

March 2000

The Indian cabinet approves the purchase of seven Barak ship point defense missile systems from Israel in a deal valued at 5.8 billion rupees.

—Sandeep Unnithan, "Barak Missiles: Off the Mark?" *India Today* (New Delhi), 26 March 2001, www.india-today.com.

16 February 2000

The Indian Space Research Organization (ISRO) tests an indigenously developed 7.5 ton-thrust cryogenic engine developed for the upper stage of the Geosynchronous Satellite Launch Vehicle (GSLV). The test is carried out at the Liquid Propulsion Systems Centre (LPSC) in Mahendragiri (Tamil Nadu). Although the engine was to be fired for 30 seconds, a hydrogen leak led to the turning off of ignition after 15 seconds. An ISRO official says, "the exact reason for the leak can be found out only after analyzing the data that was obtained during the first 15 seconds...whether it is a major or minor problem will be known after analyzing the data which will take two days." Although the engine was supposed to have been fired for 30 seconds, during actual flight, it will power the GSLV for 730 seconds. According to an Indian official, "we [ISRO] will have to qualify the engine for twice that period or 1,400 seconds before certifying it for actual flight." Despite the setback, ISRO sources say that the test-firing of the cryogenic engine had several accomplishments. They include fabrication, assembly, and integration of the complete cryogenic engine, validation and commissioning of the test stand, chill-down trials of the engine and associated system, production of cryogenic propellants to required specifications, validation of appropriate safety procedures, and the collection of data during the 15 seconds of testing.

—"Cryogenic engine-ISRO reaches a milestone," *Indian Express* (Mumbai), 17 February 2000, www.expressindia.com; "Rocket launch stopped due to hydrogen leak," *Deccan Herald* (Bangalore), 19 February 2000, www.deccanherald.com.

5 February 2001

Israeli radio announces that India and Israel have signed a \$270 million contract for an initial order to purchase Barak ship point defense missile system, which is designed to defeat anti-ship missile threats to naval vessels. A single unit of the Barak system costs \$21.5 million. The Barak will initially be retrofitted on the Indian Navy's aircraft carrier Viraat. At a later stage, the Barak systems will be incorporated in each of the Type 16A frigates currently under construction. The Type 16A class frigates were supposed to be fitted with the indigenous Trishul surface-to-air missile (SAM); however, delays in the development of the Trishul have resulted in the Indian Navy opting for the Barak. According to media reports, the Barak will also replace the Soviet-designed SA-N-1 SAMs on Indian Navy's Rajput-class destroyers (Soviet Kashin-class design). [Note: The Barak is a 10km-range interceptor missile armed with a "22kg blast-fragmentation warhead" and an "advanced proximity fuse"; it is designed to destroy incoming anti-ship missiles. The Barak is fitted onto an "eight-tube vertical launch system." The missile uses an "Elta X/Ka band fire control radar and an Elbit fire control system capable of automatic operation and able to engage two targets simultaneously." The Barak missile and its launcher have been developed by Israel's Rafael

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industries.]

—"India buys Barak naval SAM," *Jane's Missiles & Rockets* (Coulsdon, Surrey), April 2001, p. 11.

2 February 2000

Defense Research & Development Organization (DRDO) officials say that India will test the nuclear-capable Dhanush in March 2000. Once the missile has been tested successfully, it will be deployed on board offshore patrol vessels. Missiles on other Navy destroyers such as the *INS Delhi* and *INS Mysore* could also be armed with nuclear weapons.

—"Dhanush missile to be test fired in March," PTI (New Delhi), 2 February 2000, in BBC Summary of World Broadcasts, 4 February 2000, Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>.

February 2000

Due to US President Bill Clinton's visit to New Delhi in March 2000, the Dhanush test is delayed until April 2000.

—"A New Surface-to-Surface Missile to be Test Fired in March," *Indian Express* (Mumbai), 2 February 2000, www.expressindia.com.

22 January 2000

According to Dr. A. Sivathanu Pillai, Chief Controller R&D, Defense Research & Development Organization (DRDO), "technologies developed under the Integrated Guided Missile Development Program (IGMDP) made our [India's] missiles globally competitive in their performance and built a strong foundation for future technologies and systems developments...we have today operational Agni II and Prithvi. We have mastered propulsion technology, guidance and control and introduced innovative software packages, algorithms, and new devices." In the case of the Prithvi, India has "mastered liquid-propulsion technology, supersonic maneuverable trajectory, multiple-field interchangeable warheads, and launch capabilities from mobile platforms." India has also developed computational fluid dynamics, super computers, carbon-carbon technology, advanced composites, special guidance systems, and software for the Agni program. Indian scientists have also developed a "fire-and-forget" guidance system by mounting an infrared seeker on the NAG anti-tank missile, making it the first third-generation anti-tank missile in the world. Similarly, the "ramjet technology" and guidance system developed for the Akash surface-to-air missile (SAM) will lead to "several futuristic systems including hypersonic re-usable missiles."

—"Fire-and-forget system for 'Nag' tested," *Times of India* (New Delhi), 22 January 2000, www.timesofindia.com.

20 January 2000

India delays tests of the Dhanush and Agni ballistic missiles. The missiles were originally scheduled to be tested on 26 January 2000. According to Indian government sources, the Dhanush test has been postponed due to a technical snag in the "control system." The new version of the Agni will test a new mid-air guidance system, which involves a satellite-based global positioning system (GPS). According to Indian defense sources, the GPS will receive satellite-based feeds of its geographic position in mid-air. An on-board computer will carry out the necessary corrections to steer the weapon to its target. However, these sources have also warned against relying on the US GPS system during "critical occasions." [Note: In theory, the US GPS system could be shut off to deny a country access to positional information. In practice, however, such an option is becoming increasingly dubious given the

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growing commercial dependence on GPS.]

—"Test-firing of Agni, Dhanush missiles put on hold," *Hindu* (Chennai), 20 January 2000, www.thehindu.com.

January 2000

The Indian Navy modifies the Offshore Patrol Vessel, *INS Subhadra*, at the naval dockyard in Mumbai to transport and flight-test the Dhanush ballistic missile. The helicopter deck is strengthened and a hydraulically stabilized rail-mounted platform and erector are installed. The ship's helicopter hangar is modified to house two missiles. A portable console to feed the missile pre-launch guidance parameters is also installed on the ship.

—Sandeep Unnithan, "Navy to Acquire Its Own Nuclear Missile - Dhanush," *Indian Express* (Mumbai), 10 January 2000, www.expressindia.com.

4 January 2000

In an address to the 87th Indian Science Congress in Pune (Maharashtra), the principal scientific advisor to the government of India, Dr. A. P. J. Abdul Kalam, says that India is trying to design an anti-ballistic missile system on the lines of the US program. Kalam says that India can "also pursue an intercontinental ballistic missile (ICBM) program if adequate funds are made available for the project." He discloses that the Indian Space Research Organization (ISRO) is developing a supersonic aircraft that will combine the critical technologies used in missiles and aircraft. In the event of a nuclear attack on India, this aircraft will be activated automatically to carry out retaliatory attacks.

—"India trying to design ABM system on US lines: Kalam," *Hindustan Times* (New Delhi), 4 January 2000, www.hindustantimes.com.

Early 2000

India's national security council approves a \$3 billion plan to create a nuclear command and control system. The plan proposes to allocate \$1 billion for "modernizing and integrating the command, control, communications, and intelligence systems of the Army, Navy, and Air Force through 2002." Funds will also be used to build command centers to link the political leadership, the military service chiefs, nuclear forces, and various intelligence and surveillance assets. One such center will be built in Delhi; a second center will be built outside the range of Pakistan's present ballistic missile force. An additional eight command centers will be built; some of these will be regional commands, others will focus on bomber command, ballistic missile forces, and surveillance. The plan also proposes to invest in satellite communications and intelligence gathering systems, air-defense, and air-to-ground communications facilities, airborne reconnaissance systems, and electronic countermeasures. [Note: According to media reports, the satellite communications equipment will be procured from Israel and France.]

—Vivek Raghuvanshi, "Top Indian Defense Official Urges Better Nuclear Weapon Controls for Military," *Defense News* (Springfield, VA), 2-8 July 2001, p. 19; Vivek Raghuvanshi, "India Chats 15-Year, \$95 Billion Path," *Defense News* (Springfield, VA), 11-17 June 2001, p. 46.

2000

The Indian defense ministry's annual report expresses concern over continuing "Sino-Pakistan and Pakistan-North Korea" defense cooperation, which encompass transfer of "nuclear technology, assistance in the missile development program, and the transfer of conventional military equipment to Pakistan..." Pointing to advances in

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China's nuclear deterrent the report says that "China has further improved her ICBM [intercontinental ballistic missile] capability by test-firing DF-31 and laboratory testing DF-41 missiles. The presence of Chinese SSBNs [nuclear ballistic missile submarines] in the Indian Ocean may soon be a reality."

—Ministry of Defence, *Annual Report: 1999-2000*, <http://mod.nic.in>, pp. 3, 4, 5, 9.

1999

15 November 1999

The *INS Sindhuvir* returns from Russia after a two-year mid-life refit involving the installation of new weapon and sensor systems. This is the first Indian Kilo-class submarine to be armed with the tube launched Club-S supersonic anti-ship missile. India's remaining eight Kilo-class submarines are expected to undergo refits by 2002/03. The three Krivak III-class destroyers, which are being built for the Indian Navy at the Baltiysky Zavod shipyard in St. Petersburg, will also be armed with N-version of the Club missile. Speculation persists that India may try and obtain a land-attack version of the Club-family of missiles. [Note: The Club is one of a family of missiles developed by the Russian firm, Novator, in Ekaterinburg. These missiles are evolutions of the earlier 3K14 Granat-M (SS-N-21) submarine-launched cruise missiles (SLCM). Two different missiles have evolved from the Granat-3M54E1 subsonic anti-ship missile, and the 3M54E Club supersonic anti-ship missile. Testing of the 3M54E was completed in 1999; development of the 3M54E1 was halted due to lack of development funds. The 3M54E has a length and diameter of 8.22 and 0.5333 meters, respectively. It has a launch weight of 1,920kg and can deliver a 200kg-payload over a 220km-range. The missile has a cruise speed of 650-865km/h and terminal speed of 1,000m/s. It flies toward its target at a high subsonic speed like a conventional anti-ship missile. But instead of the entire airframe flying into the target, the Club warhead separates from the airframe about 60km from the target. During this stage, the warhead is powered by a secondary rocket engine, which allows it to accelerate from a speed in the high subsonic range to Mach 3 (3,600km/h; 2,235mph).]

—Rahul Bedi, "India Fortifying Naval Strength," *Asian Age* (New Delhi), 15 November 1999, pp. 1, 2, in FBIS Document FTS19991116000120, 15 November 1999; Steve Zaloga, "India joins the Russian naval missile system club," *Jane's Intelligence Review* (Coulsdon, Surrey), December 2000, pp. 43-45.

8 November 1999

The Indian defense ministry denies Bachchi Singh Rawat's 7 November 2000 (1999, I assume) statement on the Surya. A ministry spokesperson says, "the government does not have any plans to develop or test any missile of the reported range, nor has projects called Surya or Sagarika."

—"Report on 'Surya' Denied," *Hindu* (Chennai), 9 November 1999, www.hinduonnet.com.

7 November 1999

Indian Minister of State for Defense Bachchi Singh Rawat says that a 5,000km-range Surya ballistic missile will be tested soon.

—"Long-Range Ballistic Missile Test Soon: India," *Nation* (Lahore), 7 November 2000, www.syberwurx.com.

Related content is available on the website for the Nuclear Threat Initiative, www.nti.org.



4 November 1999

A Russian defense team led by Deputy Prime Minister Ilya Klebenov arrives in New Delhi. Russia reiterates its offer to sell advanced S-300 anti-aircraft/anti-missile systems to India. Klebenov says that India and Russia are working on jointly developing a new generation of anti-missile systems.

—"Russian defence team arrives," *Hindu* (Chennai), 5 November 1999, www.hinduonnet.com; Atul Aneja, "Russia to lease out AWACS to India," *Hindu* (Chennai), 6 November 1999, www.hinduonnet.com.

12 October 1999

A high official in India's defense ministry says that India has begun work on building a land-attack cruise missile capable of delivering a 500kg payload over a range of 700 nautical miles. The \$500 million project was approved in December 1998 and the first missile is likely to be tested in 2003. Although the missile will be designed to carry conventional warheads, longer-range versions could be nuclear-capable. The missile's initial test version will be land-based, and will be followed by a ship-based version. The Indian Institute of Sciences (IISc) in Bangalore (Karnataka) recently acquired a supercomputer—Param 10,000—from the Centre for Development of Advanced Computing (CDAC) and has begun conducting wind-tunnel tests of scale models for the missile. Another Bangalore-based Defense Research & Development Organization (DRDO) laboratory is working on terrain-contour-matching (TERCOM) and digital scene-matching area-correlation (DSMAC) missile-guidance systems for the missile. The Indian cruise missile will incorporate most of the features of the US Block III Tomahawk cruise missile such as TERCOM, DSMAC, and global positioning system (GPS) and navigation capabilities. It will also include some of the features of the Block IV Tomahawk such as in-flight retargeting, and mission planning from the launch platform. Although all features might not be ready by the tentative launch date, a working prototype of the cruise missile with a solid-fuel booster, turbofan engine, and precision guidance system are likely to be developed. India has competence in stealth design, ballistic missile, and precision guidance technologies that could be used for developing cruise missiles; but it does not have an appropriate turbofan engine and "switchover mechanism" which enables a missile to settle into cruise phase after takeoff with a solid-fuel booster. Indian missile scientists and engineers hope to retool the gas turbine engine developed by the Bangalore-based Gas Turbine Research Establishment for the light combat aircraft (LCA) for the cruise missile project. When asked to comment on the project, an Indian defense ministry spokesman said, "we do not comment on defense projects."

—Mohammed Ahmedullah, *Defense Week* (Washington, DC), 12 October 1999, p. 1.

October 1999

The Indian government approves the development of an 800-900km-range road mobile, solid-propellant variant of the Agni ballistic missile. The development and first flight-test of the shorter-range variant of the Agni is expected within 15 months.

—K. Santhanam, "Agni-I: A short-range N-missile India urgently needs," *Times of India* (Mumbai), 27 January 2002, www.timesofindia.com in FBIS Document SAP20020127000025, 27 January 2002.

21 August 1999

Dr. A.P.J. Abdul Kalam says that despite technology denials and sanctions, "DRDO [Defense Research & Development Organization], with its industry partners, have established gallium arsenide and silicon foundries for making special grade devices, supercomputers, and vital technologies required for missiles and other systems

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using indigenous facilities." He also reveals that "two types of missiles...UAV [unmanned aerial vehicle] will reach production after user trials [1999]." [Note: Gallium arsenide is a "semiconductor compound used in some diode, field-effect transistors, and integrated circuits...gallium arsenide components are useful at ultra-high radio frequencies, and in fast electronic switching applications. Gallium arsenide devices generate less noise than most other types of semiconductor components. This is important in weak-signal amplification. Gallium arsenide is used in the manufacture of light-emitting diodes which are found in optical communications and control systems...and can replace silicon in the manufacture of linear integrated circuits and digital integrated circuits. Linear devices include oscillators and amplifiers. Digital devices are used for electronic switching, and also in computer systems."]
 —A.P.J. Abdul Kalam, "Podium: Empowerment through partnership," *Hindustan Times* (New Delhi), 21 August 1999, www.hindustantimes.com; "gallium arsenide," *Whatis?.com*, <http://whatis.techtarget.com>.

17 August 1999

India's National Security Advisor Brajesh Mishra releases the draft Report of the National Security Advisory Board on India's nuclear doctrine to the public for debate. The document outlines the "broad principles for the development, deployment, and employment of India's nuclear forces." The draft says, "India shall pursue a doctrine of credible minimum nuclear deterrence...India's nuclear forces will be effective, enduring, diverse, flexible, and responsive to the requirements in accordance with the concept of credible minimum deterrence. These forces will be based on a triad of aircraft, mobile land-based missiles, and sea-based assets..."
 —"Draft Report of National Security Advisory Board on Indian Nuclear Doctrine," Embassy of India, Washington, DC, 17 August 1999, www.indianembassy.org.

15 August 1999

In an address to the nation kicking off India's independence day celebrations, Prime Minister Vajpayee announces that the Agni II will be "integrated into our [India's] armed forces."
 —"Prime Minister Atal Behari Vajpayee's Address to the Nation," Prime Minister's Office, 15 August 1999, <http://pmindia.nic.in>.

4 August 1999

The Indian government announces the "Agni Self-Reliance Award" for the year 1999. A team of four scientists is selected for its contribution to the Agni II missile program. The team designed and developed all the ground systems for the missile. These included the rail mobile launcher, mobile shelter for carrying out pre-launch operations, mechanized barge for transportation of the systems, and the jet deflector. The awardees are: Project Director V.B. Ghorpade; scientist "F" Vasanta Ramaswamy; Colonel Kamala Singh; and scientist "D" P.K. Mehta.
 —"R&D (E) team honoured for work on Agni," *Indian Express* (Mumbai), 5 August 1999, www.expressindia.com.

May-July 1999

Indian scientists arm one Agni missile with a nuclear warhead during the Kargil conflict with Pakistan. The missile is allegedly deployed somewhere in Western India.
 —Raj Chengappa, "The Earth Broke Under Our Feet," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power*, Harper Collins Publishers, India, New Delhi, p. 437.

Related content is available on the website for the Nuclear Threat Initiative, www.nti.org.



June 1999

India's external affairs and defense ministers, Jaswant Singh and George Fernandes, discuss the need for a ballistic missile to cover the gap between the short-range Prithvi and the longer-range variants of the Agni ballistic missile.
—K. Santhanam, "Agni-I: A short-range N-missile India urgently needs," *Times of India* (Mumbai), 27 January 2002, www.timesofindia.com, in FBIS Document SAP20020127000025, 27 January 2002.

May-July 1999

Indian scientists allegedly ready four Prithvi and at least one Agni missile for possible nuclear counterstrikes against Pakistan during the Kargil border conflict. The missiles are activated to a state known as "Readiness State-3." In this stage, warheads are kept ready to be mated with missiles at short notice.

—Raj Chengappa, "The Earth Broke Under Our Feet," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power*, (New Delhi: Harper Collins Publishers, 2000), p. 437.

26 May 1999

Second operational launch of the Polar Satellite Launch Vehicle (PSLV-C2). Three satellites—IRS-P4 (India), KITSAT (South Korea), and DLR-TUBSAT (Germany)—successfully placed in orbit.

—"Multiple payload launch becomes reality," *Times of India* (Mumbai), 27 May 1999, www.timesofindia.com.

16 May 1999

India's Chief of Air Staff, Air Chief Marshall Ashok Yashwant Tipnis, says that the Air Force would like to take possession of the Agni intermediate-range ballistic missile (IRBM).

—"Let's be stronger and smarter, says IAF chief," *Times of India* (New Delhi), 16 May 1999, www.timesofindia.com.

May 1999

Defense Research & Development Organization (DRDO) sources say that program to develop Surya is likely to cost \$50 million and the missile will be ready for launch by mid-2001. An advanced version of the Surya will also be developed after the first missile is tested. About 90 scientific and private institutions are participating in the development of the Surya. DRDO scientists disclose that they are also working on a project to extend the range of the Army-version of the Prithvi (SSM-150) from 150km to 350km; a 250km-range naval-version of the missile will be tested later during 1999. In addition, 20 2,000km-range Agni ballistic missiles will be built at a cost of \$150 million by the end of 2001.

—Vivek Raghuvanshi, "India To Develop Extensive Nuclear Missile Arsenal," *Defense News* (Springfield, VA), 24 May 1999, p. 14.

May 1999

Indian Minister of Defense George Fernandes denies reports that India is developing an intercontinental ballistic missile (ICBM) named Surya.

—"India Not Planning to Create Agni-3 IRBM or Surya ICBM," RIA Novosti (Moscow), 11 May 1999.

May 1999

Defense Research & Development Organization (DRDO) officials say that a 250km-range Dhanush will be tested in late 1999.

Related content is available on the website for the Nuclear Threat Initiative, www.nti.org.



—Vivek Raghuvanshi, "India to Develop Extensive Nuclear Missile Arsenal," *Defense News* (Springfield, VA), 24 May 1999, p. 14.

24 April 1999

Indian defense officials say that they are preparing to carry out user trials of the Air Force version (250km-range) of the Prithvi. Defense Research & Development Organization (DRDO) officials have already conducted three user-trials of the Air Force version, which is also known as the Prithvi II.

—Dinesh Kumar, "Naval version of the Prithvi will be test fired shortly," *Times of India* (New Delhi), 24 April 1999, www.timesofindia.com.

24 April 1999

Defense Research & Development Organization (DRDO) officials say that they are preparing to test a 350km-range naval version of the Prithvi ballistic missile, named Dhanush. The missile has been designed, fabricated, and installed, and is currently undergoing tests. According to DRDO officials, "efforts to launch the missile from a ship have been underway," and a launcher stabilization system is crucial since ships are unstable missile launch platform on sea.

—Dinesh Kumar, "Naval version of the Prithvi will be test fired shortly," *Times of India* (New Delhi), 24 April 1999, www.timesofindia.com.

April 1999

The principal scientific advisor to the Indian government, Dr. A.P.J. Abdul Kalam, says that the Agni II is designed to carry a nuclear warhead; he also says that the May 1998 nuclear tests included a test of an Agni-class payload.

—Rahul Bedi, "Agni-II IRBM: Built to Carry Nuclear Warhead," *Jane's Defence Weekly* Vol. 31, No. 17 (Coulsdon, Surrey), 28 April 1999, p. 7.

April 1999

Defense Research & Development Organization (DRDO) scientists say that a 3,500km-range Agni III is in the advanced stages of development.

—Rahul Bedi, "India: No Arms Race, No Danger," *Jane's Defence Weekly* (Coulsdon, Surrey), 21 April 1999, p. 3.

14 April 1999

The principal scientific advisor to the Indian government, Dr. A.P.J. Abdul Kalam, tells Indian defense analyst Brahma Chellaney in television interview that the Agni is "operationally ready." Referring to nuclear warheads, he says that the Agni can carry "special warheads." Kalam adds that the scientists have completed their job and "it is for the government" to proceed with the deployment of the Agni II.

—"Agni-II 'ready' to carry N-warhead," *Hindustan Times* (New Delhi), 15 April 1999, www.hindustantimes.com.

12 April 1999

Pakistan reacts angrily to India's test of the Agni II. A Pakistani foreign ministry spokesperson says that "the development of Agni II adds to our concerns and is a threat to our security." Pakistan's Foreign Minister Sartaj Aziz comments that "since they [India] have gone ahead, we will probably have to give a befitting response."

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—"India triggers missile row," *Daily Mail* (London), 12 April 1999, in Lexis-Nexis Academic Universe, 12 April 1999, <http://web.lexis-nexis.com>.

11 April 1999

The United States expresses regret at India's decision to test the Agni II. White House spokesperson Nanda Chitre says, "we regret the decision to go ahead with this test...[the Agni test] appears to be out of step with recent political developments in the region."

—"US 'regrets' Indian ballistic missile test," AFP, 11 April 1999, in Lexis-Nexis Academic Universe, 11 April 1999, <http://web.lexis-nexis.com>; "India triggers missile row," *Daily Mail* (London), 12 April 1999, in Lexis-Nexis Academic Universe, 12 April 1999, <http://web.lexis-nexis.com>.

April 1999

The principal scientific advisor to the Indian government, Dr. A.P.J. Abdul Kalam, reveals that contrary to popular perceptions, the Agni project was never stopped; all governments supported it. He also says the Agni's import content is less than 10% and India now has the indigenous capability to design, develop, and produce any type of missile. When asked if it was feasible to declare the Agni II operational after a single test, Kalam says that India has data from three previous tests of the Agni I and 16 flight-tests of the Prithvi. In addition, the simultaneous monitoring of over 600 test parameters and ground simulation technologies obviate the need for multiple flight-tests. Kalam also says that the Agni was "never conceived only as a nuclear weapon system. What it did was to afford us [India] the option of developing the ability to delivery non-nuclear weapons with precision at long ranges. That it provided us with a viable non-nuclear option was of the greatest relevance to contemporary strategic doctrines."

—"Interview: A.P.J. Abdul Kalam," *India Today* (New Delhi), 26 April 1999, www.india-today.com; A.P.J. Abdul Kalam with Arun Tiwari, "Propitiation," in *Wings of Fire: An Autobiography*, (Hyderabad: Universities Press (India) Limited, 1999), p. 153.

11 April 1999

Following the successful test of the Agni II, Prime Minister Vajpayee, in a public address to the nation says, "[the test] is a vindication of our steadfast commitment to self-reliance. In a rapidly changing security environment, India cannot depend on others to defend her. We have to develop our own indigenous capabilities. Agni is a symbol of a resurgent India which is able to say: 'Yes, we will stand on our own feet'...as was the case with nuclear tests at Pokhran in May last year [1998], the test-firing of the Agni missile is also a purely defensive step...Agni is proof of our determination to strengthen our national security so comprehensively that we can defend ourselves. I have said earlier, and I reiterate, that India remains committed to minimum deterrence, to no-first-use of nuclear weapons, and never to use them against non-nuclear weapon states.

—Address to the Nation by Prime Minister Atal Behari Vajpayee," Discover India: Ministry of External Affairs, 11 April 1999, www.meadev.gov.in.

11 April 1999

India tests the Agni II missile from a new launch facility at the IC-4 on Wheeler's Island. The new facility has been built to bypass the problem of evacuating villagers from the Interim Test Range's (ITR) surrounding areas every

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time a missile is tested. This is the fourth test in the Agni program. The 20 meter-high missile is launched from a rail-mobile platform at 9:47 a.m. and reaches the point of impact in 11 minutes. Defense Minister George Fernandes says that, "we [India] have reached the point of operationalization of Agni II as a weapon system." The salient features of this test are demonstration of mobile launch capability; an all solid-solid propulsion system; range of over 2,000km; improved guidance and navigation system; and an advanced communication interface. According to Defense Research & Development Organization (DRDO) sources the Agni II is equipped with a global positioning system (GPS); satellite inputs during the missile's flight time help an on-board computer to correct for navigational errors and improve accuracy. Unlike the earlier models, which used a liquid configuration in the second stage, the Agni-II has an all solid-fuel configuration. The Agni's designers and engineers say that the missile is highly mobile and can be transported by rail or road anywhere within India. When compared to the Agni I, which required half a day of preparation for launch, the Agni II can be launched within 15 minutes. The Agni II also incorporates a terminal navigation and guidance system; the missile uses ground-based beacons to correct for deviations in the missile's path even as it travels at hypersonic speeds of over Mach 14. According to DRDO's chief controller of R&D (missiles), the Agni's accuracy has been "improved by a factor of three." Indian nuclear and missile scientists also test an actual nuclear warhead assembly without its plutonium core during the test. In an earlier static test involving a dummy warhead, severe vibrations had caused it to trigger prematurely due to a high-arching voltage problem. Flight telemetry data from the Agni's test shows that the dummy warhead's safety locks unlocked in a predetermined manner.

—"Over 2,000km Range Agni-II Successfully Test-Fired," *Times of India* (New Delhi), 12 April 1999, www.timesofindia.com; Manvendra Singh, "Agni-II Adds Fire Power to N-Deterrence," *Indian Express* (Bombay), 12 April 1999, www.expressindia.com; Duncan Lennox, ed., *Jane's Strategic Weapons Systems*, Issue 32, (Coulsdon, Surrey), 2000, p. 73; "Agni-II joins nation's missile showcase," *Hindustan Times* (New Delhi), 11 April 1999, www.hindustantimes.com; Raj Chengappa, "Boom for Boom," *India Today* (New Delhi), 26 April 1999, www.india-today.com.

9 March 1999

A planned test of the Dhanush is aborted due to technical problems. However, Pakistani news sources say that the test failed and the Indian navy is trying to keep it a secret.

—Atul Aneja, "Technical Snag Aborts 'Dhanush' Launch," *Hindu* (Chennai), 15 March 1999, www.hinduonline.com; Zafar Mehmood Malik, "Pakistani Paper Reports Failure of Indian Missile Test," *Jang* (Rawalpindi), 15 March 1999, pp. 1, 7, in FBIS Document FTS19990315001032, 15 March 1999.

7 March 1999

Responding to media queries on the Agni test, Indian Defense Minister George Fernandes says that, "the Agni project is in good shape and it will be test-fired at an appropriate time."

—"Agni test at appropriate time," *Hindu* (Chennai), 8 March 1999, www.hinduonnet.com.

5 March 1999

Indian Defense Minister George Fernandes and the government's principal scientific advisor Dr. A.P.J. Abdul Kalam visit Inner Wheeler's Island. After conferring with senior scientists, they decide to postpone the Agni test.

Fernandes says that the government has not made any decision on the test. However, government sources admit

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that current preparations on the island are linked to the missile test. The Indian government extends the navigational area warning to aviators and ships to keep out of the designated missile testing zone until 9 March 1998.

—"Agni II test put off till further orders," *Rediff on the Net*, 5 March 1999, www.rediff.com; "No decision yet on Agni-2 test-firing," *Hindu* (Chennai), 5 March 1999, www.hinduonnet.com; Atul Aneja, "Technical snag aborts 'Dhanush' launch," *Hindu* (Chennai), 15 March 1999, www.hinduonnet.com.

4 March 1999

Agni II test is aborted due to technical problems.

—Atul Aneja, "Technical Snag Aborts 'Dhanush' Launch," *Hindu* (Chennai), 15 March 1999, www.hinduonnet.com.

3 March 1999

Preparations to test the Agni II from the IC-4 Inner Wheeler's Island off the Interim Test Range (ITR) in Chandipur (Orissa) are completed. The test is likely to occur sometime between 5-7 March. India's defense ministry declines to confirm or deny reports about the impending test.

—Agni-2 to be test-fired from Orissa coast this week," *Rediff on the Net*, 3 March 1999, www.rediff.com.

18 February 1999

The Defense Research & Development Organization (DRDO) clarifies that all Indian missiles are "explicitly Y2K proof and cannot be accidentally triggered or guided to the wrong target, because of a possible effect of the Year 2000 computer glitch." The Chief Controller, Research & Development at DRDO. Dr. Sivathanu Pillai states that Indian missile scientists have conducted simulation experiments to ensure that all computers used in indigenously developed missiles, as well as those incorporated in ground-support systems are Y2K compliant.

—"Indian missiles Y2K proof," *Hindu* (Chennai), 18 February 1999, in Lexis-Nexis Academic Universe, 18 February 1999, <http://web.lexis-nexis.com>.

8 February 1999

The *Asian Age* reports that India is developing an 8,000km-range intercontinental ballistic missile (ICBM) by marrying the Defense Research & Development Organization's (DRDO) Agni technology with the The Indian Space Research Organization's (ISRO) Polar Satellite Launch Vehicle (PSLV). The Indian government denies the report. An Indian defense ministry spokesperson says, "the report is incorrect, fabricated, and has no basis."

—"Government denies developing ICBM through Agni missile," *Rediff on the Net*, 8 February 1999, www.rediff.com; "India denies report on developing long-range missile," DPA, 8 February 1999, in Lexis-Nexis Academic Universe, 8 February 1999, <http://web.lexis-nexis.com>.

26 January 1999

India displays the Agni missile publicly for the first time during the Republic Day parade.

—"Agni Hogs Limelight at R-Day Parade," *Hindu* (Chennai), 27 January 1999, www.hinduonnet.com.

22 January 1999

Indian government sources clarify that the Agni and Dhanush missiles will be tested during the summer of 1999. The tests have been postponed due to technical snags, which have not been rectified. They dismiss as "highly

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speculative and unwarranted" a report, which said that plans to test the missiles had been given up indefinitely. A government source asserts, "there is no diplomatic or political angle to the delay...if India could carry out nuclear tests last year [May 1998], test-firing of missiles, which is part of an ongoing program, need not be influenced by extraneous factors."

—"Govt. refutes speculative report on 'Agni'," *Times of India* (New Delhi), 22 January 1999, www.timesofindia.com.

January 1999

India postpones a scheduled test of the Agni II.

—Tara Shankar Sahay, "Agni put to bed 'indefinitely,' confirms MOD," *Rediff on the Net*, 21 January 1999, www.rediff.com.

January 1999

Dhanush test is delayed due to technical problems.

—Shishir Gupta, "India Buckles, Test-Firing of Agni Put Off Indefinitely," *Hindustan Times* (New Delhi), 21 January 1999, www.hindustantimes.com.

21 January 1999

The district collector of Balasore (Orissa) and federal defense officials meet to arrange for the temporary evacuation of four villages on 23-24 January 2001 for the proposed missile tests at the Interim Test Range (ITR). The defense ministry in New Delhi declines to comment on the reported meeting, but does not deny it.

—"Missile tests not put off under international pressure: govt.," *Statesman* (Calcutta), 21 January 1999, in Lexis Nexis Academic Universe, 21 January 1999, <http://web.lexis-nexis.com>.

20 January 1999

During a visit to Japan, India's Foreign Secretary K. Raghunath says that India is likely to test a new missile in January.

—"India to test-fire new missile this month: Raghunath," *Times of India* (New Delhi), 20 January 1999, www.timesofindia.com.

1999

The Defense Research & Development Organization (DRDO) says that Prithvi's range will be extended to 350km.

—Vivek Raghuvanshi, "India to Develop Extensive Nuclear Missile Arsenal," *Defense News* (Springfield, VA), 24 May 1999, p. 14.

1998

December 1998

India and Russia sign a new 10-year defense cooperation accord on 21 December 1998. According to unnamed Indian defense sources, Russia will assist India in the development of the Sagarika missile; another Indian defense source says that the Sagarika will be armed with nuclear warheads.

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—Rahul Bedi, "Russia Signs to Help India," *Jane's Defence Weekly*, Vol. 30, No. 21 (Coulsdon, Surrey), 25 November 1998, p. 4; "India, Russia sign 10-Year Defence Cooperation Accord," AFP, 21 December 1998, in Lexis-Nexis, 21 December 1998, <http://web.lexis-nexis.com>.

13 December 1998

A defense ministry report tabled in parliament says a 250km-range naval version of the Prithvi is under development. The missile will be capable of being launched from a ship; the missile will be deployed on an experimental basis on certain combat ships by the end of January 1999.

—"Defence Ministry of firing range of Prithvi surface-to-surface missile," PTI (New Delhi), 13 December 1998, in Lexis-Nexis Academic Universe, 14 December 1998, <http://web.lexis-nexis.com>.

10 December 1998

The principal scientific advisor to the Indian government, Dr. A.P.J. Abdul Kalam, announces that "by 2000, all the strategic and tactical missiles will be made in the country [India]. He also discloses that the Nishant remotely piloted vehicle (RPV) will be ready for induction in 1999."

—"India will be missile power by 2000-Kalam," *Hindu* (Chennai), 10 December 1998, in Lexis-Nexis Academic Universe, 10 December 1998, <http://web.lexis-nexis.com>.

9 December 1998

Principal scientific advisor to the Indian government, Dr. A.P.J. Abdul Kalam, tells reporters that India is ready to sell tactical missiles within two years to its "political friends." These missiles include the Trishul and Akash surface-to-air missiles (SAMs) and NAG anti-tank guided missile (ATGM). Kalam admits that the government will not allow him to sell Prithvi. He says, "we want to communicate that certain types of missiles are marketable as our aerospace and military technology is comparatively cheaper."

—"India's strategic missiles to be battle-ready by 2000," AFP, 9 December 1998, in Lexis-Nexis Academic Universe, 9 December 1998, <http://web.lexis-nexis.com>.

9 December 1998

Defense Minister George Fernandes reiterates that India is getting ready to test its long-range Agni missile. Fernandes tells reporters, "you will hear about it in the future."

—"Long-range 'Agni' missile getting ready: Fernandes," *Indian Express* (Mumbai), 9 December 1998, www.expressindia.com.

4 December 1998

India cancels a test of the Agni II due to technical problems.

—Bhashyam Kasturi, "India Treads Cautiously on Test Firing of Agni-II," Deccan Herald News Service, Bangalore, 16 March 1999; in "Daily Lists Reasons for Indian Missile Postponement," FBIS Document FBIS-FTS19990317000384, 17 March 1999.

3 December 1998

Indian Defense Minister George Fernandes informs parliament that India's talks with the United States and other states have not led to any changes in the plans for the Agni missile program. He says that India has explained its

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security concerns to the United States and that the government has approved the development of a longer-range state-of-the-art Agni to address those threat perceptions.

—"No change in Agni programme: George," *Times of India* (New Delhi), 3 December 1998, www.timesofindia.com.

December 1998

India launches a joint Army-Air Force military exercise—Exercise Shiva Shakti—along the Indo-Pakistan border in the Rajasthan desert to simulate India's ability to survive and win in a "nuclear and chemical war." The Army deploys Prithvi missiles during the exercise.

—Prakash Nanda, "Biggest military exercise begins near border," *Times of India* (New Delhi), 3 December 1998, www.timesofindia.com.

30 November 1998

Addressing a press conference on the eve of "Navy Week," Indian Chief of Naval Staff, Admiral Vishnu Bhagwat says that work on the naval version of the Prithvi is progressing well, and missiles will be deployed on board a ship by 26 January 1999 on an "experimental basis." Bhagwat says that "launching Prithvi from a ship is a demanding task because of the roll and pitch of the vessel and other factors." He said, "we already have Prithvi, but certain modifications have to be carried out. We have to ensure that all systems of a missile should be sufficiently reliable to function effectively at sea under tough weather conditions." Bhagwat dismisses reports about the Sagarika missile as "fiction" and says, "we have no project called Sagarika."

—"Prithvi naval version to be deployed by Jan. 26," *Hindu* (Chennai), 1 December 1998, www.hinduonnet.com.

13 November 1998

Indian Defense Secretary Ajit Kumar and Russian Deputy Defense Minister Nikolai Mikhailov finalize the details for a new 10-year Indo-Russian defense agreement, which will be signed during President Boris Yeltsin visit to New Delhi in December 1998. *Kommersant Daily* says that India is planning to purchase six Russian S-300V air defense systems, which are capable of destroying both aircraft and ballistic missiles. According to the S-300V's chief designer, Alexander Lemansky, India has indicated its preference to take the S-300 complexes from the Russian defense ministry's stocks, rather than wait 18 months until new ones are built. Reports say that the Russian system will be integrated with the indigenously developed Rajendra radar and Akash surface-to-air missile (SAM).

—Vladimir Radyuhin, "India, Russia to expand defence cooperation," *Hindu* (Chennai), 14 November 1998 www.hinduonnet.com.

October 1998

Defense Research & Development Organization (DRDO) conducts static tests of "specialized" warheads for the Prithvi, which includes the pre-fragmented variable mass warhead.

—Dinesh Kumar, "Naval version of Prithvi will be test fired shortly," *Times of India* (New Delhi), 24 April 1999, www.timesofindia.com.

4 September 1998

Indian Defense Minister George Fernandes admits that India is developing the Sagarika submarine-launched cruise missile. He also reiterates that the development of the Agni II is on course and the missile will be tested soon.

Related content is available on the website for the Nuclear Threat Initiative, www.nti.org.



—"Agni-II to be Test-Fired Soon," *Hindu* (Chennai), 4 September 1998, www.hinduonnet.com; "Agni-II range to be enhanced: Fernandes," *Times of India* (New Delhi), 5 September 1998, www.timesofindia.com.

4 September 1998

Indian defense ministry sources say that the 2,500km-range Agni II is almost ready and will be tested in the "very near future." The development of the "superior Agni II has reached a definitive stage," the sources said.

—"2,500-km plus Agni II almost ready," *Rediff on the Net*, 4 September 1998, www.rediff.com.

2 September 1998

First test-flight of the Nishant unmanned aerial vehicle (UAV).

—"Nishant finally in the air," *Times of India* (New Delhi), 2 February 2001, www.timesofindia.com.

September 1998

The Indian government clears a Defense Research & Development Organization (DRDO) project to integrate a number of high-end Russian anti-aircraft/anti-ballistic missile systems such as the S-300V and S-300P with Israeli fire-control radar and battle management systems to create a limited anti-ballistic missile system. The proposed Indian anti-ballistic missile system will be designed to intercept Pakistani M-11 type missiles; but it will not have the capability to intercept longer-range missiles such as the Ghauri, which have a peak velocity of 4km/second. The project is expected to cost 20 billion rupees.

—Manoj Joshi, "Dubious Shield," *India Today* (New Delhi), 19 October 1998, www.india-today.com.

17 August 1998

The defense ministry announces that the Balasore Interim Test Range (ITR), where most of India's missiles have been tested, is being upgraded to the level of a world-class range facility. The range is being upgraded to meet the urgent requirements of the Defense Research & Development Organization (DRDO). According to defense ministry sources, in-house facilities for repair and maintenance have been upgraded continuously. Efforts are underway to develop a system for aiding safety decisions during launch.

—"Interim Test Range to be upgraded," *Indian Express* (Mumbai), 18 August 1998, www.expressindia.com.

12 August 1998

Defense Minister George Fernandes holds a meeting with the parliament's defense consultative committee to discuss the Integrated Guided Missile Program (IGMDP). Among others, Dr. A.P.J. Abdul Kalam, principal scientific advisor to the Indian government, and Defense Secretary Ajit Kumar also attend the meeting. Fernandes reiterates that the government has approved the development of the second phase of the Agni intermediate-range ballistic missile (IRBM) with an enhanced range. He says that efforts are on to ensure that there was no adverse impact of sanctions on the missile program, which is in a "very advanced stage of development." Fernandes also says that the 150km-range Prithvi I has already been inducted into the Army and development work on the 250km-range Air Force version, the Prithvi II, has been completed.

—"Govt. approves second phase of Agni missile programme," *Times of India* (New Delhi), 12 August 1998, www.timesofindia.com.

Related content is available on the website for the Nuclear Threat Initiative, www.nti.org.



16 July 1998

According to *Asian Age*, India plans to test two Agni II missiles in August 1999. The new version will have a range of 2,000km with a one-ton payload. Preparations to produce the solid-fueled stages of the missile have been hurried up, suggesting an urgency in not only developing an improved version of the missile, but also in beginning its series production. The Indian government denies these reports. A defense ministry spokesperson says, "there is no truth in reports that test-firing of the upgraded version of the intermediate-range ballistic missile [Agni] is to take place in August."

—"India to test nuclear weapon-compatible missile," DPA, 16 July 1998, in Lexis-Nexis Academic Universe, 16 July 1998, <http://web.lexis-nexis.com>; "Ministry denies reports of Agni," *Rediff on the Net*, 16 July 1998, www.rediff.com.

16 July 1998

Defense Minister George Fernandes informs parliament that steps have been initiated to meet the new requirements of the armed forces in the wake of India becoming a nuclear power.

—"Steps taken to meet forces requirements after N-Tests: Fernandes," *Rediff on the Net*, 16 July 1998, www.rediff.com.

13 July 1998

An Indian naval defense analyst says that Sagarika is not a ballistic missile; it is an air-breathing cruise missile with a stand-off land attack capability. Sagarika was a late entrant in India's guided missile program. Design and development of the missile began in 1990 and since 1992 the Sagarika has been under development at the Aeronautical Development Establishment (ADE) in Bangalore (Karnataka). The design and development phase will be completed by 2000, and deployment will commence soon afterwards.

—Rahul Roy Chaudhury, "Equipping the Navy for War on Land," *Times of India* (New Delhi), 13 July 1998, www.timesofindia.com.

8 July 1998

The Indian parliament's standing committee on defense urges the government to press ahead with the development of long-range missiles. Its report on defense says that both China and Pakistan have missiles that can reach any part of India and that India has no credible deterrent against China. To redress this imbalance, "the government should go ahead full-steam in a time bound manner to develop a full range of missiles, in addition to variants of the Agni currently under development, as a deterrent to potential enemies from using their ballistic missile capabilities against any of our assets."

—"Indian panel urges big push on missiles," *Washington Times*, 11 July 1998, p. A7.

29 June 1998

According to Indian defense ministry sources, the Defense Research & Development Organization (DRDO) will test a new 220-mile version of the Prithvi—the Dhanush—soon. When queried on the subject of Indo-Russian missile cooperation, the official explains, "of course there has been long-standing scientific cooperation with Russia in general technology areas...we are trying to get technology from Israel, too."

Related content is available on the website for the Nuclear Threat Initiative, www.nti.org.



—"India To Test New Prithvi," *Aviation Week & Space Technology* (New York), Vol. 148, No. 26, p. 31, 29 June 1998, in Lexis-Nexis Academic Universe, 29 June 1998, <http://web.lexis-nexis.com>.

16 June 1998

Radio Pakistan alleges that India's BJP government has given clearance for the deployment of the Prithvi along the Indo-Pakistani border; the Indian armed forces "are selecting sites in a belt 20-30km from Pakistan's borders for this purpose."

—"Pakistan Radio Reports India's Deployment of Prithvi Missiles Near Border," Radio Pakistan (Islamabad), 16 June 1998, in Lexis-Nexis Academic Universe, 16 June 1998, <http://web.lexis-nexis.com>.

3 June 1998

Defense Minister George Fernandes informs parliament that the government plans to increase the range of the Agni surface-to-surface missile (SSM).

—"India clears plan for improved ballistic missile," AFX News, 3 June 1998, in Lexis-Nexis Academic Universe, 3 June 1998, <http://web.lexis-nexis.com>.

June 1998

The defense ministry says that India will start testing a new version of the Prithvi, named Dhanush, in December 1998.

—"India to Test New Prithvi," *Aviation Week and Space Technology*, Vol. 148, No. 26 (New York), 29 June 1998, p. 31, in Lexis-Nexis Academic Universe, 29 June 1998, <http://web.lexis-nexis.com>.

26 May 1998

Defense Minister George Fernandes says that India will "inevitably arm" its missiles with nuclear warheads. According to Fernandes, "without weaponization, this question of being a nuclear weapons state does not make sense...nuclear weaponization is necessary, and in the ultimate analysis inevitable."

—"India will 'inevitably' arm missiles with nuclear warheads," AFP, 26 May 1998, in Lexis-Nexis Academic Universe, 26 May 1998, <http://web.lexis-nexis.com>.

17 May 1998

Indian defense sources say that the Agni program has been revived. The scientific advisor to the defense minister Dr. A.P.J. Abdul Kalam tells a press conference that the Defense Research & Development Organization (DRDO) is working "on the next version of the Agni." Kalam says, "the [present] project has been completed, and if needed, the Agni can be made in large numbers."

—Neelesh Misra, "India Perfecting Delivery System For Nuclear Weapons," AAP Information Services Pvt. Ltd., 18 May 1998, in Lexis-Nexis Academic Universe, 18 May 1998, <http://web.lexis-nexis.com>.

17 May 1998

Indian defense scientists announce at a press conference that India has become a nuclear weapon state and the five nuclear weapon tests at Pokhran were a "culmination" of a "weaponization program" jointly undertaken by the defense and atomic energy establishments. The scientific advisor to India's defense minister Dr. A.P.J. Abdul Kalam says "the Defence Research & Development Organization [DRDO] and the Department of Atomic Energy

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have effectively and efficiently coordinated and integrated their respective technological strengths in a national mission to confer the country with a capability to vacate nuclear threats." Dr. Kalam clarifies that the "command and control" structure, which had been previously existed in various forms was now being "consolidated." Kalam also confirms that "our [Indian] missiles are designed to take any type of warhead...we have tested the size, weight, performance, and vibrations (of warheads)." Providing further details on the Agni, Kalam says that the government has authorized the DRDO to develop a longer-range variant of Agni. DRDO is developing an all solid-fuel and a two-stage liquid-fuel variant of the Agni.

—"Weaponisation is now complete, say scientists," *Hindu* (Chennai), 18 May 1998, www.hinduonnet.com.

13 May 1998

India conducts two underground nuclear tests. The tests are carried out to "generate additional data for improved computer simulation of designs and for attaining the capability to carry out subcritical experiments, if considered necessary."

—Press Release, Embassy of India (Washington, DC), 13 May 1998, www.indianembassy.org.

11 May 1998

India conducts three underground nuclear tests at its Pokhran test site in the Rajasthan desert. The tests include a fission device, a low-yield device, and a thermonuclear device. According to an Indian government press release, "the measured yields [from the tests] are in line with expected values...these tests have established that India has a proven capability for a weaponized nuclear program."

—Press Release, Embassy of India (Washington, DC), 11 May 1998, www.indianembassy.org.

11 May 1998

An Indian defense official reveals that contrary to popular perceptions that India had put its Integrated Guided Missile Program (IGMDP) on hold under US pressure, the projects were never capped "completely." The official explains, "how can we stop working on it? We cannot take a risk of reaching in a stage of technology-gap...capping the missile program at this stage means creating a considerable technological gap, and India cannot afford to do that keeping in mind India's war-history." Defense Research & Development Organization (DRDO) sources suggest that "Pakistan's Ghauri has given the country [India] a golden opportunity to legitimize R&D on the sophisticated missile projects."

—"Agni project was never capped," *Hindu* (Chennai), 11 May 1998, www.hinduonnet.com.

4 May 1998

Defense Research & Development Organization (DRDO) sources say that the government has approved the second phase of the Agni program to increase the missile's range. In this phase, the Agni's design will be modified and additional tests will be conducted to verify the modifications. Indian defense sources disclose that after the missile's last test in February 1994, the "Agni project team was never disbanded and worked on fine tuning the know-how acquired from the Agni's three tests continued quietly..."

—"Govt. okays Agni's upgradation," *Indian Express* (Mumbai), 4 May 1998, www.expressindia.com; Atul Aneja, "Agni likely to be made battle ready," *Hindu* (Chennai), 5 May 1998, www.hinduonnet.com.

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28 April 1998

Russian foreign ministry spokesperson denies that Russia is helping India to build sea-launched missiles capable of carrying a nuclear warhead. Similarly, Yevgeny Ananyev, director of Russia's state-run export company, Rosvooruzheniye, says "we have no access to India's missile program; it is closed for us...in some way or the other, Rosvooruzheniye is involved in all projects of military-technical cooperation with India, and I have not come across any such fact."

—"Russia Denies Helping India Create Missile," *Russia Today*, 28 April 1998, www.russiatoday.com; "Russia Denies Report on Sagarika Missile," *Indian Express* (Mumbai), 29 April 1998, www.expressindia.com.

28 April 1998

White House spokesperson Michael McCurry comments on the Sagarika controversy. McCurry says, "all that we have established, since we watch these matters extraordinarily carefully, is that we have made no determination at this point that any cooperation we have detected [between Russia and India] is a violation of Missile Technology Control Regime (MTCR) guidelines...there are sanctions that arise when we see any type of export activity that is in contravention of MTCR guidelines, and we have not made that determination or finding nor have we imposed any sanctions."

—Sridhar Krishnaswami, "US sees no violation of MTCR so far," *Hindu* (Chennai), 29 April 1998, www.hinduonnet.com.

28 April 1998

A US State Department official says that "we [United States] know that India is working on a missile called Sagarika and we understand this is a long-term project which is still in the early stages of development...we also understand that the project is being developed in conjunction with efforts to build and design a nuclear-powered ballistic submarine." Explaining the US concern about the Sagarika program, a senior Pentagon official says, "the key sensitivity is that the Indians will learn how to launch something from under water—get it above and ignite an engine...and then they'll go to the next step after that on their own, something with a longer range."

—"Russia Denies Helping India Develop Submarine-Launched Missiles," *Rediff on the Net*, 28 April 1998, www.rediff.com.

27 April 1998

Reacting to reports on the Sagarika, an Indian defense ministry spokesman says that "India does not have any such project."

—"India denies US newspaper report of missile development," PTI (New Delhi), 27 April 1998, in BBC Summary of World Broadcasts, Lexis-Nexis Academic Universe, 29 April 1998, <http://web.lexis-nexis.com>.

27 April 1998

US intelligence sources allege that Russia is helping India to build a sea-launched ballistic missile. The sea-launched missile, Sagarika, is believed to have a range of 200 miles. However, the sources admit that the precise nature of Russian assistance is unclear. The Clinton administration first confronted Russia with evidence about the missile cooperation in 1995. At that time Russian officials admitted that scientists from quasi-public research institutes were providing technical cooperation to India; but cooperation was limited to technology needed to launch the

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missile from underwater and did not involve assistance with the missile's design. Russian also assured the United States that missile cooperation with India would "continue to be circumscribed." However, US intelligence sources contend that Russian research institutes and scientists have provided India with "significant engineering services" as well as parts and equipment necessary to build and launch the missile. But the US State Department, Pentagon, and Central Intelligence Agency (CIA) are not in agreement about whether the missile cooperation is a violation of the Missile Technology Control Regime (MTCR). Some US officials believe that in cooperating on the Sagarika program, Russia has clearly violated MTCR rules; others contend that it "slips under the limits of the agreement." There are also conflicting intelligence estimates about whether the Sagarika is a cruise or a ballistic missile. A spokesperson from the Russian embassy, while refusing to discuss the missile issue, says that Russia fully complies with its commitments under the MTCR.

—Steven Lee Myers, "Russia is Helping India Extend Range of Missile, US Aides Say," *New York Times*, 27 April 1998, www.nytimes.com; Rahul Roy-Chaudhury, "Equipping the Navy for War on Land," *Times of India* (New Delhi), 13 July 1998, www.timesofindia.com; "Russia Denies Helping India Create Missile," *Russia Today*, 28 April 1998, www.russiatoday.com; "Russia Denies Helping India Develop Submarine-Launched Missiles," *Rediff on the Net*, 28 April 1998, www.rediff.com.

January 1998

The convenor of the BJP's foreign policy cell, Brajesh Mishra, declares that the cornerstone of the BJP's foreign and defense policy will be the exercise of India's nuclear option. According to Mishra, the party has calculated that although initially there could be serious consequences, "[the] hullabaloo would die down and the India would be accepted as a full-fledged nuclear power, even by the United States." The BJP would like to provide more budgetary support to the Defense Research & Development Organization (DRDO) and ensure that the development and testing of the Agni II are given top priority.

—Neena Vyas, "BJP in Govt. to Exercise N-Option," *Hindu* (Chennai), 14 January 1998, www.hinduonnet.com.

1998

The Defense Research & Development Organization (DRDO) reports that it may begin producing "dry tuned gyros" for missiles by the end of 1998. The dry tuned gyro after "detailed test evaluation, modeling, and S/W compensation" is expected to give "0/1deg/hr, 200ppm class performance." The design of a "fiber optic gyro...of open loop design is under progress," and a "close loop integrated optics version is likely to come to the laboratory model stage by the year 2000. A ring laser gyro of 0.1deg/hr (1σ) class is planned to be produced by 2000...with the participation of an academic institution where the first pre-production model has been developed and tested..."

—Dr. N.C. Birla and B.S. Murthy, eds., "Inertial Guidance and Sensors," *Indian Defence Technology: Missile Systems*, (DRDO, Ministry of Defence, December 1998), pp. 157-158.

1998

The Defense Research & Development Organization (DRDO) reports that projects to develop "large diameter rocket motors, thrust vector control systems like flex and swivel nozzle," are currently under development. In addition, Indian missile laboratories are developing "nitrogen gas generators" to replace "air bottles" in missiles.

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—Dr. N.C. Birla and B.S. Murthy, eds., "Propulsion Systems," *Indian Defence Technology: Missile Systems*, (DRDO, Ministry of Defence, December 1998), p. 92.

1998

Commenting on dual-use technologies, the principal scientific advisor to the Indian government, Dr. A.P.J. Abdul Kalam, says that India must focus on the development of technologies in the "aviation and propulsion sector, high-end electronics, sensors, space communications, and remote sensing, critical materials and processing, robotics and artificial intelligence." He further claims that India is almost "at par with the developed countries in the area of solid propellant power plants." The Indian Space Research Organization (ISRO) has also developed "technologies of storable liquid propellants and related propulsion."

—A.P.J. Abdul Kalam with Y.S. Rajan, "Strategic Industries," *India 2020: A Vision for the New Millennium*, (New Delhi: Penguin Books India (P) Ltd: 1998), pp. 195, 213.

1998

According to the principal scientific advisor to the Indian government, Dr. A.P.J. Abdul Kalam, the vision for "DRDO [Defense Research & Development Organization] is to promote the corporate strength of the organization, and to make the nation independent of foreign technology in critical spheres. Technology innovation is expected to lead the DRDO and its industrial partners to global competitiveness in systems design and realization." Commenting on the goals of the Integrated Guided Missile Program (IGMDP), Kalam says, "the technological goal of the program is to ensure that the systems will be contemporary at the time of their induction into the armed forces." The systems have been designed to be multi-purpose, multi-user, and multi-role in nature. The program has adopted the philosophy of concurrent development and production to reduce the time-cycle from development to induction." Explaining how the Prithvi will probably be used in a conventional war, Dr. A.P.J. Abdul Kalam says, "possession and deployment of a large number of Prithvi missiles can act as a deterrent and prevent a missile attack from our adversaries. In case of war, the powerful explosive and high accuracy of the Prithvi missile has enormous potential to bring life to a standstill in cities and urban areas, to affect the morale of the enemy. Also, a sizeable portion of the enemy Air Force would be engaged in neutralizing the mobile missile launchers...the deep penetration capability of the Prithvi missile, up to 250km range, will enhance the firepower of the Air Force against heavily defended targets in adverse weather conditions. In addition, the night attack capability of this missile will be useful for attacking targets like factories, petroleum dumps, marshalling yards, and other static installations." Kalam divulges that "the accuracy of the system at 250km will be further improved upon in phase II, when terminal homing guidance and anti-radiation systems will be integrated into the Prithvi system. A scheme for retrofit is being contemplated and designed. This capability will be an asset in attacking hard targets like armoured concentrations in their parking sites."

On India's plans to build hyperplanes in the future, Kalam divulges that "DRDO has entered into ramrocket systems where much higher energy levels (above 500 seconds with solid propellants and up to 1000 seconds with liquid propellants) will be realized. The scramjet engine will give energy level of 3000 seconds...this is not only for military application. These supersonic combustion engines have application for cruise missiles, launch vehicles, and hyperplanes in the future. India's proposed scramjet is designed for operating up to Mach 12. In the long term, it could become part and parcel of our jet aircraft too...India should at least take initiative in the elements of the

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hyperplane program so that India's hyperplane and future aerospace vehicles can be built around this power plant. The hyperplane can deliver a payload of above 30 tons for a take off weight of 250 tons, giving a quantum jump for the existing payload/take off ratios of max 3% to 15% through mass addition. A future hyperplane mission can have an integrated power plant complex working in three modes: fan ramjet engine mode in low altitude, low-speed flight regimes; scramjet engine mode in Mach number range 3 to 12 along with in-flight air-liquification and mass addition; rocket engine mode till payload launching...our aerospace scientists start with the design, development and integration of fixed geometry air intakes for a wide Mach number range supported extensively by analytical tools like Computational Fluid Dynamics and experimental set up like hypersonic wind tunnels. The combustor development including the material, fabrication technology, and combustion kinetics has just begun. Test and evaluation facilities are to be planned for prototype and full-scale engine testing."

—A.P.J. Abdul Kalam with Y S Rajan, "Strategic Industries," *India 2020: A Vision for the New Millennium*, (New Delhi: Penguin Books India (P) Ltd: 1998), pp. 198-199, 200-201, 213-214.

1998

Reports suggest that the Defense Research & Development Organization (DRDO) is developing a 150-350km-range naval-variant of the Prithvi short-range ballistic missile. Initial trials are planned for 1999 and a target date of 2005 is set for deployment.

—Duncan Lennox, ed., *Jane's Strategic Weapons Systems*, Issue 32, (Coulson, Surrey), 2000, p. 6.

1997

November 1997

Indian defense scientists say that the Agni missile's range can be extended by boosting the propellant in the second stage. They also propose building an intercontinental ballistic missile (ICBM) by using a "high-energy storable liquid propellant." Another plan under consideration is to dispense with the two-stage propulsion system in the Agni and replace it with an all solid-propulsion system. Under this plan, the first variant of the all solid-propellant missile would have a range of 2,000km; subsequent improved versions would be able to strike targets 3,000km away. Indian scientists believe that additional tests of the Agni will have to be conducted to attain a 95% assurance level, verify its performance parameters at the full-range of 2,500km, and validate a more advanced stage separation process.

—"India eager for further development of Agni missile program," *Jane's International Defense Review* (Coulson, Surrey), November 1997, Vol. 30, No. 11, p. 5.

7 November 1997

Defense Minister Mulayam Singh Yadav assures the parliament's consultative committee on defense that the Agni missile program will not be halted and fund constraints will not be allowed to come in the way of defense preparedness.

—"Agni programme will go on, says Mulayam," *Hindu* (Chennai), 7 November 1997, www.hinduonnet.com.

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October 1997

Defense Minister Mulayam Singh Yadav pledges to defend the government's ninth defense plan (1998-2002), which was approved in August 1997. The 1.5 trillion rupees defense-spending plan will be debated by parliament in November. The plan allocates 254.13 billion rupees for new equipment and upgrades including 40.85 billion rupees for indigenously produced missiles. Under the plan, the 30 Prithvi surface-to-surface missiles (SSMs) will be procured for 1.5 billion rupees; a similar sum will be spent on upgrading and developing the Agni intermediate-range ballistic missile (IRBM). In addition, 700 million rupees have been earmarked for the purchase of the Lakshya and Nishant remotely piloted vehicles (RPVs).

—Vivek Raghuvanshi, "Indian 5-Year Defense Procurement Plan Gains Support," *Defense News* (Springfield, Virginia), 13-19 October 1997, p. 72.

29 September 1997

First operational launch of the polar satellite launch vehicle—PSLV-C1 at 10:17 a.m. IST from The Sriharikota High-Altitude Range (SHAR) in Sriharikota (Andhra Pradesh). The 44.4m-high, 294-ton rocket successfully places a 1,200kg remote sensing satellite—IRS-1D—in a sun-synchronous orbit 817km above the earth. The satellite has an apogee of 817km and perigee of 300km. Indian Space Research Organization (ISRO) Chairman K. Kasturirangan explains that the weight of the rocket was reduced to enable it to carry a larger satellite weighing about 1,200kg unlike the earlier D3 version, which could only carry a 950kg satellite. The weight reduction became possible through the use of carbon-fiber technology for satellite mating and realignment of the equipment bay. He also divulges that the entire project has cost 1.3 billion rupees, of which the satellite component is estimated at 600 million rupees. Following the launch, Prime Minister Inder Kumar Gujral claims that no one can stop India from developing its missile program, including the Agni missile.

—"PSLV-C1 lifts off successfully," *Statesman* (Calcutta), 29 September 1997, in Lexis-Nexis Academic Universe, 29 September 1997, <http://web.lexis-nexis.com>; "India: Plan to launch astronomical satellite," *Hindu* (Chennai), 19 September 1997, p. 15, in Lexis-Nexis Academic Universe, 20 September 1997, <http://web.lexis-nexis.com>; "No One Could Stop India From Developing Missile Programme: Gujral," *Indian Express* (Mumbai), 30 September 1997, www.expressindia.com.

29 September 1997

Defense Minister Mulayam Singh Yadav urges Prime Minister Inder Kumar Gujral to make more funds available for continuing the Agni intermediate-range ballistic missile (IRBM) program. In an address to the directors of Defense Research & Development Organization (DRDO) laboratories, Yadav says that lack of funds cannot be an excuse for putting important projects like the Agni on a backburner.

—"Defence Minister Seeks More Funds For Agni Missile," *Deccan Herald* (Bangalore), 29 September 1997, in FBIS Document FBIS-TAC-97-272, 13 October 1997.

28 September 1997

In an address to the directors of the Defense Research & Development Organization (DRDO) laboratories during a two-day biennial conference, Dr. A.P.J. Abdul Kalam says that serial production of the Prithvi has begun.

—"Further on Official's Remarks on Missile Development," *Economic Times*, (New Delhi), 29 September 1997, in FBIS Document FBIS-TAC-97-272, 29 September 1997.

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4 September 1997

Indian Army transports six Prithvi surface-to-surface missiles (SSMs) from Hyderabad (Andhra Pradesh) to Jalandhar (Punjab) on board two IL76 transport aircraft. Soon thereafter, the missiles are moved to their forward bases.

—Raj Chengappa, "Why Play Pahalwan?" *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power*, (New Delhi: Harper Collins Publishers, 2000), p. 407.

27 August 1997

Defense Minister Mulayam Singh Yadav tells reporters that the Agni program is on track and will receive "top most priority." However, Yadav denies that Agni will enter into production soon. He clarifies, "I have never said that production of Agni would start soon. All I have said is that the program will be given top most priority."

—Atul Aneja, "Mulayam parries query on non-use of hotline," *Hindu* (Chennai), 27 August 1997, in Lexis-Nexis Academic Universe, 28 August 1997, <http://web.lexis-nexis.com>.

21 August 1997

The MDN imports a 1,000kg consignment of "aluminum vanadium master alloy" from the German firm Esselsehaft for use in building rockets and missiles. The consignment, which was originally ordered in 1994, is stolen from a storage site in Mumbai (Maharashtra).

—"1,000 kgs of special alloy imported from Germany stolen in India," DPA, 21 August 1997, in Lexis-Nexis Academic Universe, 21 August 1997, <http://web.lexis-nexis.com>.

August 1997

Prime Minister Inder Kumar Gujral's cabinet approves a new five-year military procurement program and allocates 1.5 billion rupees for the acquisition of 30 Prithvi missiles.

—Vivek Raghuvanshi, "Indian 5-Year Defense Procurement Plan Gains Support," *Defense News* (Springfield, VA), 13-19 October 1997, p. 72.

August 1997

Bharat Dynamics Limited (BDL) in Hyderabad (Andhra Pradesh) completes the assembly of 40 Prithvi ballistic missiles. The Army is forced to take delivery of the missiles due to lack of storage space at BDL. All 75 missiles are expected to be delivered by the end of 1998.

—Raj Chengappa, "Why Play Pahalwan?" *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power*, (New Delhi: Harper Collins Publishers, 2000), p. 406.

August 1997

India's nuclear bomb team led by the Bhabha Atomic Research Center (BARC) completes modifications and conducts two tests to check the functioning of the safety lock and mounting and triggering mechanisms on nuclear warheads designed for the Prithvi ballistic missile.

—Raj Chengappa, "Why Play Pahalwan?" *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power*, (New Delhi: Harper Collins Publishers, 2000), pp. 406-418.

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7 August 1997

Hindustan Aeronautics Limited (HAL) suspends production of engines for the Prithvi surface-to-surface missile (SSM) as one its key suppliers, Ascent Technologies Pvt. Ltd., halts the supply of "cooling rings" used in the engines. HAL officials say that they have not received cooling rings for almost one year. Ascent Technologies proprietor M. M. Sampath Kumar Iyengar declares that he will not do business with government companies including HAL, pending settlements of previous bills. HAL officials say that they are trying to persuade Iyengar to resume supplies. —"Indian missile production stops over money row: daily," AFP, 7 August 1997, in Lexis-Nexis Academic Universe, 7 August 1997, <http://web.lexis-nexis.com>.

30 July 1997

Defense Minister Mulayam Singh Yadav makes a statement in parliament on the Agni program and declares that "with the three flight-tests, the re-entry technology demonstration under the project Agni has been successfully completed. It has been decided to accord high priority to the next phase of the Agni program."

—"India to revive 'Agni' project," *Hindu* (Chennai), 30 July 1997, in Lexis-Nexis Academic Universe, 31 July 1997, <http://web.lexis-nexis.com>.

30 July 1997

Minister of State for Defence N.V.N. Somu declares in parliament that the government is examining a proposal for an integrated anti-missile defense program. He says, "the government has received a proposal for development of this system. It is not in national security interest to give further details at this juncture."

—"India to revive 'Agni' project," *Hindu* (Chennai), 30 July 1997, in Lexis-Nexis Academic Universe, 31 July 1997, <http://web.lexis-nexis.com>.

July 1997

Indian Army reportedly plans to raise four Prithvi missile groups by the end of the year 2000. Each group will have eight missiles plus an unspecified number of reserve holdings. The first 333rd Missile Group is being raised, and a second 444th Missile Group is expected to follow. The 333rd Missile Group will be integrated into the new 30th Artillery Division, which after being raised, will be tasked to the 2nd Corps under HQ Western Command; initially however, the 30th Artillery Division will be raised as an Army HQ reserve with the 11th Corps, Jalandhar (Punjab). The overall command of the Prithvi missile batteries will rest with the commander of India's Western Command; control will rest with the commander of the 30th Artillery Division, who in turn will serve as the top advisor to the 2nd Corps commander. Command and control of the missiles will be decentralized when additional missile units are raised after the year 2000.

—Pravin Sawhney, "Prithvi's position: India defends its missile: The debate surrounding India's indigenous TBM," *Jane's International Defense Review* (Coulsdon, Surrey), 1 July 1997, pp. 43-44.

July 1997

Jane's International Defense Review reports that the Defense Research & Development Organization (DRDO) is developing a third-variant of the Prithvi, which will be capable of delivering a 750-1,000kg payload over a range of 350km. The increased range and payload capacity will be achieved by using a "boosted liquid propellant to generate more thrust-to-weight ratio." Revealing more technical details about the Army and Air Force versions of

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the Prithvi, the report claims that the Prithvi follows a "tailored trajectory" rather than a ballistic one. Prithvi's semi-ballistic trajectory rises 30km during the initial powered phase, followed by a non-boosted cruise phase, and ends in a steep descent at nearly 80°. Missile operators can choose from six different path variations, which can be pre-selected. According to DRDO sources, this feature has been designed to prevent the Prithvi from being tracked by theater anti-ballistic missile systems. The report claims that there is controversy among Indian Army artillery officers over the accuracy of the missile. So far the Prithvi has never been fired to its "mean fighting range" on a land target. The accuracy of the missile has only been assessed from "prepared" and "pre-surveyed" sites. As a result, despite DRDO's claims that the Prithvi has a circle of equal probability (CEP) of 0.01 percent, some Army officers believe that under actual "field conditions," the CEP is likely to be 0.02 percent, which will make the Prithvi inaccurate in a conventional role.

—Pravin Sawhney, "Prithvi's position: India defends its missile: The debate surrounding India's indigenous TBM," *Jane's International Defense Review* (Coulsdon, Surrey), 1 July 1997, pp. 43-44.

12 July 1997

Defense Minister Mulayam Singh Yadav says that the United Front government has not abandoned the Agni program. He adds, "further development or flight trial program will be decided by the government based on the threat perception and at an appropriate time."

—"India has not abandoned long-range missile programme: defence minister," AFP, 12 July 1997, in Lexis-Nexis Academic Universe, 12 July 1997, <http://web.lexis-nexis.com>.

30 June 1997

Commenting on the Prithvi deployment controversy, India's former Chief of Army Staff, General K. Sundarji says, "the Prithvi is primarily designed for delivering sophisticated conventional munitions. Yet, if necessary, it can be modified to carry a nuclear warhead...the nuclear 'pits' that are to go into...the missile-warhead compartment have to be successfully miniaturized and kept ready... I expect India is in that state now."

—K. Sundarji, "Prithvi in the Haystack," *India Today* (New Delhi), 30 June 1997, p. 73.

24 June 1997

An earthquake strikes central India and damages facilities in several ordnance factories including those engaged in the Prithvi program.

—"Indian quake damaged seven munitions factories; daily," AFP, 24 June 1997, in Lexis-Nexis Academic Universe, 24 June 1997, <http://web.lexis-nexis.com>.

17 June 1997

Addressing a news conference in Bhopal (Madhya Pradesh), Prime Minister Inder Kumar Gujral says that the Prithvi will be deployed as and when an emergency arises.

—Premier says Prithvi missile to be deployed "when emergency arises," All India Radio (New Delhi), 17 June 1997, in BBC Summary of World Broadcasts, Lexis-Nexis Academic Universe, 19 June 1997, <http://web.lexis-nexis.com>.

14 June 1997

India's foreign ministry denies *Washington Post* reports and in a written statement says, "we...categorically

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reject...aspects of the *Washington Post* reports regarding details of diplomatic exchanges with the United States as false, mischievous, and motivated...it is the government's policy that decisions regarding the Prithvi or such matters will be taken in the light of our independent foreign policy and on the basis of our security perception...it has been pointed out that there is no imminent threat and thus no reason for deployment."

—Nelson Graves, "India Hotly Denies US Daily's Missile Reports," Reuters, 14 June 1997.

13 June 1997

Former prime minister and BJP leader Atal Behari Vajpayee urges the United Front government to deploy the Prithvi surface-to-surface missile (SSM). He describes Prime Minister Gujral's statement that India has not deployed the missiles as "unfortunate." Vajpayee says, "the people of this country would like to know why it [Prithvi] has not been deployed....[India has not built the missiles] to keep them in warehouses...there is no need for us to give clarification [to other countries regarding their deployment]."

—"Hindu leader wants India to deploy surface missiles," AFP, 13 June 1997, in Lexis-Nexis Academic Universe, 13 June 1997, <http://web.lexis-nexis.com>.

12 June 1997

Indian Prime Minister Inder Kumar Gujral tells reporters in Pune (Maharashtra) that India has not deployed Prithvi missiles anywhere in the country. Gujral emphasizes, "it is no secret...that we have acquired missile technology, but it is wrong to say—and a deliberate misrepresentation—that we have deployed them." However, Gujral does not specifically address the issue whether the Prithvi missiles have been moved.

—Kenneth J. Cooper, "India Denies It has Deployed Missiles; Gujral Condemns US Report of Arms Shift to Pakistani Border," *Washington Post*, 11 June 1997, p. A26.

11 June 1997

US officials give a more detailed account of the alleged Prithvi transfer to Jalandhar (Punjab). They claim that when US intelligence detected the transfer, Clinton administration officials protested the decision to Indian Prime Minister Inder Kumar Gujral. However, Gujral responded by saying that the missiles had been moved by the Army without his explicit knowledge or approval. He also promised US officials that his government would keep the missiles from being deployed.

—Kenneth J. Cooper, "India Denies It has Deployed Missiles; Gujral Condemns US Report of Arms Shift to Pakistani Border," *Washington Post*, 11 June 1997, p. A26.

10 June 1997

India informs US diplomats that it has moved a few Prithvi missiles to Jalandhar because of "insufficient storage space back at the production site [Hyderabad] and the missiles carried neither a warhead nor fuel." US Assistant Secretary of State for South Asia Robin Raphael acknowledges that India has not "openly" deployed its missiles.

—"India has not openly deployed missiles: Raphael," *Hindu* (Chennai), 21 June 1997, p. 4.

9 June 1997

Highly placed Indian officials tell *Hindu* that Prithvi missiles have been stored and not deployed at Jalandhar

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(Punjab).

—"Prithvi missile merely stored at Jalandhar," *Hindu* (Chennai), 9 June 1997, www.hinduonnet.com.

4 June 1997

India's defense ministry officials say that the development of the Prithvi is no secret; at least 30 missiles have been produced and stored in ordnance depots.

—Dinesh Kumar, "Officials Question Timing of Post Prithvi Report," *Times of India* (Mumbai), 4 June 1997, p. 1.

4 June 1997

India's defense ministry spokesperson denies the *Washington Post* story and says, "I have no knowledge of deployment of Prithvi missiles along the Indo-Pak border."

—"Defence Ministry denies knowledge of missile deployment," *Press Trust of India* (New Delhi), 4 June 1997, in Lexis-Nexis Academic Universe, 4 June 1997, <http://web.lexis-nexis.com>.

3 June 1997

US intelligence sources tell *Washington Post* that India has moved fewer than 12 Prithvi I missiles from their production plant in Hyderabad (Andhra Pradesh) to a military facility outside the city of Jalandhar (Punjab), close to the border with Pakistan. But other US officials caution that the "best judgment" is that India has not deployed the requisite gear and personnel to make the missiles operational. US intelligence agencies also believe that although India does not now have the capability to arm the Prithvi with a nuclear warhead, Indian scientists are working on acquiring such a capability. However, Indian officials claim that the "missiles were moved to Jalandhar more than three months ago...the United States was notified that they were in storage."

—R. Jeffrey Smith, "India Moves Missiles Near Pakistani Border," *Washington Post*, 3 June 1997, p. A15; Nelson Graves, "Missile reports strike at Indo-US ties," Reuters, 17 June 1997.

May 1997

The *Jane's Defence Weekly* says that according to Indian naval sources, the "Sagarika will be a hull-mounted, low-flying, air-breathing missile with a low trajectory, capable of achieving high-subsonic speeds and cruising at an altitude of 15,000m."

—Rahul Bedi, "India bolsters links with Israel in attack craft buy," *Jane's Defence Weekly* (Coulsdon, Surrey), Vol. 27, No. 19, 14 May 1997, p. 16, in Lexis-Nexis Academic Universe, 14 May 1997, <http://web.lexis-nexis.com>.

7 May 1997

Minister of State for Defense N.V.N. Somu states in parliament that, "development of the 150km-version of the Prithvi has been completed successfully and subsequent activities are in progress...no further tests will be required before its induction in the Army."

—"India's most controversial missile ready for use," AFP, 9 May 1997, in Lexis-Nexis Academic Universe, 9 May 1997, <http://web.lexis-nexis.com>; "Prithvi missiles to be introduced into Army following successful tests," All India Radio (New Delhi), 7 May 1997, in BBC Summary of World Broadcasts, Lexis-Nexis Academic Universe, 8 May 1997, <http://web.lexis-nexis.com>.

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May 1997

A senior government reveals that the government plans to double expenditures on the missile program from \$64 million in the 1992-1997 period to \$144 million between 1997-2002.

—"India to more than double missile budget despite US opposition," AFP, 18 May 1997, in Lexis-Nexis Academic Universe, 18 May 1997, <http://web.lexis-nexis.com>.

30 April 1997

The Indian parliament's 42-member consultative committee on defense urges the government to "review the Agni missile" project and "take it to its logical conclusion." In a report submitted to parliament, the committee says, "India has no option but to continue to upgrade its missile capabilities against any adventurist intentions of a hostile country. Referring to Pakistan and China, the committee report points out, "with both these countries we have unsettled boundary disputes and the need for greater attention to this aspect of our defence preparedness."

—"India urged to deploy controversial missile," AFP, 30 April 1997, in Lexis-Nexis Academic Universe, 30 April 1997, <http://web.lexis-nexis.com>.

17 March 1997

In a reference to India's Agni missile program, Defense Minister Mulayam Singh Yadav tells reporters, "financial constraints have slowed down the progress of the Agni project but there is absolutely no question of capping it...pressure tactics by some countries on the capping of the project will not yield any result as the security of the country is not going to be compromised, come what come may."

—"Defence minister rules out capping of Agni missile project," PTI, 17 March 1997, in BBC Summary of World Broadcasts, Lexis-Nexis Academic Universe, 18 March 1997, <http://web.lexis-nexis.com>.

4 March 1997

Prime Minister Deve Gowda declares in parliament that his government will give "full support" to the Agni missile program.

—"Premier says government to give 'full support' to Agni missile programme," PTI (New Delhi), 4 March 1997, in Lexis-Nexis Academic Universe, BBC Summary of World Broadcasts, 5 March 1997, <http://web.lexis-nexis.com>.

March 1997

Prime Minister Deve Gowda orders deployment of Prithvi surface-to-surface missiles (SSMs) close to the Indo-Pakistan border in Jalandhar. [Note: The Army chooses Jalandhar for deployment because of the presence of an ordnance factory where the missiles can be stored and maintained. After spending several million dollars to build a storage facility, the Army later realized the folly of deploying missiles close to the Indo-Pakistani border.

—Raj Chengappa, "Why Play Pahalwan?," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power*, (New Delhi: Harper Collins Publishers, 2000), p. 402.

19 March 1997

India's Minister of State for Defense, N.V.N. Somu informs parliament that the government has spent 2.27 billion rupees on the IGMDP between 1992-1997. He says that the government proposes to spend 5.04 billion rupees on the missile program during the Ninth Five Year Plan (1998-2002).

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—Bhashyam Kastur, "State Minister Says 504 Crore Earmarked for Missile Program," *Deccan Herald* (Bangalore), 22 March 1997, in FBIS Document FBIS-TAC-97-081, 22 March 1997.

March 1997

According to V.K. Saraswat, project director of Prithvi, the development program of the Prithvi (SSM-150 & SSM-250) has been successful and the Army and Air Force are satisfied with it. Defense Research & Development Organization (DRDO) officials say that serial-production of the missile has begun. Bharat Dynamics Limited (BDL) in Hyderabad (Andhra Pradesh), which started assembling the missile in 1996, has produced 60 missiles so far. However, Colonel Bhat, an Army spokesman said on 27 February 1997, that the Prithvi has not yet entered service. —Vivek Raghuvanshi, "India to Deploy Prithvi Despite Pakistani Concerns," *Defense News* (Springfield, VA), 10-16 March 1997, p. 34.

4 March 1997

Prime Minister Deve Gowda promises "technical support" for the Agni program. According to Indian defense sources, the government has approved a 595.4 million rupees Defense Research & Development Organization (DRDO) proposal for an additional five Agni test-flights.

—"India's PM Backs Troubled Agni Missile Project," Executive News Service (Jacksonville, Florida) 4 March 1997; Vivek Raghuvanshi, "India Foresees Gap in Defense Funding," *Defense News* (Springfield, VA), 10-16 March 1997, p. 24.

1 March 1997

The scientific advisor to the defense minister Dr. A.P.J. Abdul Kalam says that the 23 February 1997 test of the Prithvi missile proved that India now had the technology to "divert a missile's path after launch to pinpoint a desired target." He further adds that "software for Prithvi has boosted India's capabilities to be on top of this range of missiles."

—"India has world-class missile technology: project chief," AFP, 1 March 1997, in Lexis-Nexis Academic Universe, 1 March 1997, <http://web.lexis-nexis.com>.

24 February 1997

Prime Minister Deve Gowda hails the Prithvi launch as a "milestone." In a statement before parliament he says, "we have placed special emphasis on self-reliance in this field and the success of yesterday's [23 February 1997] launch is one more milestone in our program...it will significantly add to our defensive capability."

—"Indian PM hails missile launch as a milestone," AFP, 24 February 1997, in Lexis-Nexis Academic Universe, 24 February 1997, <http://web.lexis-nexis.com>.

23 February 1997

India conducts the third user-trial of the Prithvi-II, marking the sixteenth test of the system. The ballistic missile is launched from Interim Test Range (ITR) in Chandipur (Orissa) at 11:52 a.m. Mission Director S.C. Narak states that all test objectives have been met. This includes a test of the performance of advanced real-time software for trajectory maneuvers. The test also validates the modifications introduced in the ground support system at the suggestion of the Air Force. Narak says that the development phase of the Prithvi-II is complete.

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—"Report Details 'Successful' Test of Prithvi-250 Missile," *Deccan Herald* (Bangalore), 25 February 1997; in FBIS-NES-97-037, 25 February 1997; "TV Details Launching of Prithvi Missile," Doordarshan Television Network (New Delhi), 23 February 1997, in FBIS-NES-97-037, 25 February 1997; Dinesh Kumar, "Naval version of the Prithvi will be tested shortly," *Times of India* (New Delhi), 24 April 1999, www.timesofindia.com; "Prithvi Test," *Flight International* (Sutton, Surrey), 8-14 January 1997, p. 6.

9-14 February 1997

An high-level Indian defense team led by Defense Secretary Taposh Banerji visits Israel to explore the prospects of defense cooperation. Banerji initials an agreement for the purchase of 12 Searcher unmanned aerial vehicles (UAVs) for the Indian Army. The Searcher is manufactured by the Israel Aircraft Industries. Each aircraft costs \$1.5 million and the entire deal is estimated at \$18 million. Banerji is accompanied by senior Air Force and other defense officials. During his meeting with Israeli officials and industrialists, Banerji explores the possibility of purchasing missiles and missile-related technologies from Israel. In the past, India has expressed interest in purchasing the Arrow anti-missile system and related-technologies from Israel. Several Israeli firms offer to sell India command, control, and communication systems, and global positioning system (GPS) satellite navigation equipment. India signs an agreement to purchase the Barak point air defense system designed to defeat anti-ship missiles from Israel.

—Vivek Raghuvanshi and Steve Rodan, "India Begins Buying Spree in Israel," *Defense News* (Springfield, Virginia), Vol. 12 No. 7, 17-23 February 1997, pp. 1, 40; Atul Aneja, "Fernandes had no role in Barak deal: Navy chief," *Hindu* (Chennai), 22 March 2001, www.hinduonnet.com.

26 January 1997

Scientific advisor to the defense minister Dr. A.P.J. Abdul Kalam announces that the "final phase of flight trials" of the 250km-range Air Force version of the Prithvi—Prithvi II—will be "scheduled shortly." Kalam says, "this is the testing season and there will be no delay in the schedules."

—"Missile programme developments updated," PTI (New Delhi), 26 January 1997; in BBC Summary of World Broadcasts, Lexis-Nexis Academic Universe, 28 January 1997, <http://web.lexis-nexis.com>; "India on final stages of missile development: official," AFP, 26 January 1997, in Lexis-Nexis Academic Universe, 26 January 1997, <http://web.lexis-nexis.com>.

January 1997

India is a reportedly developing a missile named Koral; Koral is allegedly the Indian version of the Russian SS-N-22 Sunburn missile.

—*Strategic Comments*, Vol. 3. No. 1, International Institute of Strategic Studies (London), January 1997, p. 2.

1997

The Integrated Rail Coach Factory, Kapurthala (Punjab) is tasked with fabricating modified rail coaches to house and transport the Agni. [Note: The timing of this decision is still unclear. Literature available in the public domain suggests that the decision was made sometime in 1997.]

—Raj Chengappa, "Boom for Boom," *India Today* (New Delhi), 26 April 1999, www.india-today.com.

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1996

29 December 1996

An Indian defense official divulges that India is planning to resume tests of the Agni surface-to-surface missile (SSM) with "added attributes." He says, "Agni needs fine-tuning before we commence production...we are going in for an enhanced range from 800km to 1,400km...the date for test-firing has not been decided, but we are certain that Agni will be tested soon. We are monitoring the weather as things get into place at the test range."

—"India to test-launch ballistic missile: defence sources," AFP, 29 December 1996, in Lexis-Nexis Academic Universe, 29 December 1996, <http://web.lexis-nexis.com>.

22 December 1996

The *Pioneer* reports that Indian scientists are working on cutting down the deployment time of the Prithvi's Army variant from 45 minutes to 30 minutes. At present, the total "command-to-command" operation of the Prithvi is about two hours.

—"India to test surface-to-surface missile in two weeks," AFP, 22 December 1996, in Lexis-Nexis Academic Universe, 22 December 1996, <http://web.lexis-nexis.com>.

22 December 1996

Defense Research & Development Organization (DRDO) officials announce that India will test a test of the 250km-range Air Force version of the Prithvi within a fortnight. This will be the second test of the Prithvi II and the missile will carry a 450kg warhead.

—"Second test on Prithvi missile to be carried out "within a fortnight," Doordarshan (New Delhi), 22 December 1996, in BBC Summary of World Broadcasts, Lexis-Nexis Academic Universe, 23 December 1996, <http://web.lexis-nexis.com>.

14 December 1996

Defence minister Mulayam Singh Yadav denies reports that the Agni missile program has been suspended.

—"Defence minister on Agni missile, Russian weaponry, Army budget, militants," PTI (New Delhi), 14 December 1996, in BBC Summary of World Broadcasts, Lexis-Nexis Academic Universe, 16 December 1996 <http://web.lexis-nexis.com>.

10 December 1996

Opposition members of parliament express concern over the government's decision to shelve the Agni missile program. The leader of the opposition, Sikandar Bakht, who belongs to the BJP, says that the government is playing with the country's security by not producing the Agni.

—"Deputies express concern over India's move to shelve Agni missile," DPA, 10 December 1996, in Lexis-Nexis Academic Universe, 10 December 1996, <http://web.lexis-nexis.com>.

December 1996

The Defense Research & Development Organization (DRDO) says that it is planning to incorporate global positioning system (GPS) technology into the Prithvi missile to enhance its accuracy. Indian scientists claim that at present Prithvi has a circle of equal probability (CEP) of 0.1%; with the GPS, the CEP will be reduced to .05%.

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—Dinesh Kumar, *Times of India* (Bombay), 25 December 1996, p. 6, in "India: DRDO Plans to Enhance Prithvi's Accuracy," FBIS-NES-96-249, 25 December 1996.

December 1996

India decides not to produce the Agni intermediate-range ballistic missile (IRBM), unless its security is threatened. A defense ministry report states, "Agni is a re-entry technology demonstration project which has been successfully completed and all the objectives have been met...Agni project did not envisage development of a missile system...the decision to develop and produce a missile system based on Agni technology, however, can be taken at an appropriate time consistent with the prevailing threat perception and global or regional security environment."

—Cited in, "India Puts Agni Programme Back on Hold," *Current Missile News*, Center for Defence and International Security Studies (Lancaster University, United Kingdom), 5 December 1996, www.cdiss.org.

17 November 1996

Defense Minister Mulayam Singh Yadav asserts that India's guided missile program will continue in view of the volatile security situation in South Asia. Yadav tells newsmen in Mumbai (Maharashtra) that there is no question of bowing to foreign pressure on the issue of defense preparedness and the trials of the Agni, Prithvi, and Nag missiles will continue.

—"Defence minister says indigenous missile programme will continue," All India Radio (New Delhi), 17 November 1996, in BBC Summary of World Broadcasts, Lexis-Nexis Academic Universe, 19 November 1996, <http://web.lexis-nexis.com>.

12 September 1996

Dr. A.P.J. Abdul Kalam states that India will conduct one or two more tests of the 250km-range Prithvi-II ballistic missile before the end of 1996.

—Dinesh Kumar, *Times of India* (Bombay), 13 September 1996, p. 1, in "India: Two More Prithvi Missile Tests Planned in 1996," FBIS-NES-96-180, 13 September 1996.

September 1996

The *Hindustan Times* reports that India has successfully completed the test-flight of the Nishant unmanned aerial vehicle (UAV). The Nishant should be deployed operationally after a "couple of years."

—Cited "Success for Indian UAV," *Jane's Defence Weekly* (Coulsdon, Surrey), 11 September 1996, p. 21.

20 August 1996

Dr. A.P.J. Abdul Kalam says that the first phase of development testing for the Agni is finished. Operational testing can begin as soon as the government sanctions it.

—Vivek Raghuvanshi, "India's DRDO Awaits Approval for Agni Flight Tests," *Defense News* (Springfield, VA), 26 August 1996, p. 14.

8 August 1996

The Defense Research & Development Organization (DRDO) sends a proposal to the Deve Gowda-led United Front government to resume testing of the Agni. According to the scientific advisor to the defense minister, Dr. A.P.J. Abdul Kalam, the objective is to test the missile's optimum 2,500km-range. During the third and last test on 19

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February 1994, the Agni was tested to a range of 1,400km.

—Rahul Bedi, "Countdown starts for India's ballistic missile," *Jane's Defence Weekly* (Coulsdon, Surrey), 11 September 1996, p. 21; "India may go ahead with trials flights of locally-made IRBMs," DPA, 8 August 1996, in Lexis-Nexis Academic Universe, 8 August 1996, <http://web.lexis-nexis.com>.

15 July 1996

Minister of State for Defense N.V.N. Somu informs parliament that India's indigenous missile program has not been postponed. He explains that user trials of the Prithvi surface-to-surface (SSM) have been completed successfully and subsequent activities are in progress. Somu says, "the Agni project has also been successfully completed with three flight-tests of the re-entry technology demonstrators," and "there has been no change in the government's decisions on these programs."

—"Government informs lower house no postponement of missile programme," All India Radio (New Delhi), 15 July 1996, in BBC Summary of World Broadcasts, Lexis-Nexis Academic Universe, 16 July 1996, <http://web.lexis-nexis.com>.

June 1996

Defense Research & Development Organization (DRDO) Director Dr. A.P.J. Abdul Kalam makes a secret visit to Israel. During his visit, he expresses an interest in purchasing missile launchers for India's Prithvi and Agni surface-to-surface missile (SSM) programs. Kalam also studies Israel's Arrow antimissile program.

—Vivek Raghuvanshi and Steve Rodan, "India Begins Buying Spree in Israel," *Defense News* (Springfield, VA), Vol. 12 No. 7, 17-23 February 1997, p. 40.

1 June 1996

An explosion injures 16 people at the Defense Research & Development Laboratory (DRDL) in Hyderabad (Andhra Pradesh). A grass fire that spread apparently caused the explosion at the chemical gas-processing unit in the complex.

—"India missile plant shut by explosion: residents flee as 16 hurt in blast likened to quake," *Toronto Star* (Toronto), 1 June 1996, in Lexis-Nexis Academic Universe, 1 June 1996, <http://web.lexis-nexis.com>.

21 March 1996

Third and final developmental launch of the Polar Satellite Launch Vehicle (PSLV) at 0454 GMT from the Sriharikota High-Altitude Range (SHAR) in Sriharikota (Andhra Pradesh). The 44-meter-high, 283-ton rocket successfully places a 930kg remote sensing satellite, the IRS-P3, into a sun-synchronous orbit 807/816km above the earth. Allaying apprehensions that India's satellite launch vehicles could be used for military applications, Indian Space Research Organization (ISRO) Chairman K. Kasturirangan says that "we need for defence a different type of configuration with quick burnout of fuel, which is not possible with the solid and liquid propellant-backed PSLV." Kasturirangan also denies that ISRO is planning to launch a defense surveillance satellite.

—"India set to enter global launch market," Xinhua News Agency, (Beijing), 21 March 1996, in Lexis-Nexis Academic Universe, 21 March 1996, <http://web.lexis-nexis.com>; "India launches satellite, denies PSLV has defence implications," DPA, 21 March 1996, in Lexis-Nexis Academic Universe, 21 March 1996, <http://web.lexis-nexis.com>; "Polar Satellite Launch Vehicle Launched; voyage 'smooth'," All India Radio (New Delhi), 21 March 1996, BBC

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Summary of World Broadcasts, Lexis-Nexis Academic Universe, 21 March 1996, <http://web.lexis-nexis.com>; "News Breaks," *Aviation Week & Space Technology* (New York), Vol. 144, No. 13, 25 March 1996, p. 17, in Lexis-Nexis Academic Universe, 25 March 1996, <http://web.lexis-nexis.com>.

March 1996

Indian environmentalists demand the closure of the missile testing range on India's eastern seaboard in Orissa state. They claim that the test range is threatening the survival of the Olive Ridley turtles; approximately 400,000-500,000 turtles migrate to Wheeler's Islands between January and March annually. The environmentalists claim that exhaust fumes, oil and hydrocarbon, and noise pollution from boats plying in and out of the testing range and missile launches are threatening the survival of the world's largest rookery of the Olive Ridley turtles. The pollution thins the shells of the hatchlings leading to their death soon after birth. The World Wildlife Fund is also investigating reports that artificial lights adjoining the rookery upsets the turtles' nesting and hatching habits. Defense Research & Development Organization (DRDO) officials decline to comment on the issue. The Indian government says that it has no plans to shift the testing range.

—Rahul Bedi, "India hides in its shell over test range charge," *Jane's Defence Weekly* (Coulsdon, Surrey), 27 March 1996, Vol. 25, No. 13, p. 5, in Lexis-Nexis Academic Universe, 27 March 1996, <http://web.lexis-nexis.com>.

5 February 1996

A Defense Research & Development Organization (DRDO) official says that Bharat Dynamics Limited (BDL) in Hyderabad (Andhra Pradesh) is having difficulties with the Prithvi I's guidance system and the handling of the missile's fuel. According to the official, 15 Prithvi-I ballistic missiles are in the process of production, but will not be delivered for at least one year. Indian sources also say that the Army lacks trained personnel to handle the volatile 50:50 mix of xylidene and triethylamine liquid fuel used in the missiles.

—Vivek Raghuvanshi, "India Delays Prithvi Deployment," *Defense News* (Springfield, VA), 12 February 1996, p. 32; *Missile Systems of the World, AMI International* (Bremerton, Washington), 1999, p. 494.

4 February 1996

Foreign Affairs Minister Pranab Mukherjee rejects US calls to halt India's ballistic missile program. Mukherjee says, "there is no question of abandoning the Prithvi program." Responding to US State Department spokesperson Nicholas Burns's statement that the Prithvi threatened to destabilize South Asia, Mukherjee says, "we do not consider it a mistake. We have no intention of destabilizing in any way the situation already prevailing in the region."

—Scott Neuman, "India: no to US on missile tests," UPI (Washington, DC), 4 February 1996, in Lexis-Nexis Academic Universe, 4 February 1996, <http://web.lexis-nexis.com>.

2 February 1996

The *Times of India*, quoting defense sources, reports that between 15-30 [Prithvi] missiles have already been prepared for induction into the Army; in addition, a program to test the longer-range Air Force variant of the Prithvi has been put into motion [Note: The longer-range variant was tested in late January 1996.]

—"India to deploy controversial missile despite US opposition," AFP, 2 February 1996, in Lexis-Nexis Academic Universe, 2 February 1996, <http://web.lexis-nexis.com>.

Related content is available on the website for the Nuclear Threat Initiative, www.nti.org.



January 1996

V.K. Saraswat, senior scientist at the Defense Research & Development Laboratory (DRDL) and director of the Prithvi project states that; "Prithvi is now among the world's most accurate missiles of its class." The Indian Army, which had originally planned the purchase of 75 Prithvi I missiles, now reportedly plans to purchase only 30. Other reports state that the Indian Army has ordered 90 missiles and received 30 so far.

—"India Puts Agni IRBM Program in Ice," *Jane's International Defense Review* (Coulson, Surrey), 1 January 1996, p. 5; Raj Chengappa, "Boosting the Arsenal," *India Today* (New Delhi), 29 February 1996, pp. 98-99.

29 January 1996

US State Department spokesperson Nicholas Burns terms India's latest Prithvi test a "mistake" and adds that it "will not lead to what India and Pakistan want—which is stability in South Asia."

—"India to deploy controversial missile despite US opposition," AFP, 2 February 1996, in Lexis-Nexis Academic Universe, 2 February 1996, <http://web.lexis-nexis.com>.

27 January 1996

The Defense Research & Development Organization (DRDO) tests an extended-range version of the Prithvi (250km-range) from Interim Test Range (ITR) in Chandipur (Orissa) at 0852 GMT. The missile hits a target located approximately 250km from the launch site in the Bay of Bengal. The extended-range version of the Prithvi (Prithvi II) is being developed for the Air Force. This is the fifteenth test of the Prithvi ballistic missile system and an Indian defense ministry official says that all main objectives of the flight were met.

—"Extended Version of India's Prithvi 'Successfully' Test Fired," All India Radio (New Delhi), 27 January 1996; in FBIS Document FBIS-NES-96-019, 27 January 1996; Farhan Bokhari and Vivek Raghuvanshi, "Pakistan Vows Response to New India Missile Threat," *Defense News* (Springfield, VA), 5 February 1996, p. 18.

16 January 1996

A planned test of the Prithvi is cancelled for undisclosed reasons. A PTI report speculates that the test might have been postponed due to inclement weather. Defense officials in New Delhi say that India intends to deploy the Prithvi I and that serial production is already in progress at Bharat Dynamics Limited (BDL) in Hyderabad (Andhra Pradesh). Reportedly, 18-20 Prithvi I ballistic missiles have been produced and are armed with five different types of conventional warheads.

—Raj Chengappa, "Boosting the Arsenal," *India Today* (New Delhi), 29 February 1996, pp. 98-99; "India postpones launch of surface-to-surface missile," DPA, 16 January 1996, in Lexis-Nexis Academic Universe, 16 January 1996, <http://web.lexis-nexis.com>.

14 January 1996

The Prithvi is included in a catalogue of defense items available for export. The defense ministry's Department of Defense Production & Supplies first published the catalogue in September 1994. According to the Minister of State for Defense, M. Malikarjun, the catalogue was published to show "Indian defense products available for export as a step towards projecting the defense export potential of our country."

—Dinesh Kumar, "Prithvi, Other Missiles 'Available For Export'," *Times of India* (New Delhi), 14 January 1996, p. 1;

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"India to export controversial missile: daily," AFP, 14 January 1996, in Lexis-Nexis Academic Universe, 14 January 1996, <http://web.lexis-nexis.com>.

1996

Ved Prakash Sandlas is appointed Defense Research & Development Organization's (DRDO) Chief Controller of Research & Development.

—Gopal Raj, "SLV-3: India's First Launch Vehicle," *Reach for the Stars: The Evolution of India's Rocket Programme*, (New Delhi: Viking by Penguin Books India, 2000), p. 72.

1996

The Defense Research & Development Organization (DRDO) introduces design modifications on the Prithvi to enable it to carry a nuclear warhead. Two tests are conducted to verify mounting of the nuclear warhead and unlocking of the safety and triggering systems during flight. [Note: The precise dates of these tests are not available in public literature.]

—Raj Chengappa, "The Eyes of Yama," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power*, (New Delhi: Harper Collins Publishers, 2000), p. 418.

1996

According to Indian news media sources, the Sagarika missile is in the final stages of scale model testing and its propulsion system is under development. The projected completion date of the Sagarika program is delayed from 2000 to 2005.

—M. Ahmed, *Business Standard* (New Delhi), 1 April 1996, p. 5; in "India: Report Details Navy's New Long-Range Missile Project," FBIS document FBIS-NES-96-065, 1 April 1996.

1995

November 1995

The BJP, India's largest opposition party, adopts a resolution saying that it will initiate a nuclear weapons program and significantly strengthen the country's military. The resolution also promises to expedite the production of the Prithvi surface-to-surface missile (SSM) and operationalize the longer-range Agni. Criticizing the ruling Congress party's national security policy, Jaswant Singh, the BJP's deputy leader in parliament, tells his party's delegates, "the national will has never been as diluted as it is today under [the current prime minister] Narasimha Rao, and never before has India been ruled by such a supine government."

—Rahul Bedi, "Party's tough line on security," *South China Morning Post* (Hong Kong), 13 November 1995, p. 11, in Lexis-Nexis Academic Universe, 13 November 1995, <http://web.lexis-nexis.com>; Rahul Bedi, "Poll pledge of nuclear weapons for India," *Daily Telegraph* (London), 11 November 1995, p. 15, in Lexis-Nexis Academic Universe, 11 November 1995, <http://web.lexis-nexis.com>.

October 1995

A Defense Research & Development Organization (DRDO) official says that serial production of the Prithvi has resumed at Bharat Dynamics Limited (BDL) in Hyderabad (Andhra Pradesh) but declines to comment on the

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number of missiles produced so far. Indian defense sources divulge that 18-20 missiles have been delivered to the Army; the Air Force will receive its version after the Army's orders are met.

—Rahul Bedi, "Prithvi put back in production," *Jane's Defence Weekly* (Coulsdon, Surrey), 7 October 1995, p. 17.

August 1995

The parliament's Standing Committee on Defense, in its report to the 10th Lok Sabha (India's lower house of parliament) states, "... Agni System is known as the technological demonstration due its technological status. 'Agni' is a technology project to develop re-entry test vehicle. The first launch of 'Agni' was successfully conducted on 22 May 1989 from ITR [Interim Test Range], Balasore. The Agni-03 vehicle was configured for longer range and was tested successfully on 19 February 1994 from ITR, Balasore achieving all the mission objectives set for it like re-entry, maneuver longer range, control, guidance, two-stage propulsion and stage separation. With the successful launch of the AGNI-03 re-entry vehicle, 'Agni' project comes to an end. The total expenditure incurred so far is of the order of Rs.55.00 crores [550 million rupees]. The government is examining the situation consequent to the successful flights of Agni with respect to its future plans." It has been stated that the objective of the test flight of Agni, carried out on 19 February 1994, was to prove the re-entry and related technologies. When asked about the purpose of the demonstration, the Defence Secretary stated that it was a technology demonstration and depending on the strategic environment the Government may or may not decide to produce it. The missile programme is not adversely affected by MTCR (Missile Technology Control Regime.) Restrictions were anticipated at the time of sanction of the programme in 1983 itself and steps taken to offset the effects. Action was taken to design sub-systems based on maximum indigenous items. MTCR was founded in 1987 imposing further controls. Multiple Task Teams are indigenously developing/fabricating critical components and required facilities were being set up, where essential. On the overall, the challenge of MTCR has provided a good opportunity for promoting self-reliance and quality.

—5th report of the Standing Committee on Defence, Tenth Lok Sabha, Ministry of Defence on Defence Research and Development Major Projects, Lok Sabha Secretariat, New Delhi, August 1995.

August 1995

Indian Defense Secretary A. Nambiar announces that the Agni may be deployed with the Indian military.

—Farhan Bokhari and Vivek Raghuvanshi, "Pakistan, India Trade Barbs Over Nuclear Missiles," *Defense News* (Springfield, VA), 28 August 1995, pp. 1, 20.

1995

According to the Fifth Parliamentary Standing Committee report on defense, the Defense Research & Development Organization (DRDO) has spent 550 million rupees on the Agni program.

—"State Minister Says 504 Crore Earmarked for Missile Program," *Deccan Herald* (Bangalore), 22 March 1997, in FBIS Document FBIS-TAC-97-081, 22 March 1997.

August 1995

Indian defense scientists claim that the import content of the Prithvi has been reduced from 15% when the program started (1983) to 5%.

—Harbir K. Mannshaiya, "India's Prithvi," *International Defense Review* (Coulsdon, Surrey), August 1995, p. 24.

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August 1995

More operational details of the Prithvi emerge. Along with each four-TEL (transporter-erector launcher) battery, each unit employs six support vehicles for resupply/loading, transport, fuel-storage, and communications. Each launcher requires 10 soldiers led by an officer or junior commissioned officer. The Prithvi's launch cycle has three stages. In the first stage, the target and appropriate launch site are identified by the artillery command; this information is passed to the missile unit. In the second stage, the missile is fueled for launch. In the third stage, the TEL moves to the launch site and fires the missile. Prithvi's launch preparation time, from time of arrival to actual launch, is estimated to be about three hours. Some analysts believe that without a proper organization or a war establishment table, the preparation time could be longer. However, launch preparation time could be reduced if the Prithvi were launched from pre-surveyed sites at pre-determined targets. Since the Indian Army does not operate unmanned aerial vehicles (UAVs) for real-time reconnaissance and damage assessment, it will have to depend on the Air Force's fleet of high-altitude Mig-25 reconnaissance aircraft.

—Harbir K. Mannshaiya, "India's Prithvi," *International Defense Review* (Coulsdon, Surrey), August 1995, p. 24; Greg J. Gerardi, "India's 333rd Prithvi Missile Group," *Jane's Intelligence Review* (Coulsdon, Surrey), Vol. 7 No. 8, August 1995, p. 363; Dinesh Kumar, "India: DRDO Plans to Enhance Prithvi's Accuracy," *Times of India* (New Delhi), 25 December 1996, p. 6; in FBIS Document FBIS-NES-96-249, 25 December 1996.

July 1995

In deference to local protests, the Indian government decides to relocate India's missile test site from Chandipur to Wheeler's Islands, a group of uninhabited islands in the Bay of Bengal. Orissa state Chief Minister J.B. Patnaik says that the decision has been made to avoid permanently evacuating villages from around the Chandipur site.

—"India relocates missile launch site," *Deutsche Presse-Agentur*, 26 July 1995; in Lexis-Nexis Academic Universe, 26 July 1995, <http://web.lexis-nexis.com>.

28 May 1995

Minister of External Affairs Pranab Mukherjee denies reports that there is any pressure from the United States on India to abandon deployment of the Prithvi ballistic missiles. During a visit to Washington, DC, Mukherjee tells US officials that deployment of the surface-to-surface missile (SSM) will depend on the overall security environment in the region.

—"External Affairs Minister Returns from U.S. Visit: Claims Trip Very Useful," *All India Radio* (New Delhi), 28 May 1995, in FBIS Document FBIS-NES-95-103, 30 May 1995; Rahul Bedi, "India 'will not hesitate to deploy Prithvi'," *Jane's Defence Weekly* (Coulsdon, Surrey), 3 June 1995, p. 8.

4 May 1995

The Indian parliament's consultative committee on defense urges the government to induct and deploy the Prithvi surface-to-surface missile (SSM).

—"Indian MPs want nuclear-capable missile deployed," *AFP*, 4 May 1995, in Lexis-Nexis Academic Universe, 4 May 1995, <http://web.lexis-nexis.com>.

29 April 1995

The New Delhi-based *Asian Age* reports that the formation of the Indian Army's first group armed with Prithvi

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ballistic missiles, the 333rd Missile Group, is complete. Some of the Army's best officers have been inducted into this group. Raised in Hyderabad (Andhra Pradesh), the 333rd Missile Group has 12 missile launchers distributed in three subunits of four launchers each. The report says that the missiles were accepted after the Defense Research & Development Organization (DRDO) carried out two modifications on the Army's request. The 333rd Missile Group is awaiting orders to move to the eleven corps area under the western command. The delay in the movement of the group to an operational location along India's western borders is being attributed to US pressure on the Indian government not to deploy the Prithvi missile. Other reports suggest that the Indian Army initially had plans to equip four regiments with 16 Prithvi missiles each; these regiments were to be stationed in the northern states of Punjab, Jammu, and Kashmir. Due to US pressure, however, the Indian government has only commissioned one missile regiment, which is undergoing training with dummy missiles at Hyderabad.

—Pravin Sawhney, "Army Organizes First Prithvi Missile Unit," *Asian Age* (New Delhi), 29 April 1995, p. 1, in FBIS Document FBIS-NES-95-083, 1 May 1995, pp. 45-46; Rahul Bedi, "India pressured to halt Prithvi production," *Jane's Defence Weekly* (Coulsdon, Surrey), 15 April 1995, p. 5.

28 April 1995

Prime Minister Narasimha Rao refutes allegations that India has capped its missile program under US pressure. Replying to a debate in parliament, Rao asserts that India will not buckle under "anybody's pressure," as far as it's defense preparedness is concerned. He also claims that the program to develop the Agni is proceeding smoothly, although no date has been set for the deployment of the missile. On 27 April 1995, India's Minister of State for Defense M. Malikarjun tells parliament that user-trials for the Prithvi have been completed and the program is progressing satisfactorily.

—Pravin Sawhney, "Army Organizes First Prithvi Missile Unit," *Asian Age* (New Delhi), 29 April 1995, p. 1, in FBIS Document FBIS-NES-95-083, 1 May 1995, pp. 45-46.

April 1995

US Undersecretary of Defense Joseph Nye tells a Senate panel committee that India's Prithvi missile program is in a state of "hibernation," while the Agni project is in a state of "suspended animation." This is indirectly confirmed by India's Minister of State for Defense M Malikarjun, who says that "though the missile (Prithvi) has successfully achieved its objective and user-trials are complete, we have yet to make a decision on serial production."

—Rahul Bedi, "India pressured to halt Prithvi production," *Jane's Defence Weekly* (Coulsdon, Surrey), 15 April 1995, p. 5.

13 April 1995

After a visit to the Defense Research & Development Laboratory (DRDL) in Hyderabad (Andhra Pradesh), Prime Minister Narasimha Rao sanctions approximately 6 billion rupees for the development of the Agni program. He also orders the Defense Research & Development Organization (DRDO) to speed up efforts to build nuclear weapons and set up a nuclear command and control system for the safe custody, deployment, and employment of such weapons. DRDO Chief Kalam sets up a special cell to ensure that nuclear cores at Bhabha Atomic Research Center (BARC) in Trombay are scattered to several sites in the country to enhance their survivability; that the mechanism to ensure the mating of the core with the bomb assembly is achieved in the shortest time frame; that the command to trigger nuclear weapons remains under civilian control; and that it is a system that will win

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consent of at least "three agencies" to arm nuclear weapons.

—Raj Chengappa, "Tell Your President, I Keep My Word," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers India Pvt. Ltd., 2000), p. 391.

8 April 1995

The Prithvi enters service with an Army unit deployed near Hyderabad (Andhra Pradesh). No details are available of the numbers of missiles in service, but Indian Army officers claim that the Indian government is delaying production due to US pressure.

—"Nuclear-capable missile inducted into Indian Army: Newspaper," AFP, 8 April 1995, in Lexis-Nexis Academic Universe, 8 April 1995, <http://web.lexis-nexis.com>.

April 1995

Noting progress on the Agni program, the Indian defense ministry's annual report says, "the project, which is one of technology-proving, has been completed." Observers interpret this statement to mean that India has temporarily stopped the development of long-range ballistic missiles. However, Prime Minister Narasimha Rao secretly sanctions the development of an augmented version of the Agni I.

—"Annual Report," Ministry of Defence, Government of India, 1994-1995, p. 39; Raj Chengappa, "Nuclear Policy: Making Compromises," *India Today* (New Delhi), 30 April 1995, p. 36; Raj Chengappa, "Boom for Boom," *India Today* (New Delhi), 26 April 1999, www.india-today.com.

18 March 1995

US Deputy Assistant Secretary of State Robert Einhorn testifies before a US Senate panel subcommittee that the "two versions of the Prithvi missile might be intended for deployment with conventional warheads, but are inherently capable of carrying nuclear weapons." He claims that India has "produced a number of missiles for testing, but the program has not "passed the threshold of serial production."

—C. Raja Mohan, "US Warns Against Production of Prithvi," *Hindu* (Chennai), 18 March 1995, p. 8.

January-February 1995

The *Wisconsin Project on Nuclear Arms Control's* "Risk Report" alleges that, "...India has consistently used foreign help to convert its space rockets to nuclear-capable missiles. Imports, some clandestine, some overt, have nourished India's nuclear and rocket efforts from the start. India built the medium-range Agni missile by taking a first-stage rocket from a small space launcher and combining it with guidance technology developed by the German space agency...one of India's ablest students was A.P.J. Abdul Kalam. While training in the United States, he visited the space centers where the US Scout rocket was conceived and was being flown. Kalam returned home to build India's first space rocket, the Satellite Launch Vehicle-SLV-3—a carbon copy of the Scout. NASA made Kalam's task easier by supplying unclassified technical reports on the Scout's design. But aid from America...was soon dwarfed by aid from Germany. In the late 1970s and throughout the 1980s, Germany helped India with three indispensable missile technologies: guidance, rocket-testing, and composite materials. Earmarked for the space program, all were equally useful for building missiles. In 1978, Germany installed an interferometer on an Indian rocket to measure, from the ground, a rocket's angle of flight. Four years later, India tested its own version. From 1982 to 1989, Germany helped India build a navigation system for satellites based on a Motorola microprocessor.

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During the same period, and following the same steps, India developed its own navigation system for missiles and rockets based on the same microprocessor. Germany also...helped India build its own rocket test facility; and it trained Indians in glass and carbon fiber composites at Stuttgart and Braunschweig. These lightweight, heat-resistant fibers are ideal for missile nozzles and nose cones. To help India use the fibers, Germany provided the documentation for a precision filament winding machine...an item...now controlled for export by other countries, including the United States....In 1993, ...a Massachusetts company was charged with violating US export laws by selling India components for a hot-isostatic press. The press, which India obtained through the company's Scottish subsidiary, can be used to shape advanced composites for missile nose cones... But India still needs crucial help. A recent Pentagon study cites composites, electronics, computers, sensors and navigation equipment as some of the technologies in which India is still weak."

[Note: Indian scientists have refuted some of these allegations. According to Madhavan Nair, who headed Indian Space Research Organization's (ISRO) electronic group in the 1970s and was part of the team which collaborated with the West German aerospace company, DFVLR, ISRO's involvement was limited to low-level experiments. One of the experiments involved a study of the effects of the ionosphere on the altitude of rockets. According to Nair, "it was a very limited experiment and to say that [it] helped us to develop our guidance systems or that of DRDL [Defense Research & Development Laboratory] is a very funny story." Similarly, S. C. Gupta, former director of Vikram Sarabhai Space Centre (VSSC) in Thiruvananthapuram (Kerala) and head of ISRO's guidance and control team, points out that organizational rivalry between DRDL and ISRO made cooperation between the two agencies during the 1970s impossible. Whereas DRDL switched to developing "strap-down" technology, ISRO stuck with the "platform-type" guidance system. It was only after Kalam took over as director of DRDL that ISRO began cooperating with DRDL in a very limited way. That cooperation involved independent reviews of DRDL's work. According to Gupta, "there was intellectual involvement by us. But to deduce too much from that would be absurd." Similarly, Dr. A.P.J. Abdul Kalam has dismissed allegations that an aerodynamic model of the Agni was tested in a DFVLR wind-tunnel or that DFVLR developed the Agni's guidance system, first-stage rocket, and composite nose cone. Referring to allegations that he picked up the basic design for the Agni during his four-month training stint at Wallop's Island in the United States in 1962, Kalam says, "the fact that I was in Wallop's 25 years ago, and at that time the technology used in the Agni did not exist even in the United States, was not mentioned."]

—"The Risk Report," *Wisconsin Project on Nuclear Arms Control*, Vol. 1, No. 1, January/February 1995, pp. 3, 5, www.wisconsinproject.org; Raj Chengappa, , "Caught in the Crosshairs," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers India Pvt. Ltd., 2000), pp. 376-378; A.P.J. Abdul Kalam with Arun Tiwari, "Propitiation," in *Wings of Fire: An Autobiography* (Hyderabad: Universities Press (India) Limited, 1999), p. 153.

1995

The Defense Research & Development Organization (DRDO) subcontracts the development of the solid-fuel second stage for the augmented version of the Agni I to the Indian Space Research Organization (ISRO).

—Raj Chengappa, "Boom for Boom," *India Today* (New Delhi), 26 April 1999, www.india-today.com.

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1995

According to Haridwar Singh of the Explosives Research & Development Laboratory (ERDL), Pune (Maharashtra), India has "achieved world standards" in the field of solid propellants (conventional and advanced). Research in the area of double base propellants (DBP) is centered around "formulation, processing, and evaluation of both extruded double base (EDB) and cast double base (CDB) propellants containing nitrocellulose, nitroglycerine, stabilizer, plasticizer, and additives (coolant, ballistic modifiers) for different applications...a large number of EDB/CDB propellants in different dimensions (60-200mm) and configurations (tubular, slotted, tube, internal star) have been developed to meet various requirements. A considerable amount of work has been done on the catalysis and platonization of DBP to obtain pressure- and temperature-insensitive low- and high-calorimetric value compositions." In the area of composite propellants (CP), research in India has followed the requirements of "higher ballistic performance coupled with better mechanical integrity under extreme operating conditions." Between 1965-1995, the size of the "rocket propellant grain has grown...from 75mm diameter, weighing 4.5kg to...more than 128 tons. Correspondingly, the propellant grain technology has moved from free-standing to case-bonded propellant grains for improving the performance. Keeping pace with this growth, the polymeric binders used in propellants have undergone changes from the conventional polyvinyl chloride (PVC), to polybutadiene-acrylic acid-acrilonitrile (PBAN), to carboxyl-terminated polybutadiene (CTPB), and hydroxyl-terminated polybutadiene (HTPB). Both the Defense Research & Development Organization (DRDO) and the Indian Space Research Organization (ISRO) are working on HTPB-based propellant systems for different applications."

ISRO has developed three more new polymeric binders, in addition to the above binders, for use in solid composite propellants: HEF-20, which is used as a "substitute for CTPB," ISRO Polyol-based propellants used in sounding rockets, and hydroxyl-terminated natural rubber (HTNR). HTNR "based propellants are...under development." DRDO has "developed a series of HTPB and polyoxy propylene glycol-based polyurethane compositions to meet wide and varied requirements of rockets/missiles. Most of the charges are cartridge-loaded and inhibited with either filled HTPB or filled flexible epoxy resin. Gas generator compositions having high burn rates at low pressures have also been developed using HTPB as binder, fine ammonium perchlorate (AP) as oxidizer, and butyl ferrocene derivatives as ballistic modifier. The broad spectrum...include burn rates of 2-40mm/s, *Isp* of 230-245s, density of 1.8g/cc, pressure exponent of 0.1-0.3, and tensile strength of 25kg/cm²...burn rate data of propellants based on AP/N-N bonded epoxy binder at various pressures show significant enhancement, some of the order of 400% over conventional AP/CTPB systems with the same amount of AP loading." Significant developments in composite modified double base propellant (CMDB) propellants includes research in "CMDB propellants containing both AP, aluminum, and nitramines...used for the boost phase of a surface-to-air missile, using the IRR (integrated rocket ramjet) propulsion system. One of the major contributions of Indian scientists in this area has been the development of crosslinked CMDB propellants of high mechanical properties (tensile and compressive strength) and high-energy (*Isp* 246s)." ERDL has also conducted research on "glycidyl azide polymer (GAP)-based propellants...as [GAP] offers a unique energetic binder and plasticizer system for advanced propellants to achieve higher performance, superior mechanical properties, and low vulnerability. Its chief advantages are higher density and positive heat of formation as compared to the widely used HTPB. Research work at ERDL has indicated that GAP acts as a high-energy desensitizer and is capable of enhancing the energy and burn rates."

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DRDO has also researched "pressed- and cast-type of fuel-rich propellants (FRP) for IRR applications, based on Mg [magnesium] powder, and hydrocarbons...studies are being conducted at ERDL with Ti [titanium], Ni [nickel], Zr [Zirconium], Mg-Al powders with HTPB, and GAP-plasticized double base matrix." Overall, the current CP in use by DRDO and ISRO are "based on HTPB with AP as oxidizer...major efforts at present are in increasing the solid content from 86% to 90% by the use of a multimodal distribution of oxidizer, improving the mechanical properties of the propellant by the use of bonding agents, and increasing the burn rate without increasing the pressure exponent. Use of other metallic fuels (Ti, Zr, B) are being studied with a view to use these fuel-rich propellants in air breathing propulsion systems." Future research will most likely focus on "new energetic binders/plasticizers/additives/oxidizers in solid propellants,...hybrid propulsion systems,high energy solid fuels and liquid oxidizers,...and applications of N-N-bonded epoxides as hypergolic fuels for hybrid propulsion." In addition, the "new emphasis on performance will require the development of low-cost composite cases to reduce the weight of the motor."

—Haridwar Singh, "High Energy Material Research and Development in India," *Journal of Propulsion and Power*, Vol. 11, No. 4, July-August 1995, pp. 848-851, 854.

1995

The Defense Research & Development Organization (DRDO) begins "systematic and exhaustive" work on developing "thermally stable" explosives for oil well shooting charges and space programs. The DRDO and the Indian Space Research Organization (ISRO) also develop "flexible linear shaped charges having explosive loading of 1-100g/m" for military and civilian applications including "stage separation of space vehicles, cutting of outer cases of warheads, and canopy severance system..." One such composition "recently tested" gave a "clean cut of a 7mm-thick acrylic sheet without any adverse effect (shock, vibration) on other subsystems."

—Haridwar Singh, "High Energy Material Research and Development in India," *Journal of Propulsion and Power*, Vol. 11, No. 4, July-August 1995, p. 853.

1994

November 1994

The Defense Research & Development Organization (DRDO) contracts Godrej & Boyce Manufacturing Company Limited, Bombay (Maharashtra), to manufacture critical sub-systems for the Agni and Prithvi ballistic missiles. These include oxidizer and fuel tanks for the Agni and Prithvi, and engine, nose cone assembly, and riveted aluminum structures for the Agni.

—"Further Agni Tests Likely to Be Carried Out Soon," *Financial Express* (New Delhi), 27 November 1994, p. 5.

15 October 1994

A successful developmental launch of the second polar satellite launch vehicle-PSLV-D2 from the Sriharikota High-Altitude Range (SHAR) occurred in Sriharikota (Andhra Pradesh) at 0508 GMT. The 44-meter-tall, 283-ton rocket places an 870kg remote sensing satellite-IRS-P2-into a sun-synchronous orbit 825km above the earth. Indian Space Research Organization (ISRO) Chairman K. Kasturirangan says, "what we have achieved today is the culmination of 12 years of work." [Note: According to ISRO sources, the first-stage PS-1 core consists of a 2.8m diameter, five-

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segment solid motor loaded with 129 metric tons of propellant generating about 1.01-million pounds of thrust at liftoff. The first-stage motor is 20m long. The core vehicle is equipped with six solid strap-on boosters that generated about 148,500-pounds of thrust. The core and two of the strap-on rockets were ignited at liftoff, while the other four strap-on boosters were ignited 30.5 seconds into the launch. Each strap-on fired for 74 seconds. First-stage burnout and ignition of the second stage occurred at 111 seconds into the mission. The second-stage liquid rocket engine has a thrust of about 161,000 pounds and burns 37 metric tons of nitrogen tetroxide and unsymmetrical dimethylhydrazine. It fired for 150 seconds before ignition of the third-stage solid rocket motor, 261 seconds into the flight. The third-stage solid rocket motor, with 7.2 metric tons of propellant, generated about 76,500 pounds of thrust and burned for 76 seconds. The third-stage cutoff occurred 380 seconds following liftoff at an altitude of 421km. The vehicle then coasted for 3.5 minutes before ignition of the small fourth-stage liquid-propulsion system that uses two engines generating about 3,300 pounds of thrust. They burned two metric tons of propellant during a 405-second firing sequence.]

—"India launches most powerful space rocket, deploys satellite," AFP, 15 October 1994, in Lexis-Nexis Academic Universe, 15 October 1994, <http://web.lexis-nexis.com>; Craig Covault, "India Launches New Booster," *Aviation Week & Space Technology* (New York), Vol. 141, No. 17, 24 October 1994, p. 24, in Lexis-Nexis Academic Universe, 24 October 1994, <http://web.lexis-nexis.com>.

12 October 1994

Indian Space Research Organization (ISRO) Chairman Dr. Kasturirangan tells the press that India will not launch its first geostationary satellite launch vehicles (GSLV) before 1997. Russia will provide the cryogenic engine for the first vehicle by the end of 1996. Kasturirangan says that ISRO is augmenting its facilities at the Sriharikota High-Altitude Range (SHAR) in Sriharikota (Andhra Pradesh) to handle cryogenic engines. The first two-stages of the Polar Satellite Launch Vehicle (PSLV) will be used in the GSLV. Referring to the Augmented Satellite Launch Vehicle (ASLV) program he says that ISRO has no plans to go in for additional launches of the ASLV-series following the success of the fourth developmental flight in May 1994.

—"India's GSLV not to be launched before 1997," Xinhua News Agency (Beijing), 12 October 1994, in Lexis-Nexis Academic Universe, 12 October 1994, <http://web.lexis-nexis.com>.

21 September 1994

A four-nation team of representatives from the United States, Britain, Australia, and Switzerland visit New Delhi and begin a dialogue on the Missile Technology Control Regime (MTCR). The delegation urges India to give up its nuclear and ballistic missile program.

—"MTCR Team Visits India/Pakistan," *Flight International* (Sutton, Surrey), 21 September 1994, p. 18.

20 September 1994

General Romesh Khosla of the Indian Army states, "we are in the final stages of the user trials and the missile system [Prithvi] should be ready for induction very soon. We are working on establishing a complete infrastructure before these missile are eventually inducted into the Army."

—Cited in Greg J. Gerardi, "India's 333rd Prithvi Missile Group," *Jane's Intelligence Review* (Coulsdon, Surrey), Vol. 7 No. 8, August 1995, p. 361.

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12 September 1994

The scientific advisor to India's defense minister, Dr. A.P.J. Abdul Kalam, says that India will conduct another test of the Agni I missile in October 1994 and then proceed with its missile program as planned.

—Vivek Raghuvanshi, "India Plans Test of Ballistic Missile," *Defense News* (Springfield, VA), 12 September 1994, p. 36.

September 1994

Jane's International Defence Review reports that the Indian Army completed user-trials of its Prithvi tactical ballistic missile in late July 1994, enabling the weapon to enter production. Other reports suggest that India has begun producing three Prithvi missiles per month.

—"India to deploy Prithvi TBM," *International Defence Review* (Coulsdon, Surrey), September 1994, p. 14; "India," *Asia-Pacific Defence Reporter* (Herndon, VA), August-September 1994, p. 21.

August-September 1994

Asia-Pacific Defence Reporter reports that the Indian government has decided to build eight or nine prototypes of the Agni IRBM to capitalize on the success of the program. In addition, the Air Force has established a station at ITR, Chandipur (Orissa) to "establish the crucial coordination between scientists, technicians, and the users."

—"India," *Asia-Pacific Defence Reporter* (Herndon, VA), August-September 1994, p. 21.

August 1994

A special report on the Prithvi in the *Times of India* states that while "at a public level India is battling pressure to prevent the Prithvi's induction into the Indian Army, there are indications that the missile may be already available for launch from selected sites in the western borders." Since the Army "intends to integrate the Prithvi missile on a Tatra truck as a battlefield support weapon system into its corps artillery formations," special survey equipment mounted on trucks will be used to determine the point of launch. But in the interim, "...the [launch] sites have been pre-surveyed and their targets already determined." The report further claims that Prithvi will be used for accurate strikes on airfields, fuel and ammunition dumps, railway marshalling yards, and bridges.

—Ali Abbas Rizvi, "Reports About Nuclear 'Prithvi' Increase Pak Worries," *Asian Defence Journal* (Kuala Lumpur), August 1994, p. 94.

August 1994

Former Indian Vice Chief of Army Staff General Harwant Singh says that the Prithvi-I, which costs between 30-50 million rupees per unit, may not be cost effective unless armed with a nuclear warhead.

—Ali Abbas Rizvi, "Reports About Nuclear 'Prithvi' Increase Pak Worries," *Asian Defence Journal* (Kuala Lumpur), August 1994, p. 94.

July 1994

Indian magazine *Probe India* reports that Indian scientists have begun work on developing an intercontinental ballistic missile (ICBM). The ICBM, named Surya, will be an upgraded version of the Agni, which was last tested in February 1994. Defense Research & Development Organization (DRDO) scientists hope to finalize the design by 1995 and the missile is likely to be tested in 1996. The Surya is rumored to be about 35-40m in length and weighing

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approximately 40 tons. It will either comprise of a single-stage engine based on cryogenic technology or alternatively comprised of four stages, with two SLV-3s in the first two stages and two modified Prithvi missiles in the third and fourth stages.

—"Development of Indian ICBM To Be Closely Watched," *Asian Defence Journal* (Kuala Lumpur), July 1994, p. 94.

27 July 1994

Flight International reports that the Aeronautical Development Establishment (ADE) in Bangalore (Karnataka) is developing a 300km-range ramjet-powered submarine-launched missiles known as Sagarika. Design and development of the Sagarika began in 1992. The Sagarika is modeled on the Prithvi ballistic missile, but it will be much smaller in size because the ramjet engine eliminates the need to carry an oxidizer along with fuel. The Defense Research & Development Organization (DRDO) is testing scale models of the Sagarika at the testing establishment in Bangalore. One design is already being tested in a wind tunnel. According to ADE officials, a budget of \$33.3 million has been allocated to develop the Sagarika. Officials say that costs are low because DRDO already has experience in the design of missiles, propulsion, and materials. Only the submarine launch technology will have to be developed separately. Other organizations involved in the research and design of the missile include the Indian Institute of Sciences (IISc) in Bangalore (Karnataka) and the Indian Institutes of Technology (IIT) in New Delhi. Speculation persists that ADE is also seeking help in the development of the ramjet engine technology from some Russian missile and ramjet design bureaus.

—"India tests missile," *Flight International*, (Sutton, Surrey), 27 July-2 August 1994, p. 6; Vivek Raghuvanshi, "India Models SLBM After Prithvi Missile," *Defense News* (Springfield, VA), 25-31 July 1994, p. 15.

17 June 1994

Indian officials dismiss US concerns that India is building ballistic missiles to deliver nuclear warheads. They claim that the Indian Air Force's Jaguar and Mirage 2000 attack aircraft-not missiles-and it would be the obvious choice for nuclear delivery vehicles.

—Paul Mann, "Washington Outlook," *Aviation Week & Space Technology* (New York), 13 June 1994, p. 21.

June 1994

It is estimated that India has six Prithvi missiles at this time; the Indian Army plans to order 75 while the Indian Air Force may order 25, although the latter has yet to conduct user trials. The Army begins raising an independent missile unit, the 333rd Missile Group, to be based in Secunderabad (Andhra Pradesh). This unit will facilitate command, control, logistics, and the intelligence support necessary for making the missiles operational. [Note: Secunderabad is the twin sister city of Hyderabad.]

—Sunil Dasgupta, "A Quiet Launch," *India Today* (New Delhi), 30 June 1994; Raj Chengappa, "Boosting the Arsenal," *India Today* (New Delhi), 29 February 1996, pp. 98-99.

June 1994

During user-trials, the Army finds the changing of the Prithvi's warheads in the field difficult. It requests the Defense Research & Development Organization (DRDO) to introduce design modifications before placing orders for the missile.

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—Greg J. Gerardi, "India's 333rd Prithvi Missile Group," *Jane's Intelligence Review* (Coulsdon, Surrey), Vol. 7 No. 8, August 1995, p. 361.

6 June 1994

The 14th test of the Prithvi missile occurs. The missile hits the designated target located 145km from the Interim Test Range (ITR) in Chandipur (Orissa). The test is an Army user-trial conducted by artillery officers who will be assigned to the Army's missile force. This is expected to be the final test before the Army places orders for the Prithvi. According to Army officials, all user trials should be completed by the end of July 1994.

—*Navbharat Times* (Bombay), 7 June 1994, p. 9, in "Editorial Views Advent of Missiles," FBIS Document JPRS-TND-94-017, 13 July 1994, p. 32; Laxmi Shankar Yadav, *Dainik Jagran* (Delhi), 19 June 1994, p. 6, in "Importance of Missile Program Stressed," FBIS Document JPRS-TND-94-014, 13 July 1994, pp. 34-37.

4 June 1994

A Prithvi I is tested from a mobile launcher. This marks the 13th test of the Prithvi and is part of the Indian Army's pre-induction trial phase with its first user-trial. This is also the first time that a Prithvi is armed with a live warhead during a test. The missile is fired at a target on Wheeler's Island, 85km from the Interim Test Range (ITR) in Chandipur (Orissa). The Defense Research & Development Organization (DRDO) and the Army are likely to conduct six more tests under battlefield conditions and user trials are expected to be completed by the end of July 1994.

—*Navbharat Times* (Bombay), 7 June 1994, p. 9, in "Editorial Views Advent of Missiles," FBIS Document JPRS-TND-94-017, 13 July 1994, p. 32; "India to Deploy Prithvi TBM," *Jane's International Defence Review* (Coulsdon, Surrey), September 1994, p. 14; "Prithvi Missile Said 'Far Superior' to Patriot, Scud," All India Radio (New Delhi), 7 June 1994, in FBIS Document FBIS-NES-94-109, 7 June 1994, p. 72.

May 1994

The 13th test of the Prithvi I is cancelled when a faulty nozzle on the Prithvi's liquid-propellant loading system allows propellant to leak into the engine casings.

—Theresa Hitchens and Vivek Raghuvanshi, "Fuel Nozzle Grounds Prithvi," *Defense News* (Springfield, VA), 6 June 1994, p. 20.

31 May 1994

Defense Research & Development Organization (DRDO) officials indicate that the Prithvi will be tested between 4-6 June. The local district administration issues a notification requiring the evacuation of 87 families from five villages located within a one-kilometer radius of the Interim Test Range (ITR). The villagers will be notified to evacuate their homes 48 hours prior to the test-launch.

—"Prithvi missile test launch imminent; villagers evacuated from launch pad area," Press Trust of India (New Delhi), 31 May 1994, in BBC Summary of World Broadcasts, Lexis-Nexis Academic Universe, 2 June 1994, <http://web.lexis-nexis.com>.

May 1994

Prime Minister Narasimha Rao states on 12 May 1994 that India will continue with Prithvi tests despite US pressure to halt the program. The 13th test-flight of the Prithvi is scheduled for 23 May 1994, only three days after

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Rao returns from a trip to the United States.

—Theresa Hitchens and Vivek Raghuvanshi, "India Prepares for Missile Test Despite U.S. Objections," *Defense News* (Springfield, VA), 23-29 May 1994, p. 38.

May 1994

The Army decides to delay deployment of the Prithvi because of production problems among the three agencies involved in the design, manufacture, and integration of the missile system. Bharat Dynamics Limited, Hyderabad (Andhra Pradesh) was supposed to have supplied 260 missiles by 1993; but this target was postponed as more tests became necessary. Hindustan Aeronautics Limited (HAL) in Bangalore (Karnataka), which builds the liquid-fuel engines for the missile, was also forced to delay the project once Army officials demanded additional modifications in the missile.

—Theresa Hitchens and Vivek Raghuvanshi, "India Prepares for Missile Test Despite U.S. Objections," *Defense News* (Springfield, VA), 23-29 May 1994, p. 38.

14 May 1994

The prime minister's office (PMO) orders the Defense Research & Development Organization (DRDO) to postpone a Prithvi test until the prime minister returns from his state-visit to the United States. However, Prime Minister Rao clarifies before parliament that the temporary postponement will not result in any delay in the Prithvi's original trial program and that there is no pressure on him to stop the missile development program. Minister of State for Defense, M. Malikarjun also confirms before parliament that the missile test has been postponed because "major missile launchings are conducted when the prime minister is in the country." He further explains that the test has been postponed to avoid embarrassment, "in case of a particular result when the prime minister was away in another country...there is no intention of stopping the trials. Since the final-phase trials are planned for April-July 1994, the dates of the sub-phases will be suitably adjusted so that there will not be any delay in the completion of the trials."

—"Prithvi trials on schedule: PM," *Hindu International Edition* (Chennai), 21 May 1994, p. 4.

4 May 1994

Successful launch of the ASLV-D4 from the Sriharikota launch center (Andhra Pradesh) occurred. The 41-ton, 23-meter-high ASLV-D4 successfully places a 113kg satellite, the SROSS-C2, in low-earth orbit. Orbital parameters are 938km apogee and 437km perigee. Indian Space Research Organization (ISRO) Chairman Dr. Kasturirangan calls the program a "grand success."

—Neelam Jain, "India successfully launches satellite," UPI (Washington, DC), 4 May 1994; in Lexis-Nexis Academic Universe, 4 May 1994, <http://web.lexis-nexis.com>; "India's indigenous satellite successfully launched," All India Radio (New Delhi), 4 May 1994; in BBC Summary of World Broadcasts, Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>; "Recently launched satellite 'functioning normally'," All India Radio (New Delhi), 5 May 1994; in BBC Summary of World Broadcasts, Lexis-Nexis Academic Universe, 18 May 1994, <http://web.lexis-nexis.com>.

3 May 1994

Prime Minister Narasimha Rao assures parliament that his government will not cap the Agni program. Replying to a

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debate on the working of the defense ministry in parliament, Rao says that the Agni is an experiment and not a missile program, and that it is absurd to suggest that a program of national importance will be stopped for the want of 500 million rupees. Rao explains that data from the recent test is being analyzed and it will be about a year before the study is completed.

—"Rao Comments on 'Capping'," All India Radio (New Delhi), 3 May 1994, in FBIS Document FBIS-NES-94-085, p. 69.

1 May 1994

Countdown begins for the fourth developmental launch of India's ASLV-D4 at the Sriharikota High-Altitude Range (SHAR) in Sriharikota (Andhra Pradesh).

—"Countdown for satellite launch," UPI (Washington, DC), 1 May 1994, in Lexis-Nexis Academic Universe, 1 May 1994, <http://web.lexis-nexis.com>.

21 April 1994

An Indian government spokesperson describes the *Hindustan Times* report "unfounded and baseless." A written statement issued by the Indian government asserts, "after the recent successful flight of the Agni, all the objectives set for this mission have been achieved." Without denying that the government has denied a Defense Research & Development Organization (DRDO) request for funds to conduct additional Agni test launches, the note says, "fund requirements of different departments are decided in relation to progress of various projects. Individual scheme-wise allocation is not undertaken at the government level."

—"Spokesman Clarifies Report on Capping Missile Plan," *Hindustan Times* (New Delhi), 21 April 1994, p. 22, in FBIS Document FBIS-NES-94-085, 3 May 1994, p. 69.

20 April 1994

The New Delhi-based *Hindustan Times* reports that further trials of the Agni have been postponed indefinitely due to US pressure. The government has not responded to a Defense Research & Development Organization (DRDO) funding request of 500 million rupees to conduct three more test launches in the future.

—"Paper Reports Temporary Halt to Agni Missile Program," AFP, 20 April 1994, in FBIS Document JPRS-TND-94-010, 5 May 1994, p. 23.

12 April 1994

The Indian Air Force invites global tenders in specialized national and international aviation journals for the sale of sensitive missile equipment which includes, Russian surface-to-surface missile (SAM-II) guidance systems, 126 serviceable missiles, 35 SAM-II launchers, and missile liquid propellants-92 liters of "O" fuel (Nitric Acid), 53,124 liters of "G" fuel and 20,785 liters of "IPN." An Indian Air Force officer expresses concern that the sale could be a violation of India's policy of not exporting missile technology and materials, "...adding to proliferation of such dangerous and sensitive equipment."

—Dinesh Kumar, "Advertisement Smacks of Scam," *Times of India* (Mumbai), 12 April 1994, pp. 1, 9, in FBIS Document JPRS-TND-94-012, 7 June 1994, p. 22.

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9 April 1994

Indian Minister of State for Defense M. Malickarjun tells reporters that India will not slow or halt its missile program under pressure from any country. He says that the Prithvi has been successfully tested and the technical experts will decide the schedule of its induction into the armed forces.

—"Minister Says Government Not to Slow Down Missile Program," All India Radio (New Delhi), 9 April 1994, in FBIS Document JPRS-TND-94-010, 5 May 1994, p. 21.

6 April 1994

The US Deputy Secretary of State Strobe Talbott arrives in New Delhi. He urges India not to deploy the Prithvi and Agni missiles and participate in a regional conference on denuclearization with the United States, Russia, China, and some other countries.

—"US seeks peace on subcontinent," *Washington Times*, 16 April 1994, p. A8.

25 March 1994

US Assistant Secretary of State for South Asia, Robin Raphael, visits New Delhi. She proposes a regional nuclear arms freeze in South Asia. Indian officials reject the US proposal, saying that India is opposed to regional arrangements and prefers the negotiation of a global agreement on the elimination of nuclear weapons.

—John F. Burns, "India Rebuffs US Effort to Slow Nuclear Arms Race With Pakistan," *New York Times*, 26 March 1994, p. 1.

12 March 1994

The Chennai-based *Hindu* reports that the Agni program has received consideration in some detail at the "highest political level." After reviewing the program, the government has decided not to induct the Agni into the armed forces, but wants efforts concentrated on refining the guidance and propulsion systems of the missile. If the missile's circular error probable (CEP) is minimized, the Agni could be deployed with conventional warheads. The Defense Research & Development Organization (DRDO) also has plans to convert the Agni's current solid-liquid configuration to a solely solid-solid design for greater efficiency.

—"Agni not to be inducted for now," *Hindu* (Chennai), 12 March 1994, p. 12.

March 1994

India's Chief of Air Staff, Air Marshal S.K. Kaul, says that the Air Force has decided to acquire 25 Prithvi missiles. The Air Force has asked "for a version that can travel with lesser weight over longer distance...the actual number [of missiles] will depend on budgetary allocations. Costs are certainly important, and we have to lay down our priorities."

—Raj Chengappa, "The Missile Man," *India Today* (New Delhi), 15 April 1994, p. 41.

March 1994

Commenting on the Army's decision to acquire 75 Prithvi ballistic missiles, India's Chief of Army Staff, General B.C. Joshi says that "Prithvi... is an extremely lethal weapon...it has a heavier warhead, increased range, and is highly mobile...in the battlefield a force multiplier has been introduced...and because it is indigenously produced...we are not beholden to any foreign power...to get more bang for the buck, we have to decide what numbers we would

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actually have to deploy. But the overall pay-offs are in terms of maintaining our independence, gaining confidence in critical technologies and the spin-off benefits that come from it. There is also a realization...that off-the-shelf purchases are no longer affordable as prices have gone sky high."

—Raj Chengappa, "The Missile Man," *India Today* (New Delhi), 15 April 1994, p. 40.

Early March 1994

The Defense Research & Development Organization's (DRDO) missile team, led by Dr. A.P.J. Abdul Kalam, Agni Program Director R. N. Agarwal, and Defense Research & Development Laboratory (DRDL) Director S. Pillai, present plans to develop an augmented (greater than 2,000km), all-solid-fuel version of the Agni missile to Prime Minister Narasimha Rao. They also discuss plans to build a rail-based transport system for the missile. Rao assures the missile team that the government will sanction funds for the projects.

—Raj Chengappa, "Tell Your President, I Keep My Word," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers India Pvt. Ltd., 2000), p. 387.

March 1994

The scientific advisor to the defense minister, Dr. A.P.J. Abdul Kalam, discloses significant details about the Agni ballistic missile program in an interview with *India Today*. According to Kalam, when the Indian government visualized the Agni program (in the early 1980s), it was meant to be a technology demonstrator. However, now that it is a proven system, India has the option to make it operational within two years. The Agni program has demonstrated that India is capable of building long-range ballistic missiles with a range between 1,000-2,500km or more if necessary. India has mastered re-entry technology, including "maneuvering the missile path." Kalam points out that "Agni can carry any type of warhead...we now have a carrier on which both conventional and non-conventional weapons can be delivered over a long range." He emphasizes that the Agni has been developed indigenously and not with covert assistance from friendly foreign countries. When the Defense Research & Development Organization (DRDO) began developing the Agni, it identified three critical technologies: re-entry, guidance, and propulsion systems. India developed the re-entry technology entirely on its own. Although India did purchase some sensors for the Agni's guidance system from Europe, the missile's propulsion system is "100% Indian." According to Kalam, each launch of the Agni costs less than 100 million rupees; because the Agni is a proven system, India can avoid doing a series of tests, and opt for batch tests instead.

—Raj Chengappa, "The Missile Man," *India Today* (New Delhi), 15 April 1994, pp. 42-43.

19 February 1994

India conducts third test of the Agni I. The missile is launched from the Interim Test Range (ITR) in Chandipur (Orissa) at 5:45 p.m. and impacts at a designated target off the Car Nicobar islands within 22 minutes at a distance of 1,400km. The 21-meter, 19-ton missile uses a solid propellant in the first stage and a liquid propellant in the second stage. A brief issued by the Defense Research & Development Organization (DRDO) says that the third test validated the innovative design features aimed at testing the missile's longer-range and advanced maneuverability during the re-entry phase. Scientists tested a new re-entry vehicle with fins, which allows it to maneuver for greater accuracy. The test also validated a more advanced stage separation process. An Indian defense ministry press release says that the Agni payload performed to the design specifications with great accuracy.

—"Report Says Agni Missile Test Met All Objectives," Doordarshan Television Network (New Delhi), 20 February

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1994, in FBIS Document JPRS-TND-94-006, 16 March 1994, p. 19; Manoj Joshi, "Agni's Launch Raises Questions," *Times of India* (Mumbai), 22 February 1994, p. 8, in FBIS Document JPRS-TND-94-010, 5 May 1994, p. 22; "Third Agni test launch fulfils 'set objectives'," *Jane's Defence Weekly* (Coulsdon, Surrey), 5 March 1994, p. 18; Rahul Bedi, "Countdown starts for India's ballistic missile," *Jane's Defence Weekly* (Coulsdon, Surrey), 11 September 1996, p. 21.

16 February 1994

Indian defense sources indicate that the next test of the Agni I will take place on 19 February. The local administration is preparing to evacuate approximately 11,000 people from the 15 villages within the 3.5km-radius of the missile launching pad.

—"Third Launch of the Agni set for 19th February," Press Trust of India (New Delhi), 16 February 1994, in BBC Summary of World Broadcasts, Lexis-Nexis Academic Universe, 17 February 1994, <http://web.lexis-nexis.com>.

February 1994

Indian officials indicate that most of the components and equipment for the Prithvi surface-to-surface missile (SSM) and Akash surface-to-air missile (SAM) will be produced at various divisions of the Bangalore-based Hindustan Aeronautics Limited (HAL), ordnance factories, as well as some private-sector engineering companies. Final assembly of the complete missile system will take place at the Hyderabad-based Bharat Dynamics Limited (BDL; Andhra Pradesh).

—Hormuz Mama, "India's no lumbering elephant when it comes to aerospace," *Business Times* (Singapore), 16 February 1994, p. 12, in Lexis-Nexis Academic Universe, 16 February 1994, <http://web.lexis-nexis.com>; Hormuz P. Mama, "HAL Arising; Hindustan Aeronautics projects await go-ahead," *Jane's International Defense Review* (Coulsdon, Surrey), Vol. 26, No. 3, 1 March 1993, p. 252, in Lexis-Nexis Academic Universe, 1 March 1993, <http://web.lexis-nexis.com>.

26 January 1994

India displays the Prithvi ballistic missile publicly for the first time during the Republic Day parade.

—John-Thor Dahlburg, "India Displays Tactical Missile in Parade," *Los Angeles Times* (Los Angeles), 27 January 1994, p. A8.

7 January 1994

India aborts a planned test of the Agni because of technical problems. The pyro mechanism, which ignites the missile, fails as the cable supplying power to the missile becomes unplugged during the process of raising the missile from a horizontal to a vertical position for launch. During a routine pre-launch inspection, scientists also discover that strontium perchlorate, the fluid used for thrust vectoring or controlling the missile's direction during flight, has leaked out prematurely. The first-stage solid-fueled motor is dismantled and sent to Indian Space Research Organization's (ISRO) Vikram Sarabhai Space Centre (VSSC) in Thiruvananthapuram (Kerala) for repairs.

—"Technical Snag Postpones Agni Missile Test," All India Radio Network (New Delhi), 7 January 1994, in FBIS Document JPRS-TND-93-003, 31 January 1994, p. 12; Raj Chengappa, "Tell Your President, I Keep My Word," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers India Pvt. Ltd., 2000), pp. 384-387.

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1994

Media reports allege that India is developing a 12,000km-range intercontinental ballistic missile (ICBM) named Surya. There are conflicting reports about the configuration of the missile. Some reports suggest that the Surya will be a single-stage, liquid-fueled missile based on cryogenic technology. According to other reports, however, the Surya will be a four-stage system. The first two stages will comprise solid-fuel boosters derived from the Indian Space Research Organization's (ISRO) SLV-3; the third and fourth stages will consist of modified Prithvi missiles. —*Missile Systems of the World*, AMI International (Bremerton, Washington), 1999, p. 455; "Development of Indian ICBM to be Closely Watched," *Asian Defense Journal* (Kuala Lumpur), July 1994, p. 94; "Commentary Says India to Test New ICBM," Radio Pakistan Network (Islamabad), 31 May 1994, in FBIS document FBIS-NES-94-107, 3 June 1994, p. 60.

1994

India's investment in the Agni project reaches 300 million rupees.

—Laxmi Shankar Yadav, *Dainik Jagran* (New Delhi), 19 June 1994, in "Importance of Missile Program Stressed," FBIS Document JPRS-TND-94-014, 13 July 1994, pp. 34-37.

1993

17 December 1993

India's Chief of Air Staff, Air Marshall S. K. Kaul tells reporters at Avia India 93—an international air show at the Air Force's Yelahanka base in Bangalore (Karnataka)—that the Defense Research & Development Organization (DRDO) has embarked on a project to develop an anti-missile system in the wake of Pakistan's acquisition of ballistic missiles. However, the anti-missile program will depend on the availability of finances. Referring to the government's budgetary cuts, Kaul says, "we will have to do some juggling with the available resources." However, Indian defense scientists claim that the government has made no firm decision on the project. The final decision will be made by the union cabinet, which will study the financial implications and political fallout, before approving the project.

—"Air Chief Says Country Developing Antimissile System," *Indian Express* (New Delhi), 17 December 1993, p. 6, in FBIS Document JPRS-TND-93-003, 31 January 1994, pp. 11-12; "Development of Antibalistic Missile System Studied," *Sunday Times of India* (Mumbai), 26 December 1993, p. 7, in FBIS Document JPRS-TND-94-005, 25 February 1994, p. 13.

16 December 1993

The Indian government announces that it will test the Agni I ballistic missile from the Interim Test Range (ITR) in Chandipur (Orissa) between 4-14 January 1994. The union government requests the Orissa state government to evacuate nearly 9,000 people living in the 15 villages close to the test-site. The United States calls the Agni a "destabilizing weapon" and mounts intense diplomatic pressure on India to suspend further Agni tests.

—"India to ignore US pressure and test Agni missile," UPI (Washington, DC), 16 December 1993.

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30 November 1993

India conducts 12th test of the Prithvi-I ballistic missile. The missile is launched from a mobile launcher at 0655 GMT. This is the fifth launch from the Interim Test Range (ITR) in Chandipur (Orissa). The missile is launched with a 250kg payload and lands within three minutes on the island of Tentuli Chada in the Bay of Bengal. Kalam says that this is the last technology demonstration flight of the Prithvi. Four villages around the test-site are evacuated prior to the test as a safety precaution.

—All India Radio Network (New Delhi), 30 November 1993, in "Surface-to-Surface Medium Range Missile Launched 30 Nov.," FBIS Document JPRS-TND-93-001, 6 January 1994, p. 13; "Scientist Says Prithvi Flight 'Tremendous Success'," *Times of India* (Mumbai), 6 December 1993, p. 8, in FBIS Document JPRS-TND-94-005, 25 February 1994, p. 13; "Details on 30 November Prithvi Launching Given," *Times of India* (Mumbai), 1 December 1993, p. 17, in FBIS Document JPRS-TND-93-003, 31 January 1994, p. 12.

October 1993

India begins integrating the Prithvi-I into an artillery regiment in the Army.

—"Capabilities, Advantage of Prithvi Missile Noted," *Hindu* (Chennai), 27 January 1994, p. 6; in FBIS Document JPRS-TND-94-006, 16 March 1994, p. 20.

22 September 1993

Indian space officials trace the Polar Satellite Launch Vehicle's (PSLV) failure to an unexpected disturbance during the rocket's second-stage separation. The disturbance changed the "pitch attitude of the rocket, resulting in the third stage not providing upward velocity despite excellent performance of the third-stage motor." An Indian Space Research Organization (ISRO) report says, "the altitude reached at third-stage separation was only 340km as against a predicted 414km. Although the fourth-stage ignition occurred and it performed normally, but the pitch disturbance in the third-stage prevented the rocket from climbing further." However, despite the mission failure, all the rocket's motors and control systems functioned normally and it successfully maneuvered through the most critical stage of the powered flight in the atmosphere.

—"ISRO releases report on PSLV mission," Xinhua General Overseas News Service (Beijing), 22 September 1993; in Lexis-Nexis Academic Universe, 22 September 1993, <http://web.lexis-nexis.com>.

20 September 1993

First developmental launch of the Polar Satellite Launch Vehicle (PSLV) with the 875kg IRS-1E payload on board occurred at 0513GMT from the Sriharikota High-Altitude Range (SHAR) in Sriharikota (Andhra Pradesh). A malfunction in the rocket's fourth stage prevents the satellite from being orbited successfully. Despite the mission's failure, the Indian space commission's chairman, Professor U.R. Rao, describes it as a "mixed bag of success.... The motors worked, the inertial navigation system worked, and the sequencing worked." According to Rao, "disturbances cropped up at the beginning of the third rocket stage and continued into the fourth and final stage. We are still studying what happened."

—Brahma Chellaney, "India's space program suffers serious setback," UPI (Washington, D.C.), 20 September 1993, in Lexis-Nexis Academic Universe, 20 September 1993, <http://web.lexis-nexis.com>.

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1 September 1993

The maiden flight of India's Polar Satellite Launch Vehicle (PSLV) is expected between 5 and 12 September 1993. The 44m-long, 280-ton PSLV has "one core, and six strap-on solid-propellant motors; the Vikas liquid-propellant second-stage; a solid-propellant third-stage; and a liquid-propellant fourth-stage motor. It can be used to place a 1,000kg payload into a 900km sun-synchronous orbit or a 3,000kg payload into an equatorial low-Earth orbit." The maiden launch will be used to place India's fourth remote-sensing satellite-IRS-1E 0-into sun-synchronous orbit. —"PSLV scheduled for first lift-off," *Flight International* (Sutton, Surrey), 1 September 1993, in Lexis-Nexis Academic Universe, 1 September 1993, <http://web.lexis-nexis.com>.

August 1993

The scientific advisor to the defense minister, Dr. A.P.J. Abdul Kalam, says that the Prithvi has entered the final phase of flight trials.

—"Rocket Developed to Carry Largest Payload," *Deccan Chronicle* (Hyderabad), 5 August 1993, p. 9, in FBIS Document JPRS-TND-93-031, 8 October 1993, p. 12.

3 August 1993

In an address to Bhabha Atomic Research Center (BARC) graduates, the chief scientific advisor to the defense minister, Dr. A.P.J. Abdul Kalam, broaches the subject of India's missile and satellite launch vehicle programs and says, "technology has to be the vision for India. Only that will bring us out of the developing country syndrome."

—"New rocket will launch satellite; defence advisor," AFP, 3 August 1993, in Lexis-Nexis Academic Universe, 3 August 1993, <http://web.lexis-nexis.com>.

12 June 1993

India conducts 11th flight-test of the Prithvi-I. The missile is tested in its battlefield configuration in conjunction with all its ground-control systems. An Indian defense ministry spokesperson says, "the launch was from the production batch and used a mobile launcher and the mobile control center." Prithvi enters user trials phase with the Indian Army.

—"Prithvi Getting Ready for User Trial Phase; Trishul Guidance Validated," *Astra* (Hyderabad), July 1993, p. 12; "Defence Ministry tests Prithvi missile 'successfully'," All India Radio (New Delhi), 12 June 1993, in BBC Summary of World Broadcasts, Lexis-Nexis Academic Universe, 15 June 1993, <http://web.lexis-nexis.com>; Brahma Chellaney, "India carries out surprise test of an extended Prithvi missile," UPI (Washington, DC), 12 June 1993, in Lexis-Nexis Academic Universe, 12 June 1993, <http://web.lexis-nexis.com>.

22 May 1993

The *Hindustan Times* reports that the Prithvi has been inducted into the Army's 11th Corps and deployed along the Pakistani border. According to the report, "the missiles have been kept at a forward ammunition depot in Punjab, from where key Pakistani towns and military installations along the Punjab border will be within the reach of the missile system."

—"India said to deploy new ballistic missile along Pakistani border," UPI (Washington, DC), 22 May 1993, in Lexis-Nexis Academic Universe, 22 May 1993, <http://web.lexis-nexis.com>.

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2 April 1993

The scientific advisor to the defense minister, Dr. A.P.J. Abdul Kalam, informs the parliament's consultative committee on defense that the Defense Research & Development Organization (DRDO) will soon begin limited series production of a pilotless target aircraft (PTA). Referring to India's integrated missile program, Kalam says that India has achieved technological breakthroughs in several areas that have come under restrictive international controls such as computers, signal processing, metallurgy, and composite materials.

—"Daily Reviews Missile Program Progress, Spinoffs," *Patriot* (New Delhi), 2 April 1993, p. 6, in FBIS Document FBIS-NES-93-070, 14 April 1993, pp. 46-47.

15 March 1993

Defense Minister Sharad Pawar informs parliament that the Prithvi surface-to-surface missile (SSM) will be inducted in the armed services in 1993-1994.

—"Prithvi, 'Trishul' To Be Inducted This Year," *India News*, 15 March 1993.

March 1993

Prime Minister Narasimha Rao secretly authorizes the Indian Space Research Organization (ISRO) to begin work on the design of a new solid-fueled motor to replace the Agni's liquid-fuel second-stage.

—Raj Chengappa, "Tell Your President, I Keep My Word," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers India Pvt. Ltd., 2000), p. 387.

1 March 1993

Hindustan Aeronautics Limited (HAL) Chairman R. N. Sharma says that the Lakshya pilotless target aircraft (PTA) will enter service soon. The PTA's PTAE-7 350kg-thrust turbojet engine, which has been developed by Aeronautical Development Establishment (ADE), is being developed for higher thrust as well as for some long-life applications such as auxiliary power. According to Sharma, "type approval" of the PTAE-7 is imminent.

—Hormuz P. Mama, "HAL Arising; Hindustan Aeronautics projects await go-ahead," *Jane's International Defense Review* (Coulsdon, Surrey), Vol. 26, No. 3, 1 March 1993, p. 252, in Lexis-Nexis Academic Universe, 1 March 1993, <http://web.lexis-nexis.com>.

9 February 1993

The Indian defense ministry proposes spending 2 billion rupees to establish production facilities for the Prithvi at Hyderabad. When produced for operational use, the Prithvi is expected to cost 18 million rupees per unit.

—Gian Singh, "MTCR 'Imposition' Decried," *All India Radio* (New Delhi), 9 February 1993, in FBIS Document JPRS-TND-93-006, 5 March 1993, pp. 12-13.

7 February 1993

India conducts tenth test-flight of the Prithvi from a mobile launcher at 0820 GMT. This is the fourth test of the missile from the Interim Test Range (ITR) in Chandipur (Orissa).

—"Medium-Range Surface-to-Surface Missile Tested," *All India Radio* (New Delhi), 7 February 1993, in FBIS Document JPRS-TND-93-005, 12 February 1993, p. 11; "Latest trials for Prithvi," *Jane's Defence Weekly* (Coulsdon, Surrey), 13 February 1993, p. 5.

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26 January 1993

Indian scientist Manoranjan Rao of the Vikram Sarabhai Space Centre (VSSC) in Thiruvananthapuram (Kerala) announces that his organization has successfully tested an air-breathing rocket, ABR-200. The test was conducted by firing two sounding rockets from the Sriharikota High-Altitude Range (SHAR) in Sriharikota (Andhra Pradesh). During the test, the rockets reached a maximum speed of Mach 2.3. According to Rao and his colleague Rajaram Nagappa, the ABR-200 is based on the principle of the ejector ram jet. Rao says that additional development is needed in "that frontier technology" (air-breathing propulsion technology) which has been cited by the Pentagon as one of the 20 "critical" technologies relating to long-term US interests. [Note: An air-breathing rocket can carry a much larger payload by using oxygen from the atmosphere to achieve targeted thrust power. Conventional rockets are bulky because they need to carry their own oxidizer stock to burn propellants, thus limiting payload capacity.

—Brahma Chellaney, "India Reports Breakthrough in Rocket Technology," UPI (Washington, DC), 26 January 1993, in Lexis-Nexis Academic Universe, 26 January 1993, <http://web.lexis-nexis.com>.

1993

The Defense Research & Development Organization (DRDO) purchases a supercomputer to help in the design of aircraft and missiles from the Hyderabad-based Advanced Numerical Research & Analysis Group (ANURAG).

—Saritha Rai, "Computers: Super Breakthrough But...," *India Today* (New Delhi), 1-15 May 1993, p. 45.

1993

According to *Defense News*, the three Prithvi tests in 1993 were conducted to test the minimum and maximum ranges of the missile. The Indian Army has placed an order for 15 missiles and has plans to purchase an additional 65 missiles.

—Theresa Hitchens and Vivek Raghuvanshi, "India Prepares for Missile Test Despite US Objections," *Defense News* (Springfield, VA), 23 May 1994, p. 38.

1992

7 October 1992

Indian Express reports that the 250km-range Air Force-version of the Prithvi-Prithvi II (SS-250)-is undergoing technical trials; its induction with the Air Force is unlikely before 1995. With an expected range of 250km, the Air Force is likely to use the missile more for disruption than destruction of strategic targets. But much will depend on the accuracy and terminal effect of the missile system. The Air Force expects a circular error probability (CEP) of 20m; but the Defense Research & Development Laboratory (DRDL), which is responsible for developing the missile, is unlikely to get a CEP less than 100m. For the required missile terminal effect, the Air Force has shown preference for cluster munitions, another indication that it is likely to use the missile in a disruption role. The Air Force has also initiated work on building an organization for the missile system. Unlike the Army, the Air Force and Navy are organized around specific weapon systems. Therefore, the creation of additional infrastructure will require the government's sanction. The Air Force is also debating whether to accept the Prithvi missiles in a pre-packed fueled state or without the propellant. According to the Defense Research & Development Organization (DRDO), the

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shelf-life of pre-packed propellant is five years as against 25 years for propellant stored in separate containers.

—Pravin Sawhney, "Future Deployment of Prithvi SS-250 Viewed," *Indian Express* (New Delhi), 7 October 1992, pp. 1, 10, in FBIS Document JPRS-TND-92-039, 28 October 1992, p. 9.

4 October 1992

The Palghat-based public sector company, [Electronic] Instrumentation [India] Limited (Kerala), announces that it "has developed prototypes of eight items for supply to defense organizations." These are manufactured as part of the company's diversification plans and include a slow relay valve for the Agni, Trishul, and Akash missiles.

—"Firm Produces Items for CIS, Gulf, Missiles, Subs," All India Radio (New Delhi), 4 October 1992; in FBIS Document JPRS-TND-92-037, 9 October 1992, p. 10.

29 August 1992

India conducts ninth test of the Prithvi-I. The missile is successfully launched from the Interim Test Range (ITR) in Chandipur (Orissa) at 10:43 a.m.; this is the third test from the ITR.

—"Ninth Launching on 29 Aug.," *Times of India* (Mumbai), 29 August 1992, p. 7, in FBIS Document JPRS-TND-92-036, 7 October 1992, p. 18.

18 August 1992

Israel offers to sell pilotless aircraft technology to India.

—Brahma Chellaney, "India Set to Produce Nuclear-Capable Missile," UPI, 18 August 1992, in Lexis-Nexis Academic Universe, 18 August 1992, <http://web.lexis-nexis.com>.

18 August 1992

India conducts eighth flight-test of the Prithvi-1. This is the second test of the Prithvi from the Interim Test Range (ITR), and the first test from a mobile platform, an eight-wheeled transporter-erector launcher (TEL) developed and manufactured by BEML in Bangalore (Karnataka). The test is conducted to test the Prithvi's maneuvering abilities after Indian defense scientists incorporate design changes to correct problems noted during an earlier test.

According to Sivathanu Pillai, a senior official in the Defense Research & Development Laboratory (DRDL), India's ballistic missiles are not only aimed at providing the Indian military with weapon systems, but also to generate exports. Indian scientists plan to conduct 11 or 12 trial launches before the Prithvi is deployed in the field.

—Brahma Chellaney, "India Set to Produce Nuclear-Capable Missile," Executive News Service, 18 August 1992; "Details Released on Prithvi Launchings," *Times of India* (Mumbai), 19 August 1992, pp. 1,14, in FBIS Document JPRS-TND-92-036, 7 October 1992, pp. 17-18.

July 1992

The United States and its G-7 allies present almost identical démarches to India's foreign ministry urging India to suspend the Agni program.

—"India to Ignore US Pressure and Test Agni Missile," UPI (Washington, DC), 16 December 1993, in Lexis-Nexis Academic Universe, 16 December 1993, <http://web.lexis-nexis.com>.

13 June 1992

Defense Minister Sharad Pawar tells Press Trust of India (PTI) that India will test an Agni missile with a higher

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payload within two months.

—"India to test ballistic missile again," AFP, 13 June 1992; in Lexis-Nexis Academic Universe, 13 June 1992, <http://web.lexis-nexis.com>.

June 1992

India sells one ton of ammonium perchlorate (AP) to the Indonesian space agency.

—Gopal Raj, "Developing Competence in Solid Propulsion," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), p. 99.

June 1992

A proposal is reportedly made to induct a Prithvi battery into the Army's 60th Heavy Artillery Regiment.

—Greg J. Gerardi, "India's 333rd Prithvi Missile Group," *Jane's Intelligence Review* (Coulsdon, Surrey), volume 7, number 8, August 1995, p. 362.

29 May 1992

US State Department spokesperson Richard Boucher regrets India decision to proceed with further tests of the Agni missile. Boucher says, "we believe that ballistic missile programs in areas where they are chronic regional tensions undermine rather than enhance regional security." Responding to Boucher's comments, Indian embassy spokesperson in Washington, DC, G. Jagannathan says, "[Agni] is not for military purposes at this stage...the whole object is to demonstrate missile technology...India does not think that it will trigger an escalation in regional tensions."

—Sid Balman Jr., "U.S. says Indian missile test threatens regional stability," UPI (Washington, DC), 29 May 1992, in Lexis-Nexis Academic Universe, 29 May 1992, <http://web.lexis-nexis.com>.

29 May 1992

India conducts second test of the Agni from the Interim Test Range (ITR). The test is unsuccessful; the missile begins to veer off course within two seconds after launch and breaks up due to vibration-induced stress. [Note: A post-test analysis reveals that the failure was caused by the extension in the missile's length from 19m to 21m and an increase in its weight from 14 tons to 16 tons. The increased length and weight changed the vehicle's vibration characteristics. However, Indian scientists and engineers failed to anticipate the impact of these changes on the sensors' calculations. When the missile lifted off, the sensors mounted on the inner skin of the missile picked up the vibrations on its structure and erroneously started making course corrections, which caused the missile to break up under stress. The *Times of India* reports that the problem was identified and resolved with the help of a Russian consultant in 1993. However Indian scientists T.K. Ghosal (Jadavpur University, West Bengal) and V.G. Sekaran (Agni's vehicle director) dispute this report. The latter claim that Indian scientists identified the problem by subjecting a full-scale model to vibration tests. For future tests, Indian scientists decide to remove the sensors from the missile's inner casing to its bulkhead to prevent the possibility of structural vibrations affecting the sensors' calculations.]

—Manoj Joshi, "Agni's Launch Raises questions," *Times of India* (Mumbai), 22 February 1994, p. 8, in FBIS Document JPRS-TND-94-010, 5 May 1994, p. 22; Raj Chengappa, "Caught In The Crosshairs," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi, HarperCollins Publishers, 2000), pp. 373-374.

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24 May 1992

India announces that it will test its Agni ballistic missile between 27-30 May 1992. The missile will be launched from the Interim Test Range (ITR) in Chandipur (Orissa).

—"China Prepares Test," Xinhua (Beijing), 24 May 1992; in FBIS Document JPRS-TND-92-017, 3 June 1992, p. 7.

20 May 1992

A successful launch of the ASLV-D3 from the Sriharikota High-Altitude Range (SHAR) in Sriharikota (Andhra Pradesh) occurred at 06:00 local time. The 24m-long, 41.7-ton, four-stage rocket successfully places a 106kg satellite into orbit at an altitude of 450km above the earth. Orbit parameters are 410km apogee and 290km perigee. The chairman of India's space commission, Professor U.R. Rao, says the important thing about the launch was "proving the rocket and orbiting the satellite."

—"India successfully launches satellite," Xinhua General Overseas News Service (Beijing), 20 May 1992, in Lexis-Nexis Academic Universe, 20 May 1992, <http://web.lexis-nexis.com>; T.S.K. Lingam, "India launches rocket, puts satellite into orbit," UPI (Washington, DC), 20 May 1992, in Lexis-Nexis Academic Universe, 20 May 1992, <http://web.lexis-nexis.com>; *Aviation Week & Space Technology* (New York), vol. 136, no.21, 25 May 1992, p. 17, in Lexis-Nexis Academic Universe, 25 May 1992, <http://web.lexis-nexis.com>.

12 May 1992

India conducts successful test of the third-stage motor for the Polar Satellite Launch Vehicle (PSLV) at the Sriharikota test center. According to Indian Space Research Organization (ISRO) sources, the motor was ignited under simulated high-altitude conditions.

—"Science and Technology; Satellite launch vehicle motor successfully tested," All India Radio (New Delhi), 13 May 1992; in BBC Summary of World Broadcasts, Lexis-Nexis Academic Universe, 27 May 1992, <http://web.lexis-nexis.com>.

11 May 1992

India's Department of Space announces that the ASLV-D3 will be launched within a few weeks. This will be the third launch of the Augmented Satellite Launch Vehicle (ASLV) after two successive failures in 1987 and 1988. Indian scientists say that changes have been made in the new vehicle based on the flight data analysis of the earlier unsuccessful flights. These changes include modifications in the internal structural elements of the launch vehicle, auto-pilot, event-based ignition system for the first two core stages and strap-on solid motors to reduce dynamic pressure. In addition, the control margin has also been enhanced. The ASLV-D3 will carry a 106kg Stretch Rohini Satellite Series-C (SROSS-C). The ASLV-D3 uses navigational computers and a closed-loop control guidance system. Indian scientists hope that the launch will help validate certain advanced technologies needed for future launch vehicles.

—"Satellite launch vehicle to be launched in India," Xinhua General Overseas News Service (Beijing), 11 May 1992, in Lexis-Nexis Academic Universe, 11 May 1992, <http://web.lexis-nexis.com>; "Indian ASLV satellite vehicle ready for launch," Xinhua General Overseas News Service (Beijing), 17 May 1992, in Lexis-Nexis Academic Universe, 17 May 1992, <http://web.lexis-nexis.com>; "India successfully launches satellite," Xinhua General Overseas News Service, 20 May 1992, in Lexis-Nexis Academic Universe, 20 May 1992, <http://web.lexis-nexis.com>.

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5 May 1992

India conducts seventh flight-test of a modified version of the Prithvi-1 from the Interim Test Range (ITR) in Chandipur (Orissa). This is the first test of the Prithvi from the ITR. Indian scientists test modifications in the propulsion and control systems aimed at raising the overall performance of the missile. The Prithvi is launched from a mobile launcher combined with a launch control center, harnessing the specially developed application software. The trial also establishes the utility of liquid-propulsion engine and inertial navigation hardware produced by Hindustan Aeronautics Limited (HAL) and other ordnance factories.

—"Successful Launch For Prithvi Missile," *Jane's Defence Weekly* (Coulsdon, Surrey), 23 May 1992, p. 880; "Trishul, Prithvi Missiles Ready For Use," *Patriot* (New Delhi), 3 August 1992, p. 5, in FBIS Document JPRS-TND-92-036, 7 October 1992, pp. 18-19.

26 March 1992

Defense Minister Sharad Pawar informs parliament that the armed forces will start receiving Prithvi surface-to-surface missiles (SSMs) in 1993.

—"Parliament Briefed on Missile System Production," All India Radio (New Delhi), 26 March 1992, in FBIS Document JPRS-TND-92-010, 8 April 1992, p. 1.

13 February 1992

During sixth test flight of the Prithvi-1, the missile breaks up in mid-flight when subjected to "torsional stress" from a pre-programmed 15° twisting maneuver.

—Zhan Dexiong, "Another Big Step Forward in Indian Missile Development," Xinhua General Overseas News Service (Beijing), 6 May 1992, in Lexis-Nexis, 7 May 1992, www.lexis-nexis.com.

February 1992

Dr. A.P.J. Abdul Kalam says that two more trial launches of the Agni I are planned in the near future. These will involve the testing of longer-range missiles with an improved control and guidance system, and a more advanced heat shield for the warhead. According to the Indian government, the Agni remains a "technology demonstrator" and there are no plans as yet for its series production.

—"Test flights of new version of Agni IRBM planned," *Jane's International Defense Review* (Coulsdon, Surrey), February 1992, p. 94.

1992

According to the head of the Defense Research & Development Laboratory's (DRDL) solid-propulsion division, A. Subhananda Rao, the Agni's first-stage solid motor case is made of high-strength 15CDV6 steel and is fabricated by conventional rolling and welding techniques. The motor is made in "three segments...the propellant used is Ap-Al-PBAN composite propellant and later switched over to HTPB [hydroxyl-terminated polybutadiene] ...the propellant is of star configuration with a loading density of 78%. It is case bonded with a liner system between propellant and insulation." The motor's nozzle is built from 15CDV6 steel; a carbon-phenolic thermal protection system is used for the convergent, high-density graphite is used for the throat, and carbon and silica-phenolic lining is used in the fore end and aft end of the divergent. The motor is one meter in diameter and ten meters in length. It has a "propellant mass of 8.6 tons and a mass fraction of 0.85." In addition, two types of "Ullage and Retro motors" have

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been developed for the Agni technology demonstrator. Both Ullage and Retro motors are made of HE-15 aluminum alloy and use a double-base propellant. The motors are lined inside with high silica glass-phenolic ablative liners. Rao claims that India now has the infrastructure for the development and production of solid-propellant motors, fabrication of motor casings and nozzles, fabrication and production of ablative liners. In addition, the Defense Research & Development Laboratory (DRDL) has achieved self-sufficiency in the design, production, inspection, qualification, static-testing, and flight-testing of propulsion systems. The raw materials required for "propellant, motors, nozzles, igniters, are all indigenously developed."

—A. Subhananda Rao, "Development of Solid Propulsion Systems for Guided Missiles," in H. S. Mukunda and A. V. Krishnamurty, eds., *Recent Advances in Aerospace Sciences and Engineering* (Bangalore: Interline Publishing, 1992), pp. 184-186.

1992

The Prithvi is scheduled for deployment with the Indian Army by the end of 1992. Changes requested by the Army, manufacturing problems at Bharat Dynamics Limited (BDL) in Hyderabad (Andhra Pradesh) and Hindustan Aeronautics Limited (HAL) in Bangalore (Karnataka), delay deployment until the end of 1993.

—Theresa Hitchens and Vivek Raghuvanshi, "India Prepares for Missile Test Despite US Objections," *Defense News* (Springfield, VA), 23 May 1994, p. 38.

1992

The Aeronautical Development Establishment (ADE) in Bangalore (Karnataka) is tasked with developing the Sagarika missile; the project is expected to be completed by 2000 and followed soon after by deployment.

—Rahul Roy-Chaudhury, "Equipping the Navy for War on Land," *Times of India* (New Delhi), 13 July 1998, www.timesofindia.com.

1991

9 August 1991

According to the Defense Research & Development Laboratory (DRDL) Director Dr. A.P.J. Abdul Kalam, 34 institutions and research and development organizations are participating in the design and development phase of India's guided missile program. In the post-development phase, the Defense Research & Development Organization (DRDO) plans to transfer the technologies involved in the production of the missiles to 22 public sector undertakings, 10 ordnance factories, and 9 private sector industries.

—"Head's Remarks," *Times of India* (Mumbai), 10 August 1991; in FBIS Document JPRS-TND-91-015, 27 September 1991, p. 18.

7 August 1991

India conducts fifth test-flight of the Prithvi-I at 10:58 a.m. at the Sriharikota High-Altitude Range (SHAR) in Sriharikota (Andhra Pradesh). Several types of warheads, including sub-munitions dispensers and fuel-air explosives are under development for use against different types of targets. Indian defense sources claim that the ratio of the missile's warhead weight (1,000kg over a 150km range) to launch weight is the highest for any weapon

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in its class. Although no mention has been made of the Prithvi's nuclear capability, Defense Minister Sharad Pawar has said that India is capable of producing nuclear weapons. Preparations are also being made for the second test of the Agni I technology demonstrator.

—"India," *Milavnews* (Romford, Essex), September 1991, p. 15.

4 July 1991

India conducts fourth test flight of the Prithvi-I from the Sriharikota High-Altitude Range (SHAR) in Sriharikota (Andhra Pradesh) at 1:52 p.m. According to Indian defense minister Sharad Pawar, despite bad weather, the missile performed well.

—"Developed by DRDO," All India Radio (New Delhi), 4 July 1991; in FBIS Document JPRS-TND-91-011, 24 July 1991, p. 14; "Prithvi Missile's Surface-to-Surface Test Fired From the Sriharikota Range," AFP (Hong Kong); in FBIS Document JPRS-TND-91-011, 4 July 1991, p. 14.

March 1991

The Indian government decides to proceed with the establishment of the integrated missile test range in the Balasore district of Orissa. The decision has been hanging fire for nearly six years due to opposition from nearly 400,000 villagers threatened by displacement.

—Mahesh Uniyal, "India: 'Greens' Seek Political Voice," IPS, 7 May 1991, in Lexis-Nexis Academic Universe, 7 May 1991, <http://web.lexis-nexis.com>.

22 February 1991

In an address to the Chennai Institute of Technology's Alumni Association, Defense Research & Development Laboratory (DRDL) Director Dr. A.P.J. Abdul Kalam says that India has attained "state-of-the-art" technology in its guided missile programs. Referring to India's 22 May 1989 Agni I test, Kalam reveals that India's indigenously developed re-entry vehicle technology was fully demonstrated when the nose-cone withstood temperatures of 3,000°C. The four-directional pre-form used in the nose cone of the Agni was made of carbon-carbon material. The temperature in the Agni payload was 30°C. Kalam also states that the Prithvi will enter production in 1992. [Note: The Agni's re-entry vehicle is designed to ensure that the temperature inside the vehicle does not exceed 60°C, a condition necessary to protect the warhead and electronic systems placed inside. The re-entry vehicle consists of "five sections." Each of these sections is made up of a "two-layer composite construction." The "inner layer is made up of carbon/epoxy filament mould" constructed on a "CNC winding machine." The inner layer is designed to bear structural loads. The outer layer is made up of "carbon/phenolic filament wound construction," and "cured in an autoclave at 7 bar pressure." The outer layer is designed to bear thermal loads.]

—"Our missile technology is most modern: Kalam," *Hindu* (Chennai), 2 March 1991, p. 16; Dr. N.C. Birla and B.S. Murthy, eds., "Airframe Structures & Composite Components," *Indian Defence Technology: Missile Systems* (DRDO, Ministry of Defence, December 1998), pp. 64-65.

11 February 1991

India conducts third test-flight of the Prithvi-1 from the Sriharikota High-Altitude Range (SHAR) in Sriharikota (Andhra Pradesh). According to Indian defense ministry sources, the test was carried out at 12:15 p.m. and the flight met "all mission requirements." The defective inertial guidance system that led to the failure of the Prithvi

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during the terminal phase of the second test is replaced by a high-performance gyro, which performs "moderately well."

—"India tests medium-range surface-to-surface missile," Xinhua General Overseas News Service (Beijing), 12 February 1991, in Lexis-Nexis Academic Universe, 12 February 1991, <http://web.lexis-nexis.com>; "India's Prithvi Strategic Ballistic Missile in Third Test," *Defense & Foreign Affairs Weekly* (Alexandria, VA), 18-24 February 1991, p. 5; Raj Chengappa, "End the Wink and Nudge Approach," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers India Pvt. Ltd., 2000), p. 361.

January 1991

The Chairman of the Integrated Guided Missile Program (IGMDP) management board, Dr. A.P.J. Abdul Kalam, says that Indian scientists are now "studying concepts for the design of reusable launch vehicles," which might be deployed at the beginning of the 21st century. These vehicles would be developed using the expertise already gained by India in re-entry technology and propulsion systems, which could also be applied to the design of a hyperplane. Kalam says that design studies have already begun at Bharat Dynamics Limited (BDL) in Hyderabad (Andhra Pradesh) and a handful of countries have shown interest.

—*Milavnews* (Romford, Essex), January 1991, p. 14.

1990

1990-1991

The Defense Research & Development Organization (DRDO) launches project to develop Nishant unmanned aerial vehicle (UAV). The first flight is expected in 1995 and the project is scheduled to be completed by the summer of 1997. Production and delivery to the armed forces is expected to begin in 1998.

—"India's Arms Industry: A Missed Opportunity?," *Strategic Comments*, Vol. 3, No.1, International Institute of Strategic Studies (London), January 1997, p. 2.

1980-1990

According to the head of the Defense Research & Development Laboratory's (DRDL) solid-propulsion division, A. Subhananda Rao, India made significant strides in the development of solid-propulsion technologies for guided missiles during the period 1980-1990. During this decade, it acquired competence in manufacturing techniques using 15CDV6 maraging steel, titanium alloys, HE-15 aluminum alloy, and stainless steel. During this phase of the missile program, DRDL also developed processing techniques and production facilities for double-base extruded- and cast-propellants, composite-propellants with carboxyl-terminated polybutadiene (CTPB), hydroxyl-terminated polybutadiene (HTPB) binders, high-energy low-smoke nitramine propellants by advanced casting powder and slurry cast techniques, composite modified double-base propellants with aluminum and ammonium perchlorate. In addition, DRDL established facilities to fabricate, process, and produce glass-phenolic, carbon-phenolic, and ablative liners. Static-test facilities for testing solid motors up to 100-ton-thrust, solid and RAM rockets in integrated and sustainer modes were established. Environmental qualification facilities for vibration, shock, acceleration, high- and low-temperature, dust, rain, salt spray were also established to qualify the propulsion systems. Expertise for the design and development of pyrotechnique igniters using gunpowder, boron, and

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potassium nitrate was developed. Pyrocartridges for initiation of these igniters, pyrogen igniters for large size solid-motors were also developed for the design of ignition systems for small and large motors.

—A. Subhananda Rao, "Development of Solid Propulsion Systems for Guided Missiles," in H.S. Mukunda and A.V. Krishnamurty, eds., *Recent Advances in Aerospace Sciences and Engineering* (Bangalore: Interline Publishing, 1992), pp. 182-183.

Winter 1990

The Arun Singh committee on defense presents its findings to the Chandra Shekhar government. It's report recommends that the chiefs of the armed forces should be brought into the nuclear decision-making loop and that the government distribute the task of nuclear warhead assembly to several agencies to minimize the dangers of an inadvertent or accidental detonation. [Note: The V.P. Singh-led United Front government lost majority in parliament and resigned in the winter of 1990; Prime Minister Singh was succeeded by Mr. Chandra Shekhar.]

—Raj Chengappa, "End the Wink and Nudge Approach," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers India Pvt. Ltd., 2000), pp. 365-366.

November 1990

Prime Minister V.P. Singh announces that the location of the National Testing Range (NTR) will be changed.

—Paul Routledge, "The Baliapal Movement," *Terrains of Resistance: Nonviolent Social Movements and the Contestation of Place in India* (Westport: Praeger Publishers, 1993), p. 70.

Mid-1990

The Indian Air Force and the Defense Research & Development Organization (DRDO) differ in their assessments of the efficacy of the Prithvi ballistic missile. The Air Force and DRDO commission separate studies to argue their cases in favor of manned bombers and ballistic missiles. The Air Force is reluctant to commit money for the Prithvi until the Air Force version is validated by the Defense Research & Development Laboratory (DRDL). There is also organizational rivalry between the Army and Air Force over which service should have operational control over the missile. The Indian government appoints an inter-service committee headed by the Vice Chief of Air Staff, Air Marshall P. M. Ramachandran to resolve these disputes. The Ramachandran committee recommends that the Army and Air Force hold joint user trials for the Prithvi to shorten the training period, and save time and financial resources. The committee also establishes zones of demarcation to resolve the Army-Air Force rivalry over the Prithvi. It rules that all targets within a 150km-zone should be the responsibility of the Army; similarly, the Air Force should engage targets beyond 150km with strategic missiles. However, the inter-organizational dispute remains unresolved. The Army maintains that all surface-to-surface weapons should remain under its jurisdiction while the Air Force should retain control over air-to-surface weapon systems.

—Raj Chengappa, "End the Wink and Nudge Approach," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers India Pvt. Ltd., 2000), pp. 364-365.

2-8 July 1990

According to Indian defense ministry sources, India will conduct a second test of the Agni I in September 1990.

—"India to Test Fire IRBM Again in September," *Defense & Foreign Affairs Weekly* (Alexandria, VA), 2-4 July 1990, p. 1.

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13 June 1990

India's defense ministry announces that it is investigating the feasibility of designing a beyond-the-visual range air-to-air missile called the Astra and may launch a formal development phase of the project in the near future. The Astra will have a range of 42 miles and be equipped with an inertial navigation system. It will be similar to the AIM-7 Sparrow and AIM-120 AMRAAM. The project will not be part of the Integrated Guided Missile Program (IGMDP). —"India Expands Missile Program to Include Air-to-Air," *Forecast International: World Weapons Review*, Issue 89, 13 June 1990, p. 4; Edmond Dantes and George Leopold, "Missiles in Gulf Buoy India's Development Drive," *Defense News* (Springfield, VA), 25 February 1991, pp. 3, 44.

16 May 1990

Minister of State for Defense Raja Ramanna says India will give priority to defense exports. Defense exports will not only be encouraged to "earn foreign exchange but also to improve the technological capabilities of the production units and to enhance levels of productivity through competition." Responding to a question about the Agni program and missile-related exports, Ramanna says, "Agni at this stage is only a technology demonstrator. I don't think we have really thought about its production in significant numbers...the question of exports of missiles has not even been considered as far as I know."

—"Indian defense minister on defense modernization," Xinhua General Overseas News Service (Beijing), 16 May 1990, in Lexis-Nexis Academic Universe, 16 May 1990, <http://web.lexis-nexis.com>.

February 1990

Biju Patnaik leads the Janata Dal to victory in the Orissa state elections. Patnaik announces that the United Front-led union government will drop the National Testing Range (NTR) project.

—Paul Routledge, "The Baliapal Movement," *Terrains of Resistance: Nonviolent Social Movements and the Contestation of Place in India* (Westport: Praeger Publishers, 1993), p. 70.

1990

India postpones second test of the Agni I.

—"India Delays Agni Launch," *Defense & Foreign Affairs Weekly* (Alexandria, VA), 3-9 June 1990, p. 3.

1990

Scientists and engineers at Aeronautical Development Establishment (ADE) in Bangalore (Karnataka) test a modified version of the Mini-RPV; the vehicle provides real time in-flight TV transmission and is modified to perform low-level flights at subsonic speeds. Work begins on developing an operational mini-RPV.

—J. Jayaraman, "Technological Advances and Cost Effectiveness of Unmanned Air Vehicle Systems," in H.S. Mukunda and A. V. Krishnamurty, eds., *Recent Advances in Aerospace Sciences and Engineering: Volume II* (Bangalore: Interline Publishing, 1992), p. 165.

1990

The revised budget for the Integrated Guided Missile Program (IGMDP) is estimated at 7.8 billion rupees, a nearly 100% increase over the initial estimate of 3.9 billion rupees in 1983.

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—"State Minister Says 504 Crore Earmarked for Missile Program," *Deccan Herald* (Bangalore), 22 March 1997, in FBIS Document FBIS-TAC-97-081, 22 March 1997.

1990

A specialized naval group is formed at the Defense Research & Development Organization (DRDO) to begin development of the 300km-range Sagarika submarine-launched missile. [Note: There is a controversy whether Sagarika is a ballistic or cruise missile. Some Indian observers believe that the Sagarika is a sea-launched cruise missile. In April 1998, the *New York Times*, citing US intelligence sources, claimed that Sagarika is a sea-launched ballistic missile. However, both Indian and Western sources agree that Sagarika is a program to develop a submarine-launched missile with a stand-off land attack capability.]

—Rahul Roy-Chaudhury, "Equipping the Navy for War on Land," *Times of India* (New Delhi), 13 July 1998, <http://web.lexis-nexis.com>; Steven Lee Myers, "Russia is Helping India Extend Range of Missile, U.S. Aides Say," *New York Times*, 27 April 1998, p. A1.

1989-1985

1989-90

Production capacity of the ammonium perchlorate (AP) plant in Alwaye (Kerala) climbs to 200 tons annually.

—Gopal Raj, "Developing Competence in Solid Propulsion," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), p. 99.

23 December 1989

Indian scientists report that they have developed a new technology to fabricate the re-entry vehicle for long-range missiles such as the Agni. According to the Defense Research & Development Laboratory (DRDL) journal *Astra*, the new technology has been developed by a team of scientists led by Murlu Manohar. The new technology, called multi-directionally reinforced carbon-fiber perform technology (MRCP), can meet the requirement for composite materials providing stringent thermal, mechanical, and frictional features required by the aerospace industry. [Note: According to a DRDO report on Indian defense technology, "multi-directionally reinforced fiber perform structures form the potential backbones for high-performance advanced composites in polymeric, ceramic, and metal matrices. The technology can be used to control the thermal, mechanical, and physical properties of the composites by appropriate design parameters such as fiber orientation, fiber volume fraction, and fiber spacing. Such [MRCP technology] in different shapes such as blocks, cylinders, cones, and other near-net shapes exhibit superior structural integrity and produce highly engineered structural composites. They also exhibit a high-degree of damage tolerance and improved inter-laminar shear strength...these composites can continue to carry load even after noticeable fractures...the [MRCP] technology...has been successfully applied to missile re-entry nose-tips and rocket nozzles....the laboratory [DRDL] has developed the [MRCP] technology and developed the 3D and 4D performs for re-entry applications. It has also acquired expertise in design of weave configurations, the design and development of tooling and actual weaving process inspection and processing of multi-directionally reinforced performs. Matrix densification technology has been developed using a high-pressure impregnation, carbonization and a high-temperature graphitization process. The multi-directional reinforced carbon fiber performs have been

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successfully densified to withstand re-entry conditions."]

—"New Technology for Medium-Range Missile Developed in India," Xinhua News Agency (Beijing), 23 December 1989, in Lexis-Nexis Academic Universe, 23 December 1989, <http://web.lexis-nexis.com>; Dr. N.C. Birla and B.S. Murthy, eds., "Airframe Structures & Composite Components," *Indian Defence Technology: Missile Systems* (DRDO, Ministry of Defence, December 1998), pp. 63-64.

27 September 1989

India conducts second test-flight of the Prithvi-I. During the terminal phase, the missile rolls uncontrollably and misses its target by several kilometers. The problem is traced to a defective inertial guidance system. [Note: There is some confusion about the date of the Prithvi's second test. Although the majority of print media sources place the date of the second test in September 1989, Indian defense journalist Raj Chengappa reports that the test occurred in November 1989.]

—"India's Prithvi Strategic Ballistic Missile in Third Test," *Defense & Foreign Affairs Weekly* (Alexandria, VA), 18-24 February 1991, p. 5; Raj Chengappa, "End the Wink and Nudge Approach," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers India Pvt. Ltd., 2000), p. 361.

27 May 1989

In an address to a press conference, Scientific Advisor to defense minister Dr. V.S. Arunachalam claims that the main purpose of the Agni test launch was to establish the design of the heat shield for re-entry, inertial navigation system, and the switch in propulsion from the first to the second stage. Arunachalam says that the successful test has proved that India has acquired vital re-entry technology. Defense Research & Development Laboratory (DRDL) Director Dr. A.P.J. Abdul Kalam says in an interview that the Agni "can carry conventional warheads...it can also carry nuclear warheads. In India we are not making nuclear warheads. We provide the carrier and the policymakers decide how to use it." Kalam discloses that the Agni costs a little less than 30 million rupees.

—"Scientist on Dec. Launch," Delhi Domestic Service, 27 May 1989, in FBIS-NES-89-102, 30 May 1989, p. 61; "Advanced Surface-to-Surface Missile Tests Planned," AFP (Hong Kong), 26 May 1989, in FBIS-NES-89-102, p. 60; Dilip Bobb with Amarnath K. Menon, "Agni: Chariot of Fire," *India Today* (New Delhi), 1-15 June 1989, pp. 10-13.

26 May 1989

Defense Minister K.C. Pant says the Agni has the potential to carry lethal warheads with a high-degree of accuracy. However, India still has a long way to go before the missiles enter operational service. Pant says that the Integrated Guided Missile Program (IGMDP) is aimed at building a missile-based defense and India will have to consider its missile option in the coming years.

—"Defense Minister Says 'Agni' Can Carry Warheads," Delhi Domestic Service, 26 May 1989, in FBIS-NES-89-101, 26 May 1989, p. 35.

22 May 1989

The United States expresses concern over the Agni test. Commenting on proliferation-related developments in South Asia, White House deputy spokesperson Roman Popadiuk says, "In the past, we have made our position very clear to the Indian government that further proliferation of ballistic missiles in South Asia would be regarded as a highly destabilizing development in the region." A US State Department spokesperson adds, "the proliferation of

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missile systems, particularly in areas of political tension, undermines regional stability and peace."

—"U.S. concerned over Indian missile test," 22 May 1989, Xinhua General Overseas News Service (Beijing), in Lexis-Nexis Academic Universe, 22 May 1989, <http://web.lexis-nexis.com>.

22 May 1989

The Agni is tested from the Interim Test Range (ITR) in Chandipur (Orissa) at 0247 GMT and travels 800km carrying a dummy warhead of tungsten. Defense Research & Development Organization (DRDO) scientists call the Agni a re-entry test vehicle because the first launch was aimed at evaluating structure, guidance, and control during re-entry into the earth's atmosphere. Prime Minister Rajiv Gandhi describes the Agni launch as a national endeavor in the pursuit of self-reliance. He says that "Agni is not a nuclear weapon system. What Agni does is to afford us [India] the option of developing the ability to deliver non-nuclear weapons with high-accuracy at long ranges." Justifying the development of modern defense technologies, Gandhi says, "we lost our independence two centuries ago because we were disunited on the home front and not vigilant on the external front. We must remember that technological backwardness also leads to subjugation. Never again will we allow our freedom to be so subjugated."

—"India's Medium-Range Missile 'Agni' Launched," Xinhua General Overseas News Service (Beijing), 22 May 1989, in Lexis-Nexis Academic Universe, 22 May 1989, <http://web.lexis-nexis.com>; *Missile Systems of the World*, AMI International (Bremerton, Washington), 1999, p. 455; "Gandhi Hails Missile Test," Delhi Domestic Service, 22 May 1989, in FBIS-NES-89-097, 22 May 1989, p. 54; "Gandhi Says Missile's Success Guards India's Independence," *St. Louis Post-Dispatch* (St. Louis, Missouri), 23 May 1989, p. 11A, in Lexis-Nexis Academic Universe, 23 May 1989, <http://web.lexis-nexis.com>; Dilip Bobb with Amarnath K. Menon, "Agni: Chariot of Fire," *India Today* (New Delhi), 1-15 June 1989, pp. 10-13.

19 May 1989

The CIA Director William H. Webster tells a senate panel that the agency has found "indicators" that India is interested in obtaining "thermonuclear weapons capability." These include attempts by the Bhabha Atomic Research Center (BARC) in Trombay (Maharashtra) to purify lithium, separate lithium isotopes, and produce tritium. Other indicators include the import of beryllium from West Germany, which according to Webster, "is used in enhancing fission reaction."

—David B. Ottaway, "Signs Found India Building an H-Bomb; W. Germany Shipped Beryllium, CIA Says," *Washington Post*, 19 May 1989, p. A29, in Lexis-Nexis Academic Universe, 19 May 1989, <http://web.lexis-nexis.com>.

10 May 1989

Defense minister K.C. Pant tells parliament that Indo-US defense-related technological cooperation covers three areas: aeronautics, missile technology, and anti-armor systems.

—"India takes no decision on production of LCA," Xinhua General Overseas News Service (Beijing), 10 May 1989, in Lexis-Nexis Academic Universe, 10 May 1989, <http://web.lexis-nexis.com>.

6 May 1989

An Indian defense ministry source tells the Chennai-based *Hindu* that the Agni will have a range between 800-

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1,200km. However, once India is able to launch a missile of the Agni's class successfully, it will be able to develop missiles with a range of 2,500km.

—"India's medium-range missile to be launched this month," Xinhua General Overseas News Service (Beijing), 6 May 1989, in Lexis-Nexis Academic Universe, 6 May 1989, <http://web.lexis-nexis.com>.

1 May 1989

A test of the Agni I is postponed for the second time after scientists discover a leak in the first-stage motor's Secondary Injection Thrust Vector Control (SITVC) system. A valve regulating the flow of strontium perchlorate, the liquid used for thrust vectoring or controlling the missile's direction during flight, ruptures, draining the fluid into the thrusters. The leak is discovered 11 seconds before launch and attempts to repair it are abandoned three hours later. The defective engine is flown to the Indian Space Research Organization's (ISRO) Vikram Sarabhai Space Centre (VSSC) for repairs. The postponement is met by cheers and the blowing of conch shells by many of the approximately 11,000-12,000 villagers who have been temporarily evacuated from their homes around the launch site as a safety precaution. The villagers oppose the test because of the Indian government's long-term plan to permanently relocate them from the fertile farmland surrounding the test-site.

—Dilip Ganguly, "India Again Postpones Ballistic Missile Test-Firing," Associated Press, 1 May 1989, in Lexis-Nexis Academic Universe, 1 May 1989, <http://web.lexis-nexis.com>; Adam Kelliher, "Indian Missile Test Aborted," UPI (Washington, DC) 1 May 1989, in Lexis-Nexis Academic Universe, 1 May 1989, <http://web.lexis-nexis.com>; Raj Chengappa, "The Agni Pariksha," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers India Pvt. Ltd., 2000), pp. 340-341; "The World," *Los Angeles Times*, 21 April 1989, p. 2, in Lexis-Nexis Academic Universe, 21 April 1989, <http://web.lexis-nexis.com>; A.P.J. Abdul Kalam with Arun Tiwari, "Propitiation," in *Wings of Fire: An Autobiography* (Hyderabad: Universities Press (India) Limited, 1999), pp. 150-151.

20 April 1989

The first test of the Agni intermediate-range ballistic missile (IRBM) from Interim Test Range (ITR) is postponed due to an alleged malfunction in the missile's ignition system. A failure analysis team later attributes the postponement to a false malfunction alarm triggered by a computer overcome by a memory overload problem and a breakdown in the mission control's intercom system. Residents of surrounding villages, who have been evacuated from their homes as a safety precaution, express opposition to the missile test. Protesters reportedly cut cables to sirens intended to alert residents within a two-mile radius of the test-range to evacuate their homes.

—Dilip Ganguly, "Launch of India's First Intermediate-Range Missile Postponed," Associated Press, 20 April 1989, in Lexis-Nexis Academic Universe, 20 April 1989, <http://web.lexis-nexis.com>; Raj Chengappa, "The Agni Pariksha," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers India Pvt. Ltd., 2000), pp. 339-340; Tony Allen-Mills, "India delays missile test," *Independent*, 21 April 1989, in Lexis-Nexis Academic Universe, 21 April 1989, <http://web.lexis-nexis.com>.

February 1989

Defense secretary Naresh Chandra forces a reluctant army to allocate 580 million rupees from its budget for the Prithvi's production. The funds are then siphoned off to make secret purchases for the Agni intermediate-range ballistic missile (IRBM) program. Although the Indian government formally allocates 400 million rupees for the Agni

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program, actual R&D costs are amortized across several projects to disguise the true scale of the program from the prying eyes of foreign intelligence agencies.

—Raj Chengappa, "The House Is On Fire," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers India Pvt. Ltd., 2000), pp. 333-334.

8 February 1989

The scientific advisor to defense minister, Dr. V.S. Arunachalam says that the Defense Research & Development Organization (DRDO) is examining the feasibility of partnering with private, public, and small industries. For this purpose, the Defense Research & Development Laboratory (DRDL) will set up "technology parks" in Hyderabad (Andhra Pradesh), Bangalore (Karnataka), and Dehra Dun (Uttar Pradesh) to encourage local entrepreneurs to start industries for manufacturing components and sub-systems required by the defense industry. [Note: Dehradun was declared capital of the newly created state of Uttaranchal in 2000.]

—"Private Sector to Join in Defense Research," Delhi Domestic Service, 9 February 1989, in FBIS-NES-89-026, p. 49.

7 February 1989

Defense Minister K.C. Pant informs parliament that the government is examining a proposal to set up an autonomous organization for promoting defense exports. Pant says that three public sector defense units-Bharat Electronics Limited (BEL), HAL, and Bharat Earth Movers Limited (BEML)-exceeded their export targets in 1987-88.

—"Autonomous Body for Defense Exports Examined," Delhi Domestic Service, 7 February 1989, in FBIS-NES-89-046, 10 March 1989, p. 46.

30 January 1989

Defense Minister K.C. Pant says that India is planning to expand its defense exports. However, he cautions that "we [Indian government] will be very careful what kinds of weapons we send and where we send...our foreign policy perceptions will govern the sales."

—"Defense Minister on Plans to Boost Arms Exports," AFP (Hong Kong), 30 January 1989, in FBIS-NES-89-019, 31 January 1989, pp. 45-46.

9 January 1989

Indian defense ministry officials announce that India will test a new surface-to-surface missile (SSM) soon. This will be India's first test of a rocket with an intermediate-range capability. However, the precise schedule for the test has not been decided yet.

—"Test of New Surface-to-Surface Missile Planned," AFP (Hong Kong), 9 January 1989, in FBIS-NES-89-005, 9 January 1989, pp. 56-57.

January 1989

The two committees appointed to investigate the July 1988 crash of the second Augmented Satellite Launch Vehicle (ASLV) conclude that the mission failed due to the failure of several key technologies. The review committees find that the ASLV's closed-loop guidance system failed to correct for deviations in the rocket's predetermined flight-path and there was "poor control of the launch vehicle in the critical transition stage when the two strap-on boosters are ejected and the next stage rocket motor is ignited." Control at this stage is critical

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"because the load on the rocket is maximum due to air pressure as well as the thrust exerted on the rocket when the strap-on boosters are being jettisoned." Loss of control leads the rocket to veer on one side and break up under stress. In the case of the second ASLV launch, flight data and photographs show that the rocket began tilting to one side 39 seconds after launch and continue to tilt until 50.5 seconds, when it broke up below the equipment bay. The committee finds that there was a "complete absence of control between 48.6 and 49.1 seconds after lift-off." This is a critical phase when the rocket is subjected to maximum dynamic pressure. Although the next-stage motor did ignite, in the absence of control, the rocket crashed. The findings note that Indian scientists and engineers also failed to account for an unexpected change in the wind direction from the east to west at a height of 11km, 38 seconds after launch, which might have disturbed the rocket.

—Amarnath K. Menon, "ASLV: Damning Findings," *India Today* (New Delhi), 1-15 January 1989, p. 94; Gopal Raj, "The ASLV: A Technological Bridge," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), pp. 134-135.

1989

According to a report on the Indian Space Research Organization's (ISRO) solid rocket motors development, the basic infrastructure for the raw materials and fabrication of the motors is available in Indian industry. In addition, "propellant processing facilities, and composite products processing facilities along with non-destructive evaluation capabilities have been established within ISRO. Assembly and testing requirements comprising environmental facilities, single and six component test stands and altitude test facilities have also been established in house. The basic aim of self-sufficiency in the realization of solid motors has been achieved by the indigenous development and production of raw materials and critical technologies. Besides engineering of the process of propellant, composite motor cases, and nozzles, facilities for the manufacturing and inspection of these have been set up. In addition, many technologies developed within ISRO have been transferred to industry. Chief among these are the production of hydroxyl-terminated polybutadiene (HTPB) binder, phenolic resin and high silica cloth. Capacities for ammonium perchlorate are available in ISRO and in Indian industry. Indian industry has capabilities to meet the requirements of aluminium powder, adhesives, insulation products and large scale fabrication of motor cases."

—R. Nagappa, M.R. Kurup, and A.E. Muthunayagam, "ISRO's Solid Rocket Motors," *Acta Astronautica*, vol. 19, no. 8, 1989, pp. 696-697.

1989

India begins production of the Konkurs anti-tank guided missile (ATGM) begins at Bharat Dynamics Limited (BDL) in Hyderabad (Andhra Pradesh) under license from the Soviet Union. [Note: The Konkurs is a "long-range, semi-automatic wire guided second generation anti-tank guided missile, which is man portable." The missile has a range of 75-4,000-meters; it has a length of 1,260mm and weighs 25.16kg.]

—"Bharat Dynamics Limited: Defence Production and Supply," *Indian Armed Forces*, www.indianarmedforces.com; "Missiles: Konkurs Anti-Tank Missile System," *Department of Defence Production & Supplies: Ministry of Defence* (Government of India), p. 124, www.defstand.gov.in.

1989

The United States cancels a contract for the sale of a Combined Acceleration Vibration Climatic Test (CAVCT)

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system from the US-based MB Dynamics and Wyle Labs in an attempt to slowdown India's missile program. The CAVCT, which is also known as the "shake and bake" system, is used to simulate heat and vibrations that rocket subsystems and components encounter during flight. The Bush administration also blocks the sales of a precision tracking radar device used to track a missile's flight path and magnesium alloys used in the construction of missiles.
—Raj Chengappa, "The Agni Pariksha," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers India Pvt. Ltd., 2000), p. 350.

1989

The Interim Test Range (ITR), a dedicated facility to test airborne weapon systems, is completed. The test range is spread over 17km along India's eastern coast and is located at Chandipur, 15km from Balasore (Orissa). The range includes a number of tracking instruments to cover the total flight path of test vehicles. Test facilities include mobile and fixed electro-optical tracking systems, mobile S-band tracking radar (KAMA-N), fixed C-band (PCMC) tracking radar, fixed and mobile telemetry systems, range computer, close circuit television system, photo processing system, meteorological system, and range safety system. According to Indian government sources, the ITR is being designed to track long-range missiles, air defense missiles, weapon systems delivered by combat aircraft, multi-target weapon systems, and high 'G' maneuverable missiles.

—"Interim Test Range, Balasore, Orissa," Federation of American Scientists: Nuclear Forces Guide, www.fas.org;
"Interim Test Range to be upgraded," *Indian Express* (Mumbai), 17 August 1998, www.expressindia.com.

1989

The Agni-team, led by R.N. Agarwal, decides to introduce design-modifications to extend the missile's range from 800-1,200km. Since the first-stage solid-fueled motor, built by the Indian Space Research Organization (ISRO), cannot be upgraded without long delays, the team decides to modify the Prithvi's liquid-fueled engines in the second stage. In the first test of the Agni (22 May 1989), the Prithvi's liquid-fuel tanks were modified to reduce burnout from 100 seconds to 50 seconds. For the second test, the missile scientists decide to restore the burnout time to 100 seconds. The team also extends the nozzle of the engine "sideways" to double the thrust. In another significant change, the Defense Research & Development Laboratory (DRDL) dispenses with the six-ullage motors that were used to keep the missile flying at the same velocity during the transition from the first to the second stage. Instead, a decision is made to ignite the second-stage motor even before the first-stage motor burns out completely. In order to do this, the first and second stages are separated by giant rings of steel held by crossed girders.

—Raj Chengappa, "Caught in the Crosshairs," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers India Pvt. Ltd., 2000), pp. 371-372.

1989

Colonel V.J. Sundaram, project director of Prithvi missile project, is promoted to the position of deputy director of the Defense Research & Development Laboratory (DRDL). V.K. Saraswat, former deputy director of Prithvi project, is appointed new director of Prithvi program.

—Raj Chengappa, "The Agni Pariksha," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers India Pvt. Ltd., 2000), pp. 350-351.

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October 1988

Indian defense scientists claim that they have developed a conceptual design for an air-breathing hypersonic vehicle in collaboration with Bharat Dynamics Limited (BDL) in Hyderabad (Andhra Pradesh). The aircraft will be based on a new principle with "payload capabilities one order of magnitude higher than even the most advanced rocket launchers." The new single-stage vehicle will be a hybrid of a jet aircraft and a rocket. It will take off from a conventional runway and a fan ramjet engine will assist its take off and climb to cruise altitude. A scramjet engine will then accelerate it to eight times the speed of sound. Thereafter, the liquid hydrogen and liquid oxygen produced and collected during flight will burn in a rocket engine and propel the vehicle into space.

—"Science and Technology; Hyperplane/self-fuelling rocket designed," 10 October 1988; BBC Summary of World Broadcasts," in Lexis-Nexis Academic Universe, 19 October 1988, <http://web.lexis-nexis.com>.

27 August 1988

President R.Venkataraman inaugurates Defense Research & Development Laboratory's (DRDL) Advanced Technology Institute in Hyderabad (Andhra Pradesh).

—"Industrial Production; Guided missile institute opened," 27 August 1988; in BBC Summary of World Broadcasts, Lexis-Nexis Academic Universe, 7 September 1988, <http://web.lexis-nexis.com>.

20 July 1988

Indian defense sources say that the government has appointed an inter-service "quality assurance panel" with representatives from the Army, Navy, and Air Force, to oversee the Integrated Guided Missile Program (IGMDP). The panel was formed after the second failure of Augmented Satellite Launch Vehicle (ASLV) to ensure that bugs are removed from India's missile programs during the development phase.

—"Defense Team to Oversee Guided Missile Program," AFP (Hong Kong), 20 July 1988, in FBIS-NES-88-141, 22 July 1988, p. 43.

July 1988

The Orissa government starts construction of 400 of the 6,500 houses in the model villages planned under the rehabilitation package for the National Testing Range (NTR) evacuees.

—Paul Routledge, "The Baliapal Movement," *Terrains of Resistance: Nonviolent Social Movements and the Contestation of Place in India* (Westport: Praeger Publishers, 1993), p. 55.

13 July 1988

Second launch of the 23.5m-high, 40-ton, four-stage Augmented Satellite Launch Vehicle (ASLV). The rocket fails to place a 145kg satellite in orbit. Mission control loses contact with the rocket 210-seconds after launch. The causes of the failure are not known and Indian Space Commission chairman Professor U.R. Rao says, "One has to suspect everything now, go back and look into everything." The Indian Space Research Organization (ISRO) appoints two committees, a "Failure Analysis Committee" headed by Dr. S.C. Gupta of Vikram Sarabhai Space Centre (VSSC) and an "Experts Review Panel" headed by Professor R. Narasimha, to investigate the reasons for failure and make recommendations on the development of future launch vehicle technology.

—"India Fails in 2nd Attempt to Launch Big Rocket," *Los Angeles Times*, 14 July 1988, p. 5; in Lexis-Nexis Academic

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Universe, 14 July 1988, <http://web.lexis-nexis.com>; Amarnath K. Menon, "ASLV: Damning Findings," *India Today* (New Delhi), 1-15 January 1989, p. 94.

May 1988

The Indian government's decision to establish an integrated test range in Orissa's Balasore district arouses strong local opposition. Thousands of villagers fearing displacement from their homes block roads to keep government officials away. The villagers demand that the site be shifted elsewhere. The government rejects the request and deploys an 8,000-member police force to maintain order.

—"Missile test range opposed in southeastern India," Xinhua Overseas General News Service (Beijing), 19 May 1986; in Lexis-Nexis Academic Universe, 19 May 1986, <http://web.lexis-nexis.com>.

22 April 1988

The Soviet Union offers to share the specifications of two supercomputer models—"Elbrus 3-1" and "EC 1068"—with India by the end of July 1988. K.P. Nambiar, secretary in the department of electronics, says that the Soviet supercomputers are compatible with the models that are available to India from the United States.

—"Computer Cooperation Accord Signed With USSR," Delhi Domestic Service, 22 April 1988, in FBIS-NES-88-081, 27 April 1988, p. 48.

April 1988

Local opposition groups in the Baliapal area destroy a model village under construction by the Orissa state government as part of the rehabilitation plan for the National Testing Range (NTR) evacuees.

—Paul Routledge, "The Baliapal Movement," *Terrains of Resistance: Nonviolent Social Movements and the Contestation of Place in India* (Westport: Praeger Publishers, 1993), p. 55.

3 March 1988

An Indian defense ministry spokesperson says that Indian scientists have successfully tested prototypes of a pilotless target aircraft (PTA), and PTA launch-boosters have been developed for the first time in the country. Scientists at Aeronautical Development Establishment (ADE) in Bangalore (Karnataka) successfully test a "Mini-RPV" with real time in-flight TV transmission.

—"Defense Ministry Spokesman on Research Projects, AFP (Hong Kong), 3 March 1988, in FBIS Document FBIS-NES-88-043, 4 March 1988, pp. 54-55; J. Jayaraman, "Technological Advances and Cost Effectiveness of Unmanned Air Vehicle Systems," in H.S. Mukunda and A.V. Krishnamurty, eds., *Recent Advances in Aerospace Sciences and Engineering: Volume II* (Bangalore: Interline Publishing, 1992), p. 165.

March 1988

A CIA source says that "....India did not stop in 1974," after it exploded a nuclear device. He says that India possesses a "nuclear arsenal" that is "sophisticated and miniaturized." Another intelligence analyst adds that the Indian Air Force Jaguars have been observed practicing the "flip-toss maneuver" over the Himalayas—a special bombing technique used to deliver nuclear munitions. Intelligence sources also suggest that there is strong evidence to suggest that India has developed a nuclear warhead for use on surface-to-surface missiles with a 200-mile range.

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—Richard Sale, "India said to upgrade nuclear arsenal," UPI, 19 March 1988; in Lexis-Nexis Academic Universe, 19 March 1988, <http://web.lexis-nexis.com>.

26 February 1988

Indian defense scientists outline the organizational scale of India's Integrated Guided Missile Program (IGMDP). They reveal that in addition to the Defense Research & Development Laboratory (DRDL), 19 other defense laboratories, 21 public-sector organizations, and six private-sector units are also participating in the program. The future missile program involves the development of "dual-thrust, 'RAM' rocket- and liquid-propulsion system, strap-down inertial and command guidance system, homing guidance system, composite and metallic air-frames, phased array radar and ground system, high-performance high-explosive warheads, missile power systems, actuators, missile software, and simulation software" technologies. To ensure secrecy, DRDL is being relocated to a maximum-security complex at Imarat, located 20km from Hyderabad (Andhra Pradesh). The new 2,000-acre complex [a probable reference to Research Centre Imarat (RCI)] may also provide underground facilities for the production of different kinds of missiles.

—"Paper Details Missile Production Plans," *Hindustan Times* (New Delhi), 27 February 1988, pp. 1, 5, in FBIS Document FBIS-NES-88-044, 7 March 1988, pp. 55-56.

25 February 1988

India conducts first flight-test of the 150km-range Prithvi-1 ballistic missile from Indian Space Research Organization's (ISRO) Sriharikota High-Altitude Range (SHAR) in Sriharikota (Andhra Pradesh) Sriharikota (Andhra Pradesh). Prime Minister Rajiv Gandhi informs parliament that all test requirements have been met.

—"Surface-to-Surface Missile Successfully Tested," Delhi Domestic Service, 25 February 1988, in FBIS Document FBIS-NES-88-037, 25 February 1988, pp. 46-47; "Paper Details Missile Production Plans," *Hindustan Times* (New Delhi), 27 February 1988, pp. 1, 5, in FBIS Document FBIS-NES-88-044, 7 March 1988, pp. 55-56.

January 1988

An Indian interagency group comprised of members from the foreign ministry and the Defense Research & Development Organization (DRDO) visits the United States to review implementation of the Indo-US technology transfer agreement. Indian government sources suggest that there is now better appreciation in the United States of India's requirements for sensitive technologies. In this regard, the United States has cleared the sale of equipment for India's missile test range in Orissa.

—"United States to review technology transfer," Xinhua General Overseas News Service (Beijing), 12 January 1988; in Lexis-Nexis Academic Universe, 12 January 1988, <http://web.lexis-nexis.com>.

1988

According to Indian scientists, the Indian Space Research Organization's (ISRO) Vikram Sarabhai Space Centre has developed "various inertial-grade sensors" like "rate-gyros, rate-integrating gyros, dynamically-tuned gyros, and servo-accelerometers" for India's satellite launch vehicles. "Rate-gyros have already been used in the SLV-3 and rate-integrating gyros with beryllium components have been qualified."

—S.C. Gupta and B.N. Suresh, "Inertial guidance system for Indian launch vehicles," in R. Narasimha and A.P.J.

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Abdul Kalam, eds., *Developments in Fluid Mechanics and Space Technology* (Bangalore: Indian Academy of Sciences, 1988), p. 349.

1988

A report on the management of India's space program states that the Department of Space (DOS) has cooperated with the industrial sector in four key areas: technology transfer from the space sector to industry; acquisition of existing industrial technology for applications in the space program; procurement of goods and services from industry; and consultancy by the Indian Space Research Organization (ISRO) to the industry. From the mid-1970s, ISRO stressed cooperation with industry as a matter of policy. The number of technologies transferred from ISRO to industry increased from 3 in 1977 to 88 in 1984 and 129 in 1986. In this regard, the monetary value of the transfers increased from 130 million rupees in 1977-78 to 1.19 billion rupees in 1986-87. Since 1974, ISRO has also supported space-related academic research in the different academic institutions under a program called RESPOND.

—Y.S. Rajan, "Management of the Indian space programme," in R. Narasimha and A.P.J. Abdul Kalam, eds., *Developments in Fluid Mechanics and Space Technology* (Bangalore: Indian Academy of Sciences, 1988), pp. 402-403.

1988

Indian scientists claim that the Indian Space Research Organization (ISRO) has achieved important successes in indigenizing solid-propellant technologies. These successes include the engineering of a plant to manufacture ammonium perchlorate (AP) in Alwaye (Kerala), "building a Propellant Fuel Complex," indigenizing equipment like "perchlorate grinder and vertical mixer, and the development of a 4MeV linear accelerator..." They also divulge that ISRO's solid-rocket motors are of the "case-bonded" type. [Note: In "case-bonded" motors, the propellant is cast inside an insulated and lined rocket chamber and during "curing" the propellant grain sticks to the wall.]

—M.R. Kurup, V.N. Krishnamoorthy, and M.C. Uttam, "Development of Solid propellant technology in India," in R. Narasimha and A.P.J. Abdul Kalam, eds., *Developments in Fluid Mechanics and Space Technology* (Bangalore: Indian Academy of Sciences, 1988), pp. 340-341.

Late 1980s

The Indian Space Research Organization (ISRO) succeeds in producing hydroxyl-terminated polybutadiene (HTPB) indigenously.

—Gopal Raj, "Developing Competence in Solid Propulsion," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), p. 91.

November 1987

Prime Minister Rajiv Gandhi tells parliament that India has decided to acquire two Cray XMP 14 supercomputers from the United States. One computer will be installed in New Delhi, while the other will be installed in Bangalore (Karnataka).

—"Gandhi on Acquiring Super Computer From US," Delhi Domestic Service, 19 November 1987, in FBIS-NES-87-225, 23 November 1987, p. 49.

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November 1987

Indian scientists, C.N.R. Rao of the Indian Institute of Sciences (IISc) in Bangalore (Karnataka) and N. Seshagiri of the National Information Centre, New Delhi, submit proposals to develop a supercomputer. The Indian government approves Seshagiri's proposal, which will be carried out by the newly created Centre for the Development of Advanced Computing (CDAT) in Pune (Maharashtra). Seshagiri dismisses talk of acquiring supercomputers from the Soviet Union, claiming that India is ahead in supercomputer technology.

—T.N. Ninan, "Supercomputers: Home Made," *India Today* (New Delhi), 1-15 November 1987, p. 56.

26 November 1987

Minister of State for Defense, Shivraj Patil, tells parliament that India has contracted to purchase Sea Eagle anti-ship missiles from Britain. [Note: The Sea Eagle is a "short-range, air-launched, turbojet-powered, single-warhead, air-to-surface missile." It has a length of 4.14m, body diameter of 0.4m, and launch weight of 600kg. The Sea Eagle can deliver a single "230kg HE semi-armor piercing warhead" over a maximum range of 110km.]

—"Contract to Buy UK Sea Eagle Missiles Signed," Delhi Domestic Service, 26 November 1987, in FBIS-NES-87-229, 30 November 1987, p. 59; "Offensive Weapons: Sea Eagle," Duncan Lennox ed., *Jane's Strategic Weapons Systems*, Issue 32, (Coulsdon, Surrey: United Kingdom, 2000).

27 September 1987

The public-sector undertaking, Mishra Dhatu Nigam (MDN), Midhani, Hyderabad, (Andhra Pradesh) begins producing maraging steel. The steel will be used to build the Polar Satellite Launch Vehicle (PSLV). The firm also manufactures a wide range of special metals and superalloys for use in India's aerospace, space, and nuclear sectors.

—"Public Firm Produces Maraging Steel," Delhi Domestic Service, 27 September 1988, in FBIS Document FBIS-NES-87-187, 28 September 1988, p. 48.

30 August 1987

An Indian defense ministry's research and development report states that Indian entities have acquired self-reliance in the development of advanced missiles.

—"Defense Ministry Notes Development of Advanced Missiles," Delhi Domestic Service, 30 August 1987, in FBIS Document, "India," V, 31 August 1987, p. R2.

27 August 1987

The government informs parliament that it is exploring the possibility of manufacturing supercomputers in India as well as importing them from the United States. In addition, the Soviet Union has assured India of providing it with the latest computers produced in the country.

—"Soviet Union to Supply 'Latest Computers'," Delhi Domestic Service, 27 August 1987; in FBIS Document "India," V. 27 August 1987, p. R2.

23 August 1987

Indian Defense Minister K. C. Pant lays the foundation stone for the second unit of Bharat Dynamics Limited (BDL) in Banaru village, Medak district (Andhra Pradesh). The unit, which is expected to cost 1.76 billion rupees, is being

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set up to manufacture anti-tank missiles.

—"Minister Notes Success in Defense Production," Delhi Domestic Service, 23 August 1987, in FBIS Document, "India," V, 27 August 1987, p. R2.

Late June 1987

The Failure Analysis Committee appointed to investigate the causes of the Augmented Satellite Launch Vehicle (ASLV) failure identifies two possible scenarios that may have led to the crash. The first theory focuses on a possible fault in the switch of the rocket's safe arm device. Scientists speculate that the switch either did not open or malfunctioned due to a short circuit. The second theory centers on an unidentifiable flaw in the ignition system and circuitry of the first-stage motor. Although the committee reaches no firm conclusions, the Indian Space Research Organization (ISRO) decides to remove the switch and safe-arm device from the second ASLV, which will be launched by April 1988. The next ASLV will also be provided with back-up systems to ensure that a single-point failure does not lead to the failure of the entire mission.

—Amarnath K. Menon, "ASLV: Finding the Flaws," *India Today* (New Delhi), 1-15 August 1987, p. 73.

3 May 1987

A Defense Research & Development Laboratory (DRDL) spokesperson says that the lab is preparing to conduct the first test of the 150km-range Prithvi-I SSM in June 1987. The liquid-fueled SSM can deliver a 1,000kg payload over a 150km-range.

—"Government to Test Long-Range SAM in June," AFP (Hong Kong), 3 May 1987, in FBIS VIII, 4 May 1987, p. E2; "Details of Missiles Revealed," Delhi Domestic Service, 3 May 1987, in FBIS VIII, 4 May 1987, p. E2.

7 April 1987

Indian space scientists at the Indian Space Research Organization (ISRO) say that a preliminary analysis carried out by the Failure Analysis Committee appointed to investigate the Augmented Satellite Launch Vehicle (ASLV) failure has concluded that the crucial strap-on booster technology performed well. The main cause of the failure has been traced to the failure of the first-stage motor to ignite on receiving an ignition command from the on-board computer.

—"ASLV Technology Good Despite Mission Failure," Delhi Domestic Service, 7 April 1987, in FBIS VIII, 8 April 1987, p. E1.

1 April 1987

The Minister for Science & Technology, K.R. Narayanan, tells parliament that the next launch of the Augmented Satellite Launch Vehicle (ASLV) will take place in a year's time. Narayanan says that the rocket launch and satellite payload cost 60 and 40 million rupees, respectively.

—"Minister Briefs Parliament on Space Programs," Delhi Domestic Service, 1 April 1987, in FBIS VIII, 2 April 1987, p. E1.

27 March 1987

The United States agrees to sell India a supercomputer of relatively limited power.

A US interagency group comprised of officials from the departments of defense, state, and commerce issue a

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communiqué saying that India is free to purchase the Cyber 205, a Cray 1 or approximately the same vintage, a single-processor Cray-XMP or some "other machine of equivalent capability." India retains the option to purchase a supercomputer from the Japan's NEC, which has agreed to sell single-processor machines to India.

—David E. Sanger, "U.S. Lets India Buy Computer," *New York Times*, 27 March 1987, pp. 1-3; in Lexis-Nexis Academic Universe, 27 March 1987, <http://web.lexis-nexis.com>.

25 March 1987

The Minister for Science and Technology, K.R. Narayanan, informs Lok Sabha that the Augmented Satellite Launch Vehicle (ASLV) launch failed due a suspected malfunction in the motor after 163 seconds. The vehicle performed normally for 48.5 seconds and telemetry data was received by mission control throughout the flight duration. The two important new technologies incorporated in the ASLV, including the strap-on booster rockets, performed satisfactorily.

—"Minister Comments on Failure of Rocket Launch," Delhi Domestic Service, 25 March 1987, in FBIS VIII, p. E1.

March 1987

The Indian Space Research Organization (ISRO) appoints a Failure Analysis Committee under the leadership of Vikram Sarabhai Space Centre (VSSC) Associate Director R. Aravamudan to determine the causes of the Augmented Satellite Launch Vehicle's (ASLV) failure. The committee is asked to submit its report within one month.

—Gopal Raj, "The ASLV: A Technological Bridge," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), p. 132.

24 March 1987

The maiden flight of the Augmented Satellite Launch Vehicle (ASLV) fails 162 seconds after lift-off from the Sriharikota High-Altitude Range (SHAR) in Sriharikota (Andhra Pradesh). The 23.5m-high, 40-ton, five-stage rocket is designed to lift a 145kg satellite into orbit. Indian Space Commission chairman Professor U.R. Rao says that the rocket appeared to have malfunctioned after the first stage. According to Rao, "the stage separation took place but may not [have been] at the right time." The Director of SHAR, M.R. Kurup says "it appears that the failure of the motor to burn is the main reason for ASLV-1 not going up, but it will be two weeks before we can conclude why the motor failed."

—Richard M. Weintraub, "Launch Failure Delays Indian Rocket Program," *Washington Post*, 24 March 1987, p. A16; in Lexis-Nexis Academic Universe, 25 March 1987, <http://web.lexis-nexis.com>; "Rocket crash strikes blow to Indian plans," *Toronto Star*, 25 March 1987, p. A9; in Lexis-Nexis Academic Universe, 25 March 1987, <http://web.lexis-nexis.com>; Amarnath K. Menon, "ASLV Programme: Setback in the Sky," *India Today* (New Delhi), 1-15 April 1987, p. 68.

1987

The Defense Research & Development Laboratory (DRDL) establishes a computer-aided design and manufacturing facility to help with the design and development of missiles.

—Dr. N.C. Birla and B.S. Murthy, eds., "Airframe Structures & Composite Components," in *Indian Defense*

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Technology: Missile Systems (New Delhi: Defence Research and Development Organization, Ministry of Defence, Government of India, 1998), p. 51.

29 December 1986

After a year deadlock, Indian and US negotiators reach a tentative agreement on the sale for a \$12-15 million Cray supercomputer to India. The United States agrees to permit the use of the supercomputer for meteorological sciences, agriculture, health, molecular biology, and solid-state physics. However, no national networking will be allowed. In addition, the security of the computer will be handled by India.

—Sheila Tefft, "Planned Sale of US Computer to India Points up to Snags in Relations," *Christian Science Monitor* (Boston), 29 December 1986, p. 8; in Lexis-Nexis Academic Universe, 29 December 1986, <http://web.lexis-nexis.com>; Inderjit Badhwar, "Supercomputer: A Diplomatic Triumph," *India Today* (New Delhi), 1-15 February 1987, p. 41.

3 December 1986

The government's decision to relocate approximately 6,000 families from the villages surrounding the missile test site in the Balasore district of Orissa draws criticism from opposition parties in parliament. India's Minister of State for Defense, Arun Singh, tells the Lok Sabha that Balasore was selected after examining a total of 30 sites in the country. Balasore is the best site on strategic and technological considerations and no alternative location is available on the north-south axis.

—"Minister defends selection of missile test site," New Delhi Home Service, 4 December 1986; in BBC Summary of World Broadcasts, Lexis-Nexis Academic Universe, 5 December 1986, <http://web.lexis-nexis.com>; "Defense Minister Views Balasore Missile Test Range," Delhi Domestic Service, 6 August 1986, in FBIS VIII, 7 August 1986, p. E1.

November 1986

The Indian-government-owned BEL faces difficulties in trying to obtain "monopulse coherent tracking radars and associated signal processors" from the US-based Scientific Atlanta; US defense officials believe that the technology, which is used for tracking satellites or missiles, is far too advanced and has proliferation implications. BEL's General Manager for Research and Development, K. Menon, says that the deal will most likely be rejected by the US government and India may have to develop the technology indigenously.

[Note: Monopulse tracking radar is capable of "obtaining directional information with great accuracy."]

—John H. Cushman Jr., "US Military Sales to India Hit Snags," *New York Times*, 2 November 1986, p. 5; in Lexis-Nexis Academic Universe, 2 November 1986, <http://web.lexis-nexis.com>; *Academic Press Dictionary of Science and Technology* (Harcourt) www.harcourt.com.

November 1986

The Reagan administration decides to permit the sale of US supercomputers to India. However, US Commerce Secretary Malcolm Baldrige cautions that the United States could sell computers to India "if the security conditions are met." Indian newspapers report that the Indian government has sent a letter of intent to purchase a supercomputer from Cray Research Corp. of Minneapolis.

—Stuart Auerbach, "U.S. to Let India Buy Supercomputer; Nation Must First Agree to Safeguard Advanced

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Machine's Secrets from the Soviets," *Washington Post*, 1 November 1986, p. C1; in Lexis-Nexis Academic Universe, 1 November 1986, <http://web.lexis-nexis.com>.

31 October 1986

India's scientific advisor to the defense minister Dr. V.S. Arunachalam tells reporters that scientists at the Defense Research & Development Laboratory (DRDL) have successfully developed and tested a high-thrust, liquid-fueled rocket engine that generates a thrust of 30-tons and is capable of lifting a payload to a height of 600km into space. According to Arunachalam, the thrust chamber of the engine has been fabricated with stainless steel; propellants are fed with the help of indigenously developed high-performance turbo-pumps.

—"India makes headway in rocket development," Xinhua General Overseas News Service (Beijing), 31 October 1986; in Lexis-Nexis Academic Universe, 31 October 1986, <http://web.lexis-nexis.com>.

11 October 1986

US Defense Secretary Caspar Weinberger arrives in New Delhi. During his visit, he tours Hindustan Aeronautics Limited (HAL) in Bangalore (Karnataka), Bharat Electronics Limited (BEL) in Hyderabad, (Andhra Pradesh), and Aeronautical Development Establishment (ADE) in Bangalore.

—"Caspar Weinberger Arrives 11 October, Issues Statement," Delhi Domestic Service, 11 October 1986, in FBIS VIII, 14 October 1986, p. E.1.

October 1986

India signs contracts worth \$6 to 7 million with two US-based companies, Vitro and Scientific Atlanta, for the supply of advanced missile range technology.

—John Elliott, "India Courts Superpowers for Technology and Aid," *Financial Times* (London), 10 October 1986, p. 8; in Lexis-Nexis Academic Universe, 10 October 1986, <http://web.lexis-nexis.com>.

2 October 1986

The United States extends a \$27 million aid package to India for a mainframe computer manufacturing plant. The plant will be built by the US-based Control Data Corporation for the Indian-government-owned Electronics Corporation of India (ECIL) in Hyderabad (Andhra Pradesh). The aid package will cover the cost of importing manufacturing equipment and related-technology transfers for building 400 to 600 Cyber 830 and 810 mainframe computers. American officials estimate that ECIL's total purchase could amount to \$500 million. Although the Indian government decided to award the contract to Control Data Corporation in 1985, the project was blocked by the Reagan administration pending Indian assurances to the US government that the computers would not be used for nuclear weapons-related research.

—John Elliott, "Aid Finalised for Indian Computer Purchase," *Financial Times* (London), 2 October 1986, p. 6; in Lexis-Nexis Academic Universe, 2 October 1986, <http://web.lexis-nexis.com>.

October 1986

The United States indicates its willingness to sell an advanced radar system to India for its new national missile test facility in Orissa. American officials say that the radar is highly advanced and will give India the capability to test rockets. India's scientific advisor to the defense minister Dr. V.S. Arunachalam says that India's approach is to "get

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the best technology available...at mutually acceptable terms."

—Steven R. Weisman, "U.S. to Sell High-Tech Equipment to India for Arms-Upgrading Plan," *New York Times*, 1 October 1986, p. 15; in Lexis-Nexis Academic Universe, 1 October 1986, <http://web.lexis.nexis.com>.

September 1986

US intelligence officials allege that India may have acquired 12 SS-21 ballistic missiles with their transporter-erector launchers (TELs) from the Soviet Union. In July 1986, US intelligence monitors detected a shipment of 12 missiles and TELs leaving a Black Sea port. The missiles were not delivered to Syria; neither were they offloaded at the Jordanian port of Aqabah. The ship carrying the missile shipment was ultimately located in an Indian port. Indian defense experts dismiss the US intelligence leak as "highly imaginative."

—"India reportedly gets Soviet SS-21 missiles," Xinhua General Overseas News Service (Beijing), 6 September 1986; in Lexis-Nexis Academic Universe, 6 September 1986, <http://web.lexis-nexis.com>.

September 1986

Ved Prakash Sandlas, former project director of the Indian Space Research Organization's (ISRO) SLV-3 program, joins the Defense Research & Development Organization (DRDO).

—Gopal Raj, "SLV-3: India's First Launch Vehicle," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), p. 72.

August 1986

Due to local opposition, the union government scales back the area of the proposed National Testing Range (NTR) at Baliapal from 160 square kilometers to 102 square kilometers (68 square kilometers for the range and 34 square kilometers for the safety zone). The revised project is expected to cost 11 billion rupees and the government estimates that it will likely affect 41,000 people. Groups opposing the project, however, estimate that the number of evictees will be closer to 130,000 people. In addition, they also estimate that the project will indirectly affect an additional 200,000 people who migrate from West Bengal to Baliapal for seasonal employment, 100,000 people who obtain indirect employment through the cash crop economy, and 30,000 fishermen from the area who fish along the Subarnarekha river and the coast.

—Paul Routledge, "The Baliapal Movement," *Terrains of Resistance: Nonviolent Social Movements and the Contestation of Place in India* (Westport: Praeger Publishers, 1993), p. 41.

August 1986

The Indian Space Research Organization (ISRO) begins preliminary discussions for a manned space flight in the 1990s. ISRO chairman Professor U.R. Rao say, "while we would have the capability of launching a man in space by the '90s, the real question is whether we can afford to do it." In addition, ISRO also plans to develop recoverable booster rockets to reduce the costs of launch.

—Raj Chengappa, "Manned Spacecraft: Plans in Orbit," *India Today* (New Delhi), 16-31 August 1986, p. 77.

July 1986

The United States says that it is prepared to respond favorably to an Indian request to purchase supercomputers, pending the negotiation of adequate safeguards with New Delhi. The United States also seeks a common policy

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with Japan for the sale of supercomputers to friendly countries outside the Western alliance to ensure that the technology does not fall into the hands of the Soviet block of countries. Under the US proposal, broad outlines for appropriate sales would be established and then specific sales would be decided on a case-by-case basis. Japanese officials say that they find the US approach "too broad and too stringent."

—Richard M. Weintraub, "US, India Near Supercomputer Deal; Sale Reportedly Hinges on Negotiations Over Safeguards," *Washington Post*, 8 July 1986, p. D1; in Lexis-Nexis Academic Universe, 8 July 1986, <http://web.lexis-nexis.com>.

21 May 1986

The Union government formally announces plans to build the National Testing Range (NTR) in Baliapal (Orissa). The missile range will cover an area of 160 square kilometers and result in the evacuation of nearly 70,000 villagers from 130 villages. The total cost of the project is estimated at 30 billion rupees. The government also announces a 1.27 billion rupee rehabilitation package in the hope of placating local opposition to the project. The plan is to be implemented by the Orissa state government, whose ruling party is the Congress-(I). The plan intends to relocate the people of Baliapal into model villages 15km away from their present homes, each family receiving a house built of 10 decimals of land (one-tenth of an acre) costing 15,000 rupees. The proposed model villages will contain schools, hospitals, community centers, and post offices. The government also proposes to establish nine industries (spinning, leather, oil, and tool manufacture) to provide job opportunities for at least one member of each displaced family. The industries are expected to employ 4,000 people; in addition, the range is expected to generate approximately 470 jobs.

—Paul Routledge, "The Baliapal Movement," *Terrains of Resistance: Nonviolent Social Movements and the Contestation of Place in India* (Westport: Praeger Publishers, 1993), pp. 41, 64-65.

April 1986

Residents of Chaumukh village in the Baliapal area (Orissa) launch a nonviolent political movement to oppose the setting up of the National Testing Range (NTR). Villagers set up barricades at Panchapali, Kachna, Jamkunda and deny entry to government officials.

—Paul Routledge, "The Baliapal Movement," *Terrains of Resistance: Nonviolent Social Movements and the Contestation of Place in India* (Westport: Praeger Publishers, 1993), p. 54.

March 1986

The Indian Space Research Organization (ISRO) postpones the Augmented Satellite Launch Vehicle (ASLV) maiden launch to July-August 1986.

—Raj Chengappa, "Space Programme: Sudden Snags," *India Today* (New Delhi), 16-30 April 1986, p. 84.

1986

Indian rocket scientists identify key technology areas for the advancement of India's long-term satellite launch vehicle (SLV) program. The technology areas encompass solid and liquid propulsion, advanced materials, fabrication, propellants, polymers, chemicals, guidance and control, fluid mechanics, atmospheric flight mechanics, astrodynamics, aerospace communication and avionics, computer systems and software technology, and ground installations. Here are the details of these key technology areas:

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Solid Propulsion

Improvements in computer-aided design capabilities; improved instrumentation and data acquisition systems for static and flight-tests; upgrades in non-destructive testing (NDT) technology; advancements in thermal design, heat transfer, and structural performance of nozzles; development of fabrication technology for advanced composites and 2D/3D carbon-carbon structures.

Liquid Propulsion

Development and qualification of cryogenic engine and stage; development of a 100-ton class thrust engine or cluster of smaller cryogenic engines for a larger cryo stage; development of ground test facilities for the testing of cryogenic engine/stage systems; development of advanced monopropellant hydrazine thrusters of different ratings for orientation and control of launch vehicles; development of liquid bipropellant systems to replace the solid apogee motors in large earth orbiting spacecraft; development of large, light-alloy structural fabrication technology for fuel tanks and auxiliary structures; software development for liquid propulsion and heat transfer analysis.

Propellants, Polymers, and Chemicals

Advanced inexpensive polymers for use as binders in high-energy solid propellants; high-strength, high-temperature resistant plastic for structural components and containers; high-strength organic fibers; advanced polyimide resin systems for fiber-reinforced plastics and composites; conducting plastic materials for vibration and shock isolators; insulating plastics, polyurethane foams, and resin systems; MYLAR, Kapton sheets and foils; production of liquid oxygen and hydrogen, unsymmetrical dimethyl hydrazine (UDMH), monomethylhydrazine, hydrazine, aerazine in pure forms, nitrogen tetroxide in different grades, Kerosene, and RP-1 fuel.

Fabrication

Integration of cast components to minimize detail parts; fabrication of large metallic composite inter-tank bulkheads for liquid cryogenic stage applications; computer-aided manufacturing techniques for fabrication of complex elements such as pump impellers, turbine blades; fabrication of thrust chambers and injectors adopting electroforming, laser drilling, spark erosion, rigi-mesh welding; flow forming of contour nozzles; forming thin walled tubes and brazing for regeneratively cooled nozzles; fabrication of integrally stiffened liquid tankage structures with isogrid construction; advanced fabrication methods for innovative designs in composites and metallic structures.

Guidance & Control

Development of laser- and fiber-optic gyros and other inertial sensors; multiple redundant guidance and navigation systems; distributed control systems for large space vehicles; advanced simulation techniques and associated software.

Fluid Mechanics

Advances in computational fluid dynamics; numerical optimization for design; time-dependent simulations of turbulent flows; development of laser holography and other techniques for non-intrusive measurement of properties and visualizing the flow field.

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Atmospheric Flight Mechanics

Atmospheric entry at high angles of attack (40° to the nominal), and aerothermodynamics; transition and turbulent flow at high-altitudes; stability and control of a large lifting vehicle; hypersonic flow interactions between control surfaces and thick boundary layers at high Reynolds numbers; compilation of flight data for creation of an extensive data bank.

Astrodynamics

Advances in mission-analysis techniques; improvements in mathematical modeling of space vehicle dynamics.

Aerospace Communication and Avionics

Adoption of more robust modulation and demodulation schemes to obviate problems of increased noise in radio signal propagation and interference; advanced digital signal processing techniques; improvements in time and frequency division, multiple-access systems; development of Ku band (44/30/20-GHz) for higher capacity; high-speed real-time processing of data from space; high-gain multiple-beam satellite antennae for use in conjunction with small terminals for data links from space vehicles; development of very large scale integration (VLSI) circuit with high reliability; laser- and fiber-optic communication links for ground systems.

Computer Systems and Software Technology

Dynamic modeling for large multibody vehicles; guidance and control algorithm, multiple reference to coordinate system; onboard microcomputers with bit slice and advanced microprocessors with multiple redundancy and self-diagnostics, FDI logic, and reconfiguration facilities; higher-level languages and programming techniques; use of supercomputers; computer-based methods in statistical quality control, quality assurance, reliability prediction, and probability of mission success.

Facilities & Ground Installations

Establishment of facilities for ground testing and evaluation of propulsion, avionics, control and auxiliary systems; operational facilities for systems integration, checkout, and launching; offshore launch base, recovery and refurbishment and servicing of space vehicles, sea and land recovery of booster/landing vehicles with powered/unpowered phase of flights; multiple global tracking and data relay spacecraft-based network support for large space vehicles; shipborne communications and tracking systems.

—S. Srinivasan and M. Sundaresan, "Technology Challenges Posed by Space Launch Vehicle Programs," *Journal of Aerospace Society of India*, vol. 38, no. 2, 1986, pp. 87-90.

1986

India sends a technical team to Japan to negotiate the sale of one or two supercomputers from the Nippon Electric Company (NEC) for Indian Institute of Sciences (IISc) in Bangalore (Karnataka). India is now believed to be in the market for up to four supercomputers from both Japan and the United States. The Indian team holds at least two rounds of talks at a technical level with NEC officials.

—Richard M. Weintraub, "US, India Near Supercomputer Deal; Sale Reportedly Hinges on Negotiations Over Safeguards," *Washington Post*, 8 July 1986, p. D1; in Lexis-Nexis Academic Universe, 8 July 1986, <http://web.lexis-nexis.com>.

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1986

The Soviet Union offers to sell 48 SS-21 (Tochka) surface-to-surface missiles (SSMs) to India for 2.88 billion rupees. The Indian Army expresses an interest in purchasing the system. However, Minister of State for Defense Arun Singh rules out the purchase unless Defense Research & Development Laboratory (DRDL) fails to deliver the Prithvi SSM on schedule. [Note: The Soviet SS-21 "Scarab" missile is also known as Tochka (Point). The SS-21 was designed by Kolomna OKB as a replacement for the short-range Free Rocket Over Ground (FROG) missile and introduced in service in 1976. The SS-21 is a short-range, road-mobile, solid-propellant, single-warhead ballistic missile. A longer-range "Scarab B" (120km-range) was introduced around 1986 and there are "unconfirmed" reports of a "Scarab C" with a range of 185km. The Scarab A is "6.4m in length and 0.65m in diameter. It has a launch weight of 2,000kg and a minimum range of 15km and maximum range of 70km. Propulsion is a single-stage solid booster, and the missile uses an inertial guidance system. The control system employs four paddle-type rear-mounted control fins...these can control the missile in boost and terminal phases when within the atmosphere. In addition, vanes in the motor efflux contribute to stability immediately after launch. The paddle-type control fins and control vanes are electrically actuated. The missile is reported to be able to fly either ballistic or cruise profiles, the latter profile uses wing lift and keeps the maximum altitude at around 30km followed by a steep dive onto the target." The Scarab A can deliver a 482kg conventional, chemical, or nuclear warhead. The missile is transported on a six-wheeled modified ZIL-5937 or BAZ 5921 transporter-erector launcher (TEL) and the associated transloader vehicle carries an additional two missiles. The SS-21 A has an accuracy of 150m circle of equal probability (CEP). The "Scarab B" uses a "new motor and improved guidance and control...the weight has been increased to 2,010kg and the maximum range has been increased to 120km...[and] minimum range of 20km..." The "Scarab B is reported to have the capability to make preprogrammed maneuvers upto 10g during the terminal phase of flight to make interception more difficult for the defense...the Scarab B has an accuracy of 95m CEP."]

—Raj Chengappa, "The Funny Guys Did It," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers, 2000) pp. 317-318; "SS-21 'Scarab' (OTR-21/9M79 Tochka)," *Jane's Strategic Weapons Systems*, Issue 32, (Coulsdon, Surrey), February 2000, pp. 126-127.

December 1985

The Augmented Satellite Launch Vehicle (ASLV) maiden launch, which was earlier scheduled for December 1985, is delayed until March 1986. Indian Space Research Organization (ISRO) scientists attribute the delay to a 1984 cyclone, which submerged all the rocket test stands under a meter of water. In addition, Indian scientists are also facing difficulties in developing the rocket's closed loop guidance system, which was originally supposed to be deployed on the second ASLV flight.

—Raj Chengappa, "Space Programme: Sudden Snags," *India Today* (New Delhi), 16-30 April 1986, pp. 84-85.

October 1985

Indian Space Research Organization (ISRO) engineers demonstrate strap-on technology in a successful test of an RH-300 sounding rocket with two RH-200 strap-on motors. [Note: Strap-on refers to the "propulsive component of a launch vehicle attached to the core vehicle to augment its thrust, using either solid or liquid propellant."]

—Gopal Raj, "The ASLV: A Technological Bridge," *Reach for the Stars: The Evolution of India's Rocket Programme*

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(New Delhi: Viking by Penguin Books India, 2000), p. 130; Mark Williamson, *Dictionary of Space Technology* (New York: Adam Hilger, 1989), p. 333.

October 1985

India expresses interest in purchasing one or two supercomputers from the United States for meteorological research and weather forecasting. The United States views the request unfavorably due to fears of potential technology leakages to the Soviet Block as well as concerns that the computers could be used for designing nuclear weapons. However, the Reagan administration approves the sale of six super minicomputers to India. A US State Department official says that the Indian request is still on the table but is unlikely to be approved. However, another Reagan administration official says that India's request is being seriously considered by the administration, and India would "get it [supercomputer] in time."

—Sanjoy Hazarika, "U.S. Said to Balk at Sale of Computer to India," *New York Times*, 16 October 1985, p. 17; in Lexis-Nexis Academic Universe, 16 October 1985, <http://web.lexis-nexis.com>.

October 1985

Prime Minister Rajiv Gandhi appoints his close confidante Arun Singh as Minister of State for defense.

—Sumit Mitra and Prabhu Chawla, "Cabinet Reshuffle: A Bold Experiment," *India Today* (New Delhi), 1-15 October 1985, p. 28.

December 1985

First successful test of a pilotless target aircraft (PTA) occurs. The PTA, which can be launched from the ground or ships, "is a reusable, high-subsonic target," used for training gun and missile crews. The PTA's rocket motor, which is developed by the Aeronautical Development Establishment (ADE) in Bangalore (Karnataka), draws on the technological spin-offs of the rocket motors for surface-to-air applications developed by the Defense Research & Development Laboratory (DRDL) in the late 1970s. The motor casing is made of "15CDV6 high-strength steel." The propellant is of "double base composition" and a "seven-grain multi-tubular configuration" is used. The motor is qualified for "various environmental conditions like vibration, drop, high- and low-temperature, cycling, saltmist, sand and dust, and rain." After conducting extensive static tests, DRDL contracts a small private-sector firm to produce a "reliable, air worthy, and high thrust-to-weight ratio rocket motor" with technological inputs from DRDL.

—A.P.J. Abdul Kalam with Arun Tiwari, "Propitiation," *Wings of Fire: An Autobiography* (Hyderabad: Universities Press (India) Limited, 1999), p. 137; J. Jayaraman, "Technological Advances and Cost Effectiveness of Unmanned Air Vehicle Systems," in H.S. Mukunda and A.V. Krishnamurty, eds., *Recent Advances in Aerospace Sciences and Engineering: Volume II* (Bangalore: Interline Publishing, 1992), p. 165; A. Subhananda Rao, "Development of Solid Propulsion Systems for Guided Missiles," in H.S. Mukunda and A.V. Krishnamurty, eds., *Recent Advances in Aerospace Sciences and Engineering* (Bangalore: Interline Publishing, 1992), p. 183.

16 September 1985

First test of the Trishul surface-to-air missile (SAM) from the Sriharikota High-Altitude Range (SHAR).

—A.P.J. Abdul Kalam with Arun Tiwari, "Propitiation," *Wings of Fire: An Autobiography* (Hyderabad: Universities Press (India) Limited, 1999), p. 136.

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August 1985

A senior team of Indian scientists and engineers led by the scientific advisor to the Defense Minister Dr. V.S. Arunachalam visits the United States at the invitation of the US Air Force. The team is on a visit to explore the prospects of high-tech and other defense-related cooperation with the United States. Team members include Roddam Narasimha of the National Aeronautical Laboratory (NAL), K.K. Ganapathy of Hindustan Aeronautics Limited (HAL), and Dr. A.P.J. Abdul Kalam of the Defense Research & Development Laboratory (DRDL).

—A.P.J. Abdul Kalam with Arun Tiwari, "Propitiation," *Wings of Fire: An Autobiography* (Hyderabad: Universities Press (India) Limited, 1999), p. 134.

3 August 1985

Prime Minister Rajiv Gandhi lays the foundation stone for the Research Centre Imarat (RCI) at Imarat Kancha (Andhra Pradesh).

—A.P.J. Abdul Kalam with Arun Tiwari, "Propitiation," *Wings of Fire: An Autobiography* (Hyderabad: Universities Press (India) Limited, 1999), pp. 133.

12 June 1985

The Reagan administration agrees to sell advanced military technology and weaponry to India. However, the United States insists on Indian acceptance of tight safeguards to prevent the leakage of US defense secrets to "third countries." A US official says that the memorandum of understanding to put the agreement on high-technology transfers into effect has now been signed and procedures have been established to expeditiously process India's requests for computers, lasers, sensors, and other items with military applications.

—Michael Weisskopf and Don Oberdorfer, "U.S. to Offer Advanced Arms, Technology to India," *Washington Post*, 13 June 1985, p. A1, in Lexis-Nexis Academic Universe, 13 June 1985, <http://web.lexis-nexis.com>; Bernard Weinraub, "Reagan-Gandhi Talks Touch on Arms," *New York Times*, 12 June 1985, p. 3, in Lexis-Nexis Academic Universe, 13 June 1985, <http://web.lexis-nexis.com>.

Summer 1985

The Defense Research & Development Laboratory (DRDL) completes groundwork for building the new missile technology research center at Imarat Kancha, (Andhra Pradesh).

—A.P.J. Abdul Kalam with Arun Tiwari, "Propitiation," *Wings of Fire: An Autobiography* (Hyderabad: Universities Press (India) Limited, 1999), p. 133.

3 May 1985

Indian and US officials say that they are close to reaching an agreement that will permit India to acquire highly advanced US technology, including technology with military applications.

—Steven R. Weisman, "US-India Technology Accord Gains," *New York Times*, 3 May 1985, p. 3; in Lexis-Nexis Academic Universe, 4 May 1985, <http://web.lexis-nexis.com>.

March 1985

Indian government officials visit Washington to lay the groundwork for Prime Minister Rajiv Gandhi's June 1985 trip to the United States. They discuss the details of a broad umbrella agreement on high-grade technology

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transfers to India with Reagan administration officials. India's request for high-technology goods is reviewed favorably in Washington.

—Venugopala Rao, "India: Moving Closer to US Through Technology?," Inter Press Service, 5 March 1985; in Lexis-Nexis Academic Universe, 5 March 1985, <http://web.lexis-nexis.com>.

January 1985

Indian engineering giant Larsen & Toubro begins drawing up plans to build a heavy engineering workshop at Hazira (Gujarat) to build "plant equipment and modules for nuclear power plants, heavy water machinery, and rocket casings" for India's nuclear and space programs.

—Jagannath Dubashi, "Larsen & Toubro: Aiming High," *India Today* (New Delhi), 16-31 January 1985, p. 68.

1985

Production of the Milan 2 anti-tank guided missile (ATGM) commences at Bharat Dynamics Limited (BDL) in Hyderabad (Andhra Pradesh). The Milan ATGM is being produced under license from M/s Euromissile, France. [Note: Milan 2 is a "man portable" ATGM with a range of 25-2,000m. The missile has a length and weight of 1,200mm and 12.50kg, respectively.]

—"Bharat Dynamics Limited: Defence Production & Supply," *Indian Armed Forces*, www.indianarmedforces.com; "Missiles: Milan 2 Anti-Tank Missile System," *Department of Defence Production & Supplies: Ministry of Defence*, (Government of India), p. 122, www.defstand.gov.in.

1984-1980

1984-1985

The production capacity of the ammonium perchlorate (AP) experimental plant in Alwaye (Kerala) climbs to 160 tons annually.

—Gopal Raj, "Developing Competence in Solid Propulsion," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), p. 99.

Post-1984

The Defense Research & Development Laboratory (DRDL) approaches the Indian Institutes of Technology (IIT) in New Delhi to develop a small working-model of a multi-directional weaving device to weave carbon fibers for the Agni's re-entry heat shield. However, Agni's design team is dissatisfied with IIT's efforts and decides to import a six-axis filament-winding machine with computer controllers from West Germany using an Indian textile manufacturer as a front. DRDL also uses a front company to import equipment from the United States to impregnate graphite into carbon fiber used in the heat shield. These are ultimately used to develop carbon-carbon fibers for the Agni's re-entry vehicle. Four Defense Research & Development Organization (DRDO) and Council of Scientific & Industrial Research laboratories develop the carbon-carbon technology within 18 months. DRDL engineers J.C. Bhattacharya and K.V. Ramana Sai also decide to use two 16-bit Intel 8086 microprocessors for the Agni's onboard computation system.

[Note: Imports are routed through front companies to defeat missile-related technology denial controls informally

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instituted by the United States.]

—Raj Chengappa, "The Agni Pariksha," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers, 2000), pp. 346-348; A.P.J. Abdul Kalam with Arun Tiwari, "Propitiation," in *Wings of Fire: An Autobiography* (Hyderabad: Universities Press (India) Limited, 1999), pp. 138-139.

Post-1984

The Defense Research & Development Organization's (DRDO) launches an extensive collaborative effort with technological academic institutions in the country. Staff faculty and their students are recruited to participate in missile related projects. Joint advanced technology programs are instituted with the IISc, Bangalore (Karnataka), and Jadavpur University, Jadavpur (West Bengal). Several other academic institutions such as the Indian Institutes of Technology (IIT) also participate in the design and development of Defense Research & Development Laboratory's (DRDL) missile programs. A team of graduate students at Jadavpur University led by Professor Ghoshal develops the "guidance algorithm" for the Prithvi. Postgraduate students at Indian Institute of Sciences (IISc) led by Professor I.G. Sharma write the software to evaluate multi-target acquisition for systems such as the Akash SAM. A team of scientists from DRDO and IIT in Chennai (Tamil Nadu) develops a re-entry vehicle system design methodology for the Agni re-entry vehicle technology demonstrator; similarly a team of scientists led by Professor S. M. Deshpande, IISc, develops software for computational fluid dynamics for hypersonic regimes, which is used for predicting the Agni payload's behavior during re-entry into the earth's atmosphere. Other successful collaborative efforts include the development of "ferrite phase shifters" by Professor Bharati Bhatt of IIT (New Delhi) and the Solid State Physics Laboratory, New Delhi and Central Electronics Laboratory in Ghaziabad (Uttar Pradesh). Professor Saraf of IIT in Kharagpur (West Bengal) and B.K. Mukhopadhyay of Research Centre Imarat (RCI) in Hyderabad (Andhra Pradesh) develop a "millimetric wave antenna" for the Nag seeker head within two years. The Navigational Electronics Research & Training Unit at Osmania University in Hyderabad (Andhra Pradesh) develops state-of-the-art signal processing algorithms for the Nag anti-tank missile. The Central Electrical & Electronics Research Institute (CEERI) in Pilani (Rajasthan) develops an impact diode in collaboration with the Space Physics Laboratory (SPL) and RCI.

—A.P.J. Abdul Kalam with Arun Tiwari, "Propitiation," *Wings of Fire: An Autobiography* (Hyderabad: Universities Press (India) Limited, 1999), pp. 137-139; "Millimeter Wave Radar," *Research Horizons* (Atlanta: Georgia Institute of Technology), <http://gtresearchnews.gatech.edu>.

Late 1984

The Defense Research & Development Organization's (DRDO) forms a "Special Purchase Team" to buy valves, chips, microprocessors, and gyros for the Integrated Guided Missile Program (IGMDP). Indian embassies in London and Washington, D.C. arrange special meetings with key suppliers in the United States and Britain for the supply of these parts. Anticipating supplier controls, the purchase team headed by J.C. Bhattacharya purchases stocks for as many as 50 missiles, including those for Prithvi, Agni, and Trishul. Gyros are purchased from France and Sweden; hydraulic actuators acquired from France. In addition, computers, motion simulators and three-axis measuring machines are procured from the United States and West Germany, respectively. The total bill for these purchases in 1984 is estimated at 500 million rupees. [Note 1: Actuators are used in flight-control systems of missiles. The "flight control system sets the actuators on control surfaces to introduce pitch, roll, and/or yaw; holds these

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settings until the orientation has changed; and then resets the actuators to maintain the new profile." An actuator can either be "rotary or linear. A rotary actuator can be powered by an electric motor...this actuator must not only be capable of rotating the control surface into a significant aerodynamic force, but also supporting the entire mass of the missile during high-acceleration launches and maneuvers. Linear actuators are connected to control surfaces through mechanical linkages that convert the linear actuator motion into an angular surface motion. These actuators are powered by an electric motor, pressurized gas, or hydraulic fluid."; Note 2: Motion simulators are "precision machines that rotate a mounting table about multiple axes at precisely known speeds and angles. They are normally used in guidance development to test instruments and inertial measurement unit assemblies."

—Raj Chengappa, "The Funny Guys Did It," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers, 2000) pp. 315-316; "Category II-Item 10: Flight Control," *Missile Technology Control Regime: Annex Handbook*, pp. 10-2-10-3; "Category II-Item 9: Navigation," pp. 9-19.

October 1984

Professor Satish Dhawan retires as Chairman of the Indian Space Research Organization (ISRO); Professor U. R. Rao is appointed as his successor. In an interview, Rao emphasizes the peaceful nature of India's space program. He says, "our space programme is based on peaceful applications...our entire profile is very open and there is not one element of military business. None of our satellites has so far been designed for spying. We are not doing it."

—Raj Chengappa, "Space: A Smooth Succession," *India Today* (New Delhi), 16-31 October 1984, pp. 70-71.

October 1984

Orissa Chief Minister J.B. Patnaik announces that the union government has selected Baliapal as the site for the proposed National Testing Range (NTR) to test and develop missiles. [Note: The union government cites the following reasons for selecting Baliapal over other potential missile test sites:

- Distance from major population centers
- Distance from major air and sea routes
- Flat terrain and absence of mineral deposits
- Good weather conditions; roughly 200 clear days a year
- Shallow seabed to enable easy missile recovery after tests
- Location outside the surveillance range of Pakistani radars
- Site sufficiently large to accommodate down-range instrumentation sites
- Location to permit testing of both short-range and long-range missiles of ranges up to 5,000km
- Shallow curved shape of coast permits easy tracking of missiles in the post-launch phase
- Firm soil conditions allow construction of supporting infrastructure

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- Good road and rail communications links]

—Paul Routledge, "The Baliapal Movement," *Terrains of Resistance: Nonviolent Social Movements and the Contestation of Place in India* (Westport: Praeger Publishers, 1993), pp. 40-41.

September 1984

A senior Indian delegation led by the Deputy Minister for Electronics Dr. Sanjeevi Rao visits the Soviet Union to purchase high-powered computers for India's defense and nuclear industry. The Soviet Union agrees to supply its latest-generation "Elbrus" computer system to India for \$20 million. Under the agreement, the USSR agrees to install the first Elbrus system in 1985 and subsequently supply computers to India after a one-year proving time. The computers are to be used for setting up a regional computer center. The USSR also agrees to sell India two other computers with a value between six and eight million dollars. Indian requests to procure fourth-generation computers are rejected by the United States, France, Britain, and Japan due to apprehensions that the computers might be used for India's defense and nuclear programs.

—D.P. Kumar, "India turns to Soviet Union for computers," *Financial Times* (London), p. 5; in Lexis-Nexis Academic Universe, 27 September 1984, <http://web.lexis-nexis.com>; "Soviet Union to give India super computer," Xinhua General Overseas News Service (Beijing), 26 October 1984; in Lexis-Nexis Academic Universe, 26 October 1984, <http://web.lexis-nexis.com>.

27 September 1984

The scientific advisor to the defense minister, Dr. V.S. Arunachalam, leads a comprehensive status review of the Integrated Guided Missile Program (IGMDP). Defense Research & Development Organization's (DRDO) labs, the Indian Space Research Organization (ISRO), academic institutions, and production agencies participate in the review. During the review, the Defense Research & Development Laboratory (DRDL) finalizes plans to establish a model high-technology research center with advanced technical facilities at the Imarat Kancha area near Hyderabad (Andhra Pradesh). The planned facilities include, "inertial instrumentation laboratory, full-scale environmental and electronic warfare test facilities, a composites production center, a high-enthalpy facility, and a state-of-the-art missile integration and checkout centre." The facility is ultimately named Research Centre Imarat (RCI).

—A.P.J. Abdul Kalam with Arun Tiwari, "Propitiation," in *Wings of Fire: An Autobiography* (Hyderabad: Universities Press (India) Limited, 1999), pp. 125, 130-131.

August 1984

News media reports suggest that the United States has refused to clear the deal between the Baroda-based NSF and the US firm Hemlock on technical collaboration for the manufacture of polycrystalline silicon. However, Indian officials deny these reports and claim that Hemlock's application is being considered "sympathetically" in Washington.

—T.N. Ninan, "Technology Transfer: Restrictive Practice," *India Today* (New Delhi), 16-31 August 1984, p. 56.

19 July 1984

Prime Minister Indira Gandhi visits the Defense Research & Development Laboratory (DRDL) in Hyderabad (Andhra

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Pradesh). Dr. Abdul Kalam informs her that the first flight-test of the Prithvi is scheduled for June 1987.

—A.P.J. Abdul Kalam with Arun Tiwari, "Propitiation," in *Wings of Fire: An Autobiography* (Hyderabad: Universities Press (India) Limited, 1999), pp. 129-130.

26 June 1984

Indian scientists decide to test the attitude control and on-board computer systems developed for the Prithvi ballistic missile program. They improvise by testing these subsystems on a modified Devil missile. A Devil missile is dismantled, modified, reconfigured, and successfully test-fired on 26 June 1984. This flight-test is also used to test an Indian strap-down inertial navigation system. According to Dr. A.P.J. Abdul Kalam, this is a historic landmark in the history of India's missile development program as it marks the shift from "reverse engineering" to designing indigenous systems.

—A.P.J. Abdul Kalam with Arun Tiwari, "Propitiation," in *Wings of Fire: An Autobiography* (Hyderabad: Universities Press (India) Limited, 1999), p. 129.

April-June 1984

A Defense Research & Development Laboratory (DRDL) team lead by Dr. A.P.J. Abdul Kalam begins visiting academic campuses around India to aggressively recruit engineers for India's missile program. DRDL hopes to hire at least 300 new engineers for its projects.

—A.P.J. Abdul Kalam with Arun Tiwari, "Propitiation," in *Wings of Fire: An Autobiography* (Hyderabad: Universities Press (India) Limited, 1999), p. 132.

April 1984

A newly created government entity, National Silicon Facility (NSF), signs a 900 million rupee contract with the US-based Hemlock Semiconductors Inc. to build a 200-ton plant to manufacture polycrystalline silicon at Baroda (Gujrat). The new plant is expected to come online in 1988. [Note: Polysilicon is used to manufacture large-scale integrated circuits and solar photo-voltaic cells.]

—"National Silicon Facility: Controversial Contract," *India Today* (New Delhi), 16-31 May 1984, p. 63.

1984

The United States and India sign a memorandum of understanding on high-technology transfers to India. Although an agreement is reached in principle, both sides have difficulties in arriving at a common language to put the agreement into effect. The United States insists that India take steps to prevent technology leakages to the Soviet Union and East European countries. US officials also demand assurances from New Delhi that the technology will not be used for making nuclear weapons.

—Steven R. Weisman, "US-India Technology Accord Gains," *New York Times*, 3 May 1985, p. 3; in Lexis-Nexis Academic Universe, 4 May 1985, <http://web.lexis-nexis.com>.

1983-1984

A missile subsystem team led by K. V. Ramana Sai and P. Banerjee develops an "attitude control system" and an on-board computer for ballistic missiles.

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—A.P.J. Abdul Kalam with Arun Tiwari, "Propitiation," in *Wings of Fire: An Autobiography* (Hyderabad: Universities Press (India) Limited, 1999), p. 129.

1983-1984

Search begins for a site to build a dedicated missile test range. The Defense Research & Development Laboratory (DRDL) identifies a suitable site along India's northeastern coastline to build test the National Testing Range (NTR). Pending the completion of the new test range, DRDL decides to build an interim facility adjacent to the Proof Experimental Establishment at Chandipur in the Balasore district of Orissa. Three hundred million rupees are sanctioned to build a dedicated test range for India's missile programs and, in an unprecedented decision, the construction is contracted to a private-sector construction firm. In the interim, Kalam and his team decide to use Indian Space Research Organization (ISRO) facilities at the Sriharikota High-Altitude Range (SHAR) in Sriharikota (Andhra Pradesh) for missile tests.

—A.P.J. Abdul Kalam with Arun Tiwari, "Propitiation," in *Wings of Fire: An Autobiography* (Hyderabad: Universities Press (India) Limited, 1999), pp. 125-127.

1983-1985

The Agni design team submits four different designs for the Agni. Agni Project Director R. N. Agarwal and Dr. A.P.J. Abdul Kalam favor an all-solid motor configuration for the missile. However, the solid-motor configuration is opposed by Dr. V.S. Arunachalam and R. Gopalswami, who favor the use of the Prithvi's liquid-fueled engines in at least one the missile's stages. Finally, the selected configuration has a solid-fuel motor derived from the Indian Space Research Organization's (ISRO) SLV-3 in the first stage and liquid-fueled engines from the Prithvi in the second stage. Indian scientists say that the hybrid configuration is the result of the Defense Research & Development Laboratory's (DRDL) historical experience with developing liquid-fueled engines. [Note: The timeframe outlined above is a rough estimate, as there is no publicly available information that provides precise information on the design, development, and production phases of the Agni.]

—Raj Chengappa, "The Agni Pariksha," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers, 2000), pp. 345-346.

October 1983

The government-owned SCL completes the construction of a 450 million rupee plant to manufacture large-scale integrated circuits at the Mohali industrial complex outside Chandigarh (Punjab). The plant will manufacture 8-bit and 16-bit microprocessors as well as 16K RAM.

—T.N. Ninan, "Electronics: The Chips are Coming," *India Today* (New Delhi), 15 October 1983, pp. 58-59.

Early 1980s

The Defense Research & Development Laboratory (DRDL) decides to develop strap-down inertial navigation systems for ballistic missiles for "up to a medium-range application."

—Dr. N.C. Birla and B. S. Murthy, eds., "Inertial Guidance and Sensors," *Indian Defence Technology: Missile Systems* (DRDO, Ministry of Defence, December 1998), p. 156.

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27 July 1983

India formally announces the launching of the Integrated Guided Missile Program (IGMDP) to develop a family of missiles. The five missiles to be developed by the Defense Research & Development Laboratory (DRDL) are a short-range ballistic missile (Prithvi), an intermediate-range ballistic missile (IRBM; Agni), an anti-tank missile (Nag), a low-level surface-to-air missile (SAM; Trishul), and a medium-range SAM (Akash).

—Dr. N. C. Birla, ed., "The Origins," *Indian Defence Technology: Missile Systems* (New Delhi: Defense Research & Development Organization, Ministry of Defense, 1998), pp. ix-x; A.P.J. Abdul Kalam with Arun Tiwari, "Propitiation," in *Wings of Fire: An Autobiography*, (Hyderabad: Universities Press (India) Limited, 1999), pp. 117-118.

July 1983

The Indian cabinet formally approves the guided missile program and sanctions 3.8 billion rupees for the project.

—Raj Chengappa, "Arsenal For The Gods," *Weapons of Peace: The Secret Story of India's Quest to Be a Nuclear Power*, (New Delhi: Harper Collins Publishers, 2000), p. 279; A.P.J. Abdul Kalam with Arun Tiwari, "Propitiation," in *Wings of Fire: An Autobiography* (Hyderabad: Universities Press (India) Limited, 1999), pp. 117.

17 April 1983

Successful launch of the SLV-3 occurs. The 23m-high, four-stage, solid-propellant rocket places a 40kg RS-D2 satellite into a nominal elliptical orbit (936km at its apogee and 420km at its perigee), at an inclination of 45 degrees to the equator. [Note: Indian rocket scientists have emphasized that although India's SLV-3 was modeled on the US Scout, it was not an exact copy. The latter would have only been possible through license manufacture. While designing the SLV-3, Indian scientists did use the Scout's configuration and design parameters as a reference, but they had to develop the propellants, materials, and sub-systems independently. Since the Scout used solid-propellant motors from US military missiles, it had better-optimized lower stages. In contrast to the Scout, which used a monolithic solid motor in its first stage, the SLV-3's first stage comprised of three segments. The upper two stages of the SLV-3 had fiberglass casings to reduce weight. However, in the fourth and final flight of the SLV-3, the fourth stage was made of Kevlar, a high-strength fiber to reduce the weight of the motor casing and subsequently increase the weight of the payload. American scientists made the transition to Kevlar in the Scout's fourth stage much earlier. In addition, the SLV-3 and Scout used different control systems. Lastly, the US Scout had better guidance capability.]

—Stewart Slavin, "India launches satellite," Sunday, 17 April 1983; in Lexis-Nexis Academic Universe, 17 April 1983, <http://web.lexis-nexis.com>; Gopal Raj, "SLV-3: India's First Launch Vehicle," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), pp. 57-59.

January 1983

First launch of the single-stage RH-300 sounding rocket occurs. [Note: The RH-300 is later lengthened to accommodate an additional 100kg of propellant. The resulting RH-300 Mk-II becomes a replacement for the two-stage Centaure sounding rocket first acquired in the 1960s from France.]

—Gopal Raj, "First Steps in Rocketry," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), p. 41.

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12 January 1983

India successfully launches a RH-560 rocket with a 90kg-payload from the Sriharikota High-Altitude Range (SHAR) in Sriharikota (Andhra Pradesh). The rocket reaches an altitude of 330km and carries a technological payload to evaluate various aerodynamic and structural parameters of rockets. Indian Space Research Organization (ISRO) sources claim, "the flight has opened up possibilities for various applications of rocket technology."

—"India launches Rohini-560 rocket," Xinhua General Overseas News Service (Beijing), 14 January 1983; in Lexis-Nexis Academic Universe, 14 January 1983, <http://web.lexis-nexis.com>.

1983

The Defense Research & Development Laboratory (DRDL) establishes an external fabrication office under P.K. Biswas to coordinate activities with government-owned, public-sector units and other private-sector companies associated with the development of missile-related hardware.

—A.P.J. Abdul Kalam with Arun Tiwari, "Propitiation," *Wings of Fire: An Autobiography* (Hyderabad: Universities Press (India) Limited, 1999), p. 143.

1983

Dr. A.P.J. Abdul Kalam involves the Indian Space Research Organization (ISRO) in the Prithvi program by requesting its liquid-fueled engine experts, including A. E. Muthunayagam and N. Narayan, who are building the Vikas engine, to conduct an independent technical audit of the scaled-up version of the Devil's liquid-propulsion system developed for the Prithvi.

—Raj Chengappa, "The Funny Guys Did It," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers, 2000), pp. 313-314.

1983

Explaining the rationale for his decision in favor of liquid-fueled engines, Dr. V.S. Arunachalam says, "there was a very strong local reason for deciding that Prithvi should be powered by liquid-fueled engines. The DRDL [Defense Research & Development Laboratory] spent years developing it. We would have completely demoralized the laboratory [DRDL] if we said we were going to space [ISRO] to get a solid propellant. Also we avoided catastrophic failures because there were no surprises with the engine. Our decision saw Prithvi becoming the missile to be proven in the stable because it already had a proven technology." His decision is seconded by Kalam, who says, "the fact was that DRDL had tremendous amount of experience in liquid propulsion systems. They had tested them for more than a thousand seconds and there was an experienced team geared up to build the engine. It also had the advantage for short-range missiles because you could terminate the engine any time, giving the missile greater amount of maneuverability....don't forget, it has saved us a lot of money and brought down our time schedules considerably."

—Cited in Raj Chengappa, "The Funny Guys Did It," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers, 2000), p. 311-312.

1983

Design work for the Prithvi begins at the Defense Research & Development Laboratory (DRDL) in Hyderabad (Andhra Pradesh). Indian scientists debate whether to develop solid-motors or liquid-fueled engines for the Prithvi.

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Kalam favors a solid-fuel configuration. He argues that solid-fueled motors are less complex and easier to maintain as they can store fuel for long periods of time. Solid-fueled motors also have no pumps or valves that are characteristic of liquid-fueled engines. Unlike liquid-fueled missiles, which are toxic and require complex handling, logistics support, and prolong launch preparations in the field by as many as 12 hours, solid-fueled missiles can be fired quickly. However, the liquid-propellant lobby argues that due to the poor conditions of Indian roads, cracks could develop in the solid-fuel casts, which in turn would have a negative effect on the missile's performance. Liquid-fueled missiles would also offer greater elasticity in range (40-150km) as the engine could be shut down by turning off the fuel supply. This could be achieved with solid-fuel motors as well, but would require complex thrust-termination technology including flexible nozzles, which DRDL would have to develop separately. Those favoring liquid-fueled engines also argue that DRDL's organizational rivalry with the Indian Space Research Organization (ISRO) and history of developing the Devil and Valiant engines give it a natural advantage in continuing with liquid-fueled engines. IISRO cites time and organizational constraints and expresses reluctance in designing a solid-fuel motor for Prithvi. Ultimately, Defense Research & Development Organization's (DRDO) Director Dr. V. S. Arunachalam decides in favor of liquid-fueled engines.

—Raj Chengappa, "The Funny Guys Did It," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers, 2000), pp. 309-311; Steven M. Flank, "Indian Missile and Space Programs: Strategic Alliance vs. National Consensus," in *Reconstructing Rockets: The Politics of Developing Military Technology in Brazil, India, and Israel*, Ph.D. Dissertation, MIT, 1993, pp. 131-194; Duncan Lennox, ed., *Jane's Strategic Weapons Systems*, Issue 32, 2000, pp. 75-76.

1983

Dr. A.P.J. Abdul Kalam appoints project directors for the missile programs.

- Colonel V.J. Sundaram: Prithvi
- Commodore S.R. Mohan: Trishul
- R.N. Agarwal: Agni
- R.R. Prahlada: Akash
- N.R. Iyer: Nag

—A.P.J. Abdul Kalam with Arun Tiwari, "Propitiation," in *Wings of Fire: An Autobiography*, (Hyderabad: Universities Press (India) Limited, 1999), pp. 122-123; Raj Chengappa, "The Devil's Workshop," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers, 2000), p. 163.

2 November 1982

Defense Minister R. Venkataraman informs parliament that India has the infrastructure to manufacture anti-tank and surface-to-surface missiles (SSMs). The Defense Research & Development Organization's (DRDO) is also developing a number of technologies for anti-tank and surface-to-air missiles (SAMs).

—"Production of Surface-to-Air Missiles Begins," Delhi Domestic Service, 2 November 1982, in FBIS Document, "India," VIII. p. E2.

1982-1983

Defense Minister R. Venkataraman, his scientific advisor, Dr. V.S. Arunachalam, and Dr. A.P.J. Abdul Kalam decide that the Defense Research & Development Laboratory (DRDL) should focus on building strategic missiles that will

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meet India's requirements beyond the year 2000. They decide to apportion 10% of the Defense Research & Development Organization (DRDO) annual budget for the project. Kalam anticipates that the United States and its Western allies will try and deny critical missile-related technologies to India. DRDL decides to defeat the anticipated denials by purchasing the requisite technologies abroad and developing key technologies simultaneously. DRDL identifies five critical technologies that will have to be developed indigenously. These include, "phase shifters for radars, impact diodes that act as high-frequency power sources, carbon-carbon composites to withstand the heat of re-entry, key sensors for guidance systems, and computerized fluid dynamic models."

—Raj Chengappa, "The Missile Man," *India Today* (New Delhi), 15 April 1994, p. 44.

12 September 1982

Dr. A.P.J. Abdul Kalam makes a formal presentation for a prospective guided missile program before Defense Minister R. Venkataraman, the three service chiefs, the union government secretaries for defense and expenditure. He proposes that India develop a surface-to-surface missile (SSM) capable of delivering a half- or one-ton warhead over a range of 150-250km (SS 150); a multi-role surface-to-air missile (SAM) called Tactical Combat Vehicle (TCV); a state-of-the-art SAM that could engage multiple targets called SAMX; an anti-tank missile with "fire-and-forget" capabilities termed ATM3; and finally, an intermediate-range ballistic missile codenamed REX (Re-Entry Vehicle Project X). Kalam estimates total project costs at 3.9 billion rupees; he also expects the project to be completed within 12 years. Kalam proposes that India first develop the TCV and SS 150 before attempting the development of other missiles. However, Defense Minister Venkataraman persuades the Defense Research & Development Laboratory (DRDL) to undertake the development of all missiles simultaneously. An estimate of 3.9 billion rupees is presented to the defense minister, which is then sent to the cabinet for approval.

—A.P.J. Abdul Kalam with Arun Tiwari, "Propitiation," in *Wings of Fire: An Autobiography* (Hyderabad: Universities Press (India) Limited, 1999), pp. 113-114; Raj Chengappa, "Arsenal For The Gods," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers, 2000), pp. 276-279.

26 June 1982

In an address to the Indian parliament's consultative committee on defense, Defense Minister R. Venkataraman says that a lot of work has been done on missiles, including their guidance system. He also informs the committee members that a plant is being built in Hyderabad (Andhra Pradesh) for producing special alloys for aircraft.

—"Defense Minister on Weapons Development," Delhi Domestic Service, 26 June 1982, in FBIS Document, "India," VIII, 30 June 1982, p. E1.

June 1982

Dr. A.P.J. Abdul Kalam forms a committee to draw up a "clear and well-defined programme for the production of indigenous missiles." Committee members include Z. P. Marshall, N. R. Iyer, A.K. Kapoor, and K.S. Venkataraman. The committee studies the design of 16 different missiles and analyzes the range of tasks involved from developing technologies, to actually producing, testing, and deploying the missiles, and drafts a paper on the future of India's indigenous missile programs for the consideration of the Cabinet Committee on Political Affairs (CCPA).

—A.P.J. Abdul Kalam with Arun Tiwari, "Propitiation," in *Wings of Fire: An Autobiography* (Hyderabad: Universities

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Press (India) Limited, 1999), pp. 113; Raj Chengappa, "Arsenal For The Gods," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power*, (New Delhi: Harper Collins Publishers, 2000), p. 276.

1 June 1982

Dr. A.P.J. Abdul Kalam formally joins the Defense Research & Development Laboratory (DRDL) in Hyderabad (Andhra Pradesh).

—A.P.J. Abdul Kalam with Arun Tiwari, "Propitiation," in *Wings of Fire: An Autobiography* (Hyderabad: Universities Press (India) Limited, 1999), pp. 111.

June 1982

The Department of Space clears proposals to build the ASLV and PSLV and apports 197.3 million rupees for the ASLV program. [Note: The four stages of the SLV-3 will form the "core of the ASLV, with two strap-on motors, each identical to the SLV-3's first stage." Unlike the SLV-3, which uses an open-loop guidance system, the ASLV will use a combination of an "open-loop" and "closed-loop" or inertial guidance systems, which will allow it to place satellites in a 400km near-circular orbit with greater precision. The ASLV will be designed to fly with an "open-loop" in the first stage of its flight. The "closed-loop" guidance will begin operation in the second stage and jettisoned after the third stage of flight. The ASLV will also carry a "bulbous heat shield so that satellites larger than the rocket's diameter" can be accommodated. Unlike the SLV-3, which was integrated horizontally and then raised to a vertical position for launch, the ASLV will be integrated vertically in a Mobile Service Tower (MST).]

—Gopal Raj, "The ASLV: A Technological Bridge," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), pp. 127-131.

18 April 1982

Indian Space Research Organization's (ISRO) secretary Dr. Y. S. Rajan reports that India has begun constructing test facilities for a liquid rocket motor—Vikas—at Mahendragiri (Tamil Nadu). The facility, which is being built in collaboration with West Germany's help, will come under the direct control of VSSC, Thiruvananthapuram (Kerala). Work on an engineering model and a prototype of the Vikas liquid-rocket engine has already started.

—"Rocketry," New Delhi Home Service, 18 April 1982; in BBC Summary of World Broadcasts, Lexis-Nexis Academic Universe, 28 April 1982, <http://web.lexis-nexis.com>.

April 1982

Dr. A.P.J. Abdul Kalam visits the Defense Research & Development Laboratory (DRDL) in Hyderabad (Andhra Pradesh). He is briefed on the laboratory's "five staff projects," and "sixteen competence-building projects." The laboratory is also involved in developing several technologies with the objective of gaining "lead time" for the development of indigenous missile systems in the future. Kalam is impressed by the DRDL's efforts to develop "twin 30-ton" liquid propellant engines.

—A.P.J. Abdul Kalam with Arun Tiwari, "Propitiation," in *Wings of Fire: An Autobiography* (Hyderabad: Universities Press (India) Limited, 1999), p. 110.

16 March 1982

Defense Minister R. Venkataraman tells parliament that India is evolving a long-term defense strategy. However,

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he refuses to divulge "anything more" about the long-term preparations.

—"Minister: Country Prepared For Any Threat," AFP (Hong Kong), 16 March 1982, in FBIS Document, "India," VIII, 17 March 1982, p. E1.

4 February 1982

The Director of SAC Professor U.R. Rao discloses that India's next satellite launch vehicle capable of launching a 150kg satellite, will be ready within two years.

—"Space Effort," New Delhi Home Service, 4 February 1982; in BBC Summary of World Broadcasts, Lexis-Nexis Academic Universe, 3 March 1982, <http://web.lexis-nexis.com>.

February 1982

Dr. A.P.J. Abdul Kalam appointed director of the Defense Research & Development Laboratory (DRDL) in Hyderabad (Andhra Pradesh). [Note: Kalam received an honorary doctorate from Anna University in 1982.]

—A.P.J. Abdul Kalam with Arun Tiwari, "Propitiation," in *Wings of Fire: An Autobiography* (Hyderabad: Universities Press (India) Limited, 1999), p. 109.

1982

Dr. V.S. Arunachalam is appointed scientific advisor to the defense minister.

—Raj Chengappa, "The Lawyer And The Blacksmith," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: HarperCollins Publishers India, 2000), p. 264.

1982

Dr. A.P.J. Abdul Kalam undertakes an intensive failure analysis of the Defense Research & Development Laboratory's (DRDL) earlier missile projects. He identifies the DRDL's key failures as poor interaction with user services such as the Army and Air Force, overemphasis on in-house research as against subcontracting to private sector companies, and academic institutions, and the paucity of funds at critical stages of projects. Kalam draws on his managerial experience at the Indian Space Research Organization (ISRO) to introduce organizational changes at DRDL. DRDL is reorganized with a Guided Missile Board at the top with Dr. V. S. Arunachalam as the chair and Dr. A.P.J. Abdul Kalam as secretary. The board includes secretaries from the defense and finance ministries, the heads of key public sector industries involved in production, and the vice-chiefs of the armed services. At the middle-organizational level, a Programme Management Board is constituted with Kalam as its chair. The board includes the heads of all laboratories involved in the missile program as well as senior officers from the armed services. At the bottom tier, Kalam forms a Project Management Board headed by individual missile project directors with representatives from public sector companies and the armed services. These organizational changes are introduced to ensure effective coordination between all agencies involved in the program. Instead of developing the key technologies in-house, Kalam and his team decide to adopt the consortium approach and collaborate with research institutes, universities, and private sector companies. To avoid past failures, Kalam also adopts ISRO's peer-review culture to provide scientists with a negative feedback loop during the design and development process. ISRO experts are invited to provide an informal pooling of knowledge for the missile program. DRDL adopts a "concurrent engineering" model of development and production. Under this model, once the commitment of the user and flexibility of the weapon system are established, the program of development, user

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interaction, industry interaction, and actual production are tightly coupled to minimize the time-gap between development and final serial-production.

—Raj Chengappa, "Arsenal For The Gods," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power*, (New Delhi: Harper Collins Publishers, 2000), pp. 279-284; Raj Chengappa, "The Missile Man," *India Today* (New Delhi), 15 April 1994, p. 44; Dr. N. C. Birla and B. S. Murthy, eds., "An Overview of Missile Technology," in *Indian Defense Technology: Missile Systems*, (New Delhi: Defence Research and Development Organization, Ministry of Defence, Government of India, 1998), pp. 2-6; A.P.J. Abdul Kalam with Arun Tiwari, "Propitiation," in *Wings of Fire: An Autobiography* (Hyderabad: Universities Press (India) Limited, 1999), pp. 111-127.

4 December 1981

Although the Indian government maintains that its space program is for purely peaceful purposes, independent observers believe that the rockets could be used for military purposes. Pointing out that all satellite launch vehicles (SLVs) have the potential to be missiles, Indian Space Research Organization (ISRO) chairman Professor S. Dhawan insists that "the government of India's policy is that its space program is a peaceful effort...but the rocket is like a knife in the kitchen. It could be a murder weapon or a thing to cut vegetables. The rocket doesn't know the difference. It's the hand that uses it." Dhawan reiterates that ISRO is not working on a missile program. He says, "we can get a payload into orbit. To bring down a payload from orbit to a specified point on the ground, which is a military target, requires another form of technology, which I hasten to add can be developed by the space engineers."

—Stuart Auerbach, "Peaceful Indian Program Has Military Potential," *Washington Post*, p. C5, 4 December 1981; in Lexis-Nexis Academic Universe, 4 December 1981, <http://web.lexis-nexis.com>.

9 June 1981

India's space program receives a setback as the Rohini satellite (RS-D1), launched on board the SLV-3 on 31 May 1981, is unable to maintain its orbit. The satellite was expected to remain in orbit for 300 days. Indian scientists have yet to determine the cause of the failure. But an Indian Space Research Organization (ISRO) spokesperson says that because the satellite kept spiraling, it could not take pictures and locate important landmarks with well-known coordinates.

—Richard S. Ehrlich, "India's space program crashes to earth," *International*, 9 June 1981; in Lexis-Nexis Academic Universe, 9 June 1981, <http://web.lexis-nexis.com>.

31 May 1981

India successfully launches a 38kg Rohini satellite (RS-D1) on board the SLV-3. This is the third test-flight of the SLV-3. The Press Trust of India (PTI) reports that the launching is "not connected with the testing of missile systems."

—"Rohini Satellite Successfully Launched 31 May," *Delhi Domestic Service* (New Delhi), 31 May 1981, in FBIS Document, "India," VIII, 1 June 1981, p. E1; "ISI Gives Details of Upcoming Satellite Launch," *Diplomatic Information Service*, 7 May 1981, in FBIS Document, "India," VIII, 7 May 1981, p. E2; "India fires second satellite in orbit," *International*, 31 May 1981, in Lexis-Nexis Academic Universe, 31 May 1981, <http://web.lexis-nexis.com>; K.K. Sharma, "New developments come close to matching capabilities of more advanced nations," *Financial Times* (London), 24 May 1982, p. V, in Lexis-Nexis Academic Universe, 24 May 1982, <http://web.lexis-nexis.com>.

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17 April 1981

The Federal German Aerospace Research Establishment DFVLR and the Indian Space Research Organization (ISRO) conduct a joint test-flight of an Indian sounding rocket carrying Indian and West German payloads. The launch is part of a collaboration program between ISRO and DFVLR "to develop modern altitude-sensing devices using a radio frequency and to perfect the determination and correction of the altitude of satellites." The Director of VSSC V.R. Gowariker says, "the rocket carried an interferometer and a radio receiver with a short wave band developed by ISRO and an onboard computer, camera, and other devices provided by the DFVLR." The rocket flew to a height of 130km and its performance was normal.

—"India, West Germany Test Indian-Made Rocket," Xinhua News Agency (Beijing), 20 April 1981; in Lexis-Nexis Academic Universe, 21 April 1981, <http://web.lexis-nexis.com>.

19 February 1981

Minister of State for Defense C.P.N. Singh tells parliament that the government has plans to launch an improved version of the SLV-3. The new variant will have additional strap-on rockets to give greater thrust; the rocket will be capable of putting a 150kg satellite in orbit. The projected new version, Augmented Satellite Launch Vehicle (ASLV), will be roughly comparable to the advanced version of the US Scout vehicle. The minister also discloses that there is a proposal to develop a more powerful launch vehicle capable of placing 600kg-class of satellites in sun-synchronous polar orbits.

—"Plans for Improved Satellite Technology Noted," AFP (Hong Kong), 19 February 1981, in FBIS Document, "India," VIII, 26 February 1981, p. E2.

January 1981

The scientific advisor to the defense minister Dr. Raja Ramanna offers A.P.J. Abdul Kalam directorship of the Defense Research & Development Laboratory (DRDL) in Hyderabad (Andhra Pradesh) with the mandate of reviving India's guided missile program. [Note: Dr. Raja Ramanna oversaw efforts to conduct India's first nuclear test in May 1974.]

—A.P.J. Abdul Kalam with Arun Tiwari, "Creation," in *Wings of Fire: An Autobiography* (Hyderabad: Universities Press (India) Limited, 1999), pp. 103-104.

1981

The government-owned Semiconductor Complex Ltd. (SCL) in Chandigarh (Punjab) signs a contract with the California-based American Microsystems Inc. (AMI) to build a plant to manufacture large-scale integrated chips (LSIs) in India. [Note: Large-scale integrated chips have applications in industrial, defense, and space sectors.]

—T.N. Ninan, "Electronics: The Chips are Coming," *India Today* (New Delhi), 15 October 1983, pp. 58-59.

1980-1981

The Indian Space Research Organization (ISRO) decides to build a new launch vehicle—Augmented Satellite Launch Vehicle (ASLV)—to act as a bridge between the SLV-3 and larger satellite launch vehicles to launch operational satellites in orbit. ISRO's Annual Report states, "the main goal of this project is to achieve in about two to three years time an augmented satellite launch vehicle based on the SLV-3, as the core with minimum modifications, but capable of placing a 150kg payload in near earth orbit from SHAR [the Sriharikota High-Altitude Range]." [Note:

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ISRO hopes to use the ASLV as an intermediate vehicle between the SLV-3 and the more ambitious Polar Satellite Launch Vehicle (PSLV) to test critical technologies for the PSLV. The development of an ASLV is also viewed as a means to give ISRO publicity during the decade-long effort required to develop the PSLV.]

—Gopal Raj, "The ASLV: A Technological Bridge," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), p. 126.

Post-August 1980

A.P.J. Abdul Kalam is appointed director of Indian Space Research Organization's (ISRO) Aerospace Dynamics & Design group. Kalam and Sivathanu Pillai conduct theoretical studies on the application of civilian satellite launch vehicle (SLV) technologies for ballistic missiles. They conclude that the SLV-3 solid rocket motors can meet the requirements of short- and intermediate-range (ranges of up to 4,000km) ballistic missiles. The development of one additional solid-fuel booster of "1.8m-diameter with 36 tons of propellant" could be used to build an intercontinental ballistic missile (ICBM) (a range of more than 5,000km with a 1,000kg payload). [Note: These concepts find applications in the formulation of the Re-entry Experiment (REX), which is later named Agni.]

—A.P.J. Abdul Kalam with Arun Tiwari, "Creation," in *Wings of Fire: An Autobiography* (Hyderabad: Universities Press (India) Limited, 1999), p. 102.

1 August 1980

Prime Minister Indira Gandhi presides over a meeting of the parliament's consultative committee of the defense ministry. The committee is told that a project to develop missiles in India is underway. In addition, the Defense Research & Development Organization (DRDO) is also developing a gas turbine engine for a future fighter aircraft. —"Project to Develop Missiles Underway," AFP (Hong Kong), 1 August 1980, in FBIS Document, "India," VIII, 4 August 1980, p. E4.

25 July 1980

Prime Minister Indira Gandhi allays fears that India might use spin-offs from the SLV-3 for military purposes. She says that such fears are unwarranted and all major achievements of Indian science so far have been for peaceful purposes.

—"Gandhi Disclaims Intent for Military Use of Satellite," Delhi General Overseas Service, 25 July 1980; in FBIS Document, "India," VIII, 28 July 1980, p. E2.

23 July 1980

Minister of State for Defense C.P.N. Singh informs parliament that a preliminary analysis of the data collected from the 18 July launch of the SLV-3 indicates that the performance parameters of the vehicle were better than predicted. As a result, it is assessed that the SLV-3 vehicle will be able to place a 60kg payload in orbit during future launches.

—"Upper House Congratulates Scientists on SLV-3 Success," Delhi Domestic Service, 23 July 1980, in FBIS Document, "India," VIII, 24 July 1980, pp. E1-E2.

18 July 1980

Indian Space Research Organization (ISRO) Chairman Professor S. Dhawan says that the successful SLV-3 launch

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gives India the capability to develop intermediate-range ballistic missiles (IRBMs). According to Dhawan, "any country which can place a satellite in orbit can develop an IRBM."

—Stuart Auerbach, "India Becomes 6th Country to Put Satellite in Orbit," *Washington Post*, 18 July 1980; in Lexis-Nexis Academic Universe, 19 July 1980, <http://web.lexis-nexis.com>.

18 July 1980

Second experimental launch of the 17-ton SLV-3; Rohini satellite successfully placed in orbit. Prime Minister Indira Gandhi informs parliament that "the four-stage, all-solid propellant vehicle has been developed in India by Indian scientists and engineers. The total development cost of SLV-3 is about 200 million rupees and the present experimental launch has cost about 10 million rupees."

—"Gandhi Makes Statement on 18 July Satellite Launch," ISI Diplomatic Information Service, 19 July 1980, in FBIS Document, "India," VIII. 21 July 1980, pp. E1-E2; Stuart Auerbach, "India Becomes 6th Country to Put Satellite in Orbit," *Washington Post*, 18 July 1980, in Lexis-Nexis Academic Universe, 19 July 1980, <http://web.lexis-nexis.com>.

February 1980

The Indian government cancels Project Devil, the program to reverse-engineer the Soviet SA-2 surface-to-air missile (SAM); the Indian Air Force decides to procure Pechora SAM batteries from the Soviet Union. Defense Research & Development Laboratory (DRDL) Director V.S. Narayanan disputes the government's decision and tenders his resignation. S. L. Bansal is appointed new director of DRDL with the mandate to revive India's flagging missile program.

—Raj Chengappa, "The Boat Owner's Son," in *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers India Pvt. Limited, 2000), pp. 233-234.

22 January 1980

The Defense Research & Development Laboratory (DRDL) conducts successful test of a 30-ton-thrust, liquid-fueled engine built for the Valiant ballistic missile program. [Note: The 30-ton-thrust, liquid-fueled engine uses a propellant combination of red-fuming nitric acid (RFNA) oxidizer and unsymmetrical dimethyl hydrazine fuel. By 1998, DRDL conducted three static tests of this engine for burn durations varying from 5 to 30 seconds.]

—Raj Chengappa, "End The Wink And Nudge Approach," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers India Pvt. Limited, 2000); Dr. N.C. Birla and B.S. Murthy, eds., "Propulsion Systems," *Indian Defence Technology: Missile Systems*, (DRDO, Ministry of Defence, December 1998), pp. 99, 102.

1980

Defense Research & Development Laboratory (DRDL) Director S.L. Bansal revives Project Valiant; he also draws up ambitious plans to build a series of missiles.

—Raj Chengappa, "The Boat Owner's Son," in *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers India Pvt. Limited, 2000), p. 234.

1980

Ved Prakash Sandlas replaces A.P.J. Abdul Kalam as project director of the satellite launch vehicle (SLV) program.

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—A.P.J. Abdul Kalam with Arun Tiwari, "Creation," in *Wings of Fire: An Autobiography* (Hyderabad: Universities Press (India) Limited, 1999), p. 101; Gopal Raj, "SLV-3: India's First Launch Vehicle," *Reach for the Stars: The Evolution of India's Rocket Programme*, (New Delhi: Viking by Penguin Books India, 2000), p. 72.

1980

Indian Space Research Organization (ISRO) terminates plans to build the three-ton-thrust liquid-fueled engine and decides instead to focus on acquiring the Viking liquid-engine technology from France.

—Gopal Raj, "Early Initiatives in Liquid Propulsion," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), pp. 113-114.

1979-1975

11 August 1979

A post-flight review committee appointed to analyze the causes of the SLV-3 launch mishap concludes that launch failure occurred due to a failure in the second-stage control system. A "solenoid valve" in the oxidizer tank remained open after the first command at T-8 minutes, which resulted in the drainage of the red-fuming nitric acid (RFNA), used as the oxidizer. As a result, no control force was available during the second-stage flight, resulting in the vehicle became aerodynamically unstable, losing velocity and altitude. This finally caused the vehicle to plunge into the sea before the other stages could ignite.

—A.P.J. Abdul Kalam with Arun Tiwari, "Creation," *Wings of Fire: An Autobiography* (Hyderabad: Universities Press (India) Limited, 1999), pp. 95-96.

10 August 1979

First experimental launch of the SLV-3 with the Rohini Technology Payload at 0228GMT from the Sriharikota High-Altitude Range (SHAR) in Sriharikota (Andhra Pradesh). The rocket fails to place the payload in orbit. An Indian Space Research Organization (ISRO) press release says that the flight was only partially successful following the abnormal behavior of the second stage of the four-stage vehicle. While the lift-off and separation of the booster stage was normal, the second stage showed abnormal change in flight attitude, preventing the payload from attaining full altitude and velocity. The flight terminated after five minutes and 15 seconds, and the first-stage motor and payload crashed into the Bay of Bengal, about 500km from Sriharikota (Andhra Pradesh). [Note: The SLV-3 is a four-stage solid-propellant vehicle, 22m tall, and having a lift-off weight of 16.9 tons. The vehicle's first stage of 1,000mm diameter is made up of 15CDV 6 steel and is loaded with 8,660kg polybutadiene-acrylic acid-acrylonitrile (PBAN) propellant. It's action time is 49 seconds and average thrust developed is 441 kN. The stage is controlled by secondary thrust vector and movable fin tips. The second-stage is 800mm in diameter. It is also built of 15CDV6 steel and 3,150kg of PBAN propellant. Action time is 39.9 seconds and average thrust developed is 196 kN. This stage is controlled by a bipropellant reaction control system. The third stage has a diameter of 815mm and is made of fiber-reinforced plastic. It has 1,060kg of HEF-20 propellant. The action time is 45 seconds and average thrust developed is 64 kN. This stage is controlled by monopropellant reaction control system. The fourth stage has a diameter of 657mm and is also made of fiber-reinforced plastic. It has 262kg HEF-20 propellant. The action time is 33 seconds and the average thrust developed is 21 kN. The fourth stage is "spin stabilized." All four stages are

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interconnected by aluminum alloy inter-stages housing instrumentation, control system, and separation system.]

—"Launch of SLV-3," New Delhi Home Service, 10 August 1979; in BBC Summary of World Broadcasts, Lexis-Nexis Academic Universe, 22 August 1979, <http://web.lexis-nexis.com>; R. Nagappa, M.R. Kurup, and A.E. Muthunayagam, "ISRO's Solid Rocket Motors," *Acta Astronautica*, vol. 19, no. 8, 1989, pp. 683-684.

23 July 1979

According to the chairman of India's Space Commission, Professor Satish Dhawan, India has the capability to build intermediate-range ballistic missiles (IRBM), if the military requires them. However, the Indian Space Research Organization (ISRO) is developing rockets for peaceful purposes and is not collaborating with the defense department to build missiles. Dhawan says that, "we would have larger launchers if the military were giving a push." A rocket expert at the Vikram Sarabhai Space Centre (VSSC) in Thiruvananthapuram (Kerala) says that the fourth stage of the SLV-3 can theoretically be substituted by a warhead.

—"Ballistic Missile Capability," Press Trust of India (New Delhi), 23 July 1979; in BBC Summary of World Broadcasts, Lexis-Nexis Academic Universe, 15 August 1979, www.lexis-nexis.com.

15 February 1979

Indian Defense Minister Jagjivan Ram tells the parliament's consultative committee on defense that India has plans to equip its armed forces with the most sophisticated missiles. A missile committee appointed by the defense ministry has recommended that in addition procuring missiles from abroad, India should plan to develop and produce missiles indigenously.

—"Missiles For Armed Forces," New Delhi Home Service, 15 February 1979; in BBC Summary of World Broadcasts, Lexis-Nexis Academic Universe, 7 March 1979, <http://web.lexis-nexis.com>.

January-March 1979

The Indian Space Research Organization (ISRO) begins integration of the SLV-3 vehicle system.

—"Major Milestone Events During 1977-78 and 1979," *Annual Report: 1978-79*, Department of Space (Government of India).

January 1979

Static test of the satellite launch vehicle (SLV) second-stage flight motor. With the conclusion of this test, all stage motors are qualified for flight. The Indian Space Research Organization (ISRO) also qualifies all the rocket interstages and begins preparations to begin assembling the launch vehicle.

—Department of Space (Government of India), *Annual Report: 1978-1979*, p. 16.

January 1979

The Balasore rocket launching station (Orissa) becomes operational with the launching of an RH-200 sounding rocket. [Note: India launched a total of 182 RH-200 sounding rockets in 1979 as part of the Monsoon Experiment (Monex).]

—Gopal Raj, "First Steps in Rocketry," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), p. 42.

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1979

The United States bans the sale of polybutadiene-acrylic acid-acrylonitrile (PBAN) binders used in solid propellants to India.

—Gopal Raj, "Developing Competence in Solid Propulsion," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), pp. 90-91.

1979

The union government accepts a proposal to build a National Testing Range (NTR) for testing rockets and missiles at Baliapal (Orissa) in principle.

—Paul Routledge, "The Baliapal Movement," *Terrains of Resistance: Nonviolent Social Movements and the Contestation of Place in India* (Westport: Praeger Publishers, 1993), p. 40.

December 1978

Between 1976-78, the Indian Space Research Organization's (ISRO) reinforced plastics facility produces a total of six stage-three motor cases, 19 stage-four motor cases, 148 igniter cases and 12 gas bottles for the satellite launch vehicle (SLV) and Rohini Sounding Rocket (RSR) programs.

—Department of Space (Government of India), *Annual Report: 1978-1979*, p. 24.

October-December 1978

Successful static test of the satellite launch vehicle (SLV) first-stage flight motor with Secondary Injection Thrust Vector Control (SITVC):

- Qualification of the fin-tip control system
- Qualification of bipropellant motors for the second-stage reaction control system; Monopropellant thrusters for the SLV third stage are hot-tested
- Vibration and shock tests on SLV-3 heat-shield
- SLV-3 launcher load-test

—"Major Milestone Events During 1977-78 and 1979," *Annual Report: 1978-79*, Department of Space (Government of India); Department of Space (Government of India), *Annual Report 1978-1979*, p. 17.

July-September 1978

Integration of the Secondary Injection Thrust Vector Control (SITVC) system for the SLV-3 first stage complete:

- Qualification of inertial subsystems for the SLV-3
- Environmental qualification of SLV-3 fourth stage

—Department of Space (Government of India), "Major Milestone Events During 1977-78 and 1979," *Annual Report: 1978-1979*.

April-June 1978

Erection of SLV-3 launcher completed:

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- SLV-3 first-stage nozzle modified

—Department of Space (Government of India), "Major Milestone Events During 1977-78 and 1979," *Annual Report: 1978-1979*.

January-March 1978

High-altitude tests on control rockets for SLV-3:

- Fabrication and assembly of SLV-3 mock-up model structure.
- Design review of problems encountered in satellite launch vehicle (SLV) second-stage nozzle.
- Award of contracts to HAL and other companies for the fabrication of SLV structural elements, assembly, and test fixtures.

—Department of Space (Government of India), "Major Milestone Events During 1977-78 and 1979," *Annual Report: 1978-1979*.

1978

The Indian Space Research Organization (ISRO) commissions a thermal humidity chamber at the Static Test & Evaluation Complex (STEX), the Sriharikota High-Altitude Range (SHAR) in Sriharikota (Andhra Pradesh). Civil engineering and electrical works are also completed on a second high-altitude test (HAT) facility at SHAR. [Note: A thermal humidity chamber is used to perform climatic and accelerated ageing tests of upper-stage motors and sub-systems of launch vehicles.]

—Department of Space (Government of India), *Annual Report: 1978-1979*, p. 24.

1978

Twenty satellite launch vehicle (SLV) stage motors are produced at the Solid Propellant Space Booster Plant (SPROB), the Sriharikota High-Altitude Range (SHAR) in Sriharikota (Andhra Pradesh). A 100-liter sigma processor for processing propellant is commissioned at SPROB; another 1,000-liter mixer is installed at the Rocket Propellant Plant (RPP) in Thiruvananthapuram (Kerala).

- The non-destructive test facility at SPROB, with its 400KV x-ray facility, is used extensively for testing SLV stage-motors, liquid-engine nozzles, and igniters.
- RPP produces 51 tons of propellants. Process developments include modifications needed to avoid cracks in the SLV second-stage flight motor. A fluid jet-cutting facility is employed to recover motor-case hardware from defective propellant grains.
- The Propellant Fuel Complex (PFC) produces 24 tons of various resins, plasticizers, and chemicals needed for the SLV and Rohini Sounding Rocket (RSR) programs.
- A new plant is commissioned to augment polybutadiene-acrylic acid-acrylonitrile (PBAN) production to 7.5 tons per annum.

—Department of Space (Government of India), *Annual Report: 1978-1979*, pp. 22-23.

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1978

Qualification of the proto model of a three-axis, four-gimbal inertial measurement unit (IMU).

—Department of Space (Government of India), *Annual Report: 1978-1979*, p. 22.

1978

The Indian Space Research Organization (ISRO) reports that facilities for the launch support and tracking of the satellite launch vehicle (SLV), which include the block house, launch pads, control center, vehicle telemetry, telecommand and tracking systems, data links, range timing, closed-circuit TV, inter-communication, computers, and range safety at the Sriharikota High-Altitude Range (SHAR) in Sriharikota (Andhra Pradesh), are in an advanced stage of completion.

—Department of Space (Government of India), *Annual Report: 1978-1979*, pp. 26-27.

1978

An insulated facility to measure electromagnetic interference on electronic packages nears completion. The Indian Space Research Organization (ISRO), Bhabha Atomic Research Center (BARC), and Indo-Burmah Petroleum also jointly undertake a project to design and develop a 4m thermovacuum chamber to provide larger environmental test facilities for spacecraft.

—Department of Space (Government of India), *Annual Report: 1978-1979*, pp. 24-25.

1978

Indian Space Research Organization (ISRO) engineers continue participation in the program to develop the Vikas liquid-fuel engine with the French firm SEP. As part of the agreement with France, India receives most of the documents and drawings on systems description, specifications, fabrication, testing, and analysis related to the engine. [Note: As part of the contract with France, in part payment for the technology, high-quality pressure-transducers manufactured at the Pressure Transducer Unit (PTU) are exported to France. Over 4,000 transducers worth 9 million francs are delivered to France until the end of 1979.]

—Department of Space (Government of India), *Annual Report: 1978-1979*, p. 21.

1978

The gas generator system for the three-ton pressure-fed engine is qualified; down-rated tests on the three-ton turbopump systems coupled with the gas generator are completed:

- Hardware for long-burning three-ton engine for possible upper-stage applications is completed.
- The three-ton thrust liquid-fuel engine is tested as a single-stage rocket. However, "sloshing and vortex development," cause the engine to shut down prematurely.

—Gopal Raj, "Early Initiatives in Liquid Propulsion," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), p. 113; Department of Space (Government of India), *Annual Report: 1978-1979*, p. 21.

1978

The Department of Space (DOS) commissions a 150-ton capacity ammonium perchlorate (AP) plant at Alwaye

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(Kerala). The plant is formally inaugurated in 1979. However, the plant is barely able to produce more than 40 tons of AP due to low demand from ISRO and an electrode process production bottleneck.

—Gopal Raj, "Developing Competence in Solid Propulsion," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), pp. 98-99.

October-December 1977

First controlled flight of the RH-560 validates vehicle control philosophy and hardware design:

- Qualification of spin-up and separation systems for the SLV-3.
- Successful static-test of [segmented] first-stage flight motor.

—Department of Space (Government of India), "Major Milestone Events During 1977-78 and 1979," *Annual Report: 1978-1979*.

August 1977

The Indian Space Research Organization (ISRO) commissions the satellite launch vehicle complex for the SLV-3 at the Sriharikota High-Altitude Range (SHAR).

—Department of Space (Government of India), *Annual Report: 1975-1976*, p. 26.

July-September 1977

Static test of the satellite launch vehicle (SLV) second-stage flight motor. The Indian Space Research Organization (ISRO) also successfully proves motor segmentation technology used to cast the first-stage motor.

—Department of Space (Government of India), "Major Milestone Events During 1977-78 and 1979," *Annual Report: 1978-1979*.

April-June 1977

Static test of satellite launch vehicle (SLV) third stage proof motor at the Static Test & Evaluation Complex (STEX). The SLV-3 heat shield and its jettisoning system are qualified in a series of tests simulating flight environments such as zero gravity, severe heat, and aerodynamic loading experienced during ascent of the vehicle in the atmosphere, vibration, and shock.

—Department of Space (Government of India), "Major Milestone Events During 1977-78 and 1979," *Annual Report: 1978-1979*.

27 March 1977

Test of the first-stage monolithic SLV-3 motor; motor explodes during the test. As a result of the failure, the Indian Space Research Organization (ISRO) decides to proceed with the original plan for a segmented solid-propellant motor using polybutadiene-acrylic acid-acrylonitrile (PBAN)-binder resin.

—Gopal Raj, "Developing Competence in Solid Propulsion," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), pp. 92-93.

27 March 1977

The first-phase of the Solid Propellant Space Booster Plant (SPROB) is completed at a cost of 77.4 million rupees.

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Although most of the equipment for the plant is manufactured in India, critical facilities such as mixers to cast large solid- propellant motors and linear accelerators to X-ray finished propellant grains are imported. [Note: Indian scientists claim that only 15% of the high-tech equipment for the Rocket Propellant Plant (RPP) in Thumba (Kerela) and SPROB in Sriharikota (Andhra Pradesh) was imported; the bulk of the facilities to manufacture solid-propellants were conceived and developed by Indian Space Research Organization (ISRO) scientists and engineers.]
 —Gopal Raj, "Developing Competence in Solid Propulsion," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), pp. 85-86; M.V. Kurup, V.N. Krishnamoorthy, and M.C. Uttam, "Development of Solid-Propellant Technology in India," *Sadhana*, vol. 12, part 3, March 1988, p. 233.

1977

The Indian Space Research Organization's (ISRO) Precision Equipment Division (PED) uses its new resin binder, ISROPolyol, to cast a monolithic SLV-3 first stage.

—Gopal Raj, "Developing Competence in Solid Propulsion," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), p. 92.

December 1976

A mid-term review of the SLV-3 program leads to the conclusion that the vehicle launch date will have to be postponed from 1978 to 1979. The postponement is caused by "delays in the delivery of stage motor and interstage hardware from outside fabricators (due to stringent quality requirements); unexpected deviations in performance of various subsystems after they had performed to satisfactions during earlier tests; and problems at system-level after integration of the subsystems."

—Gopal Raj, "SLV-3: India's First Launch Vehicle," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), p. 68; Department of Space (Government of India), *Annual Report: 1978-1979*, p. 15.

October 1976

The Indian Space Research Organization's (ISRO) three-ton thrust, liquid-fuel engine is used to power the second stage of a sounding rocket, which uses an RH-560 as the first stage. The rocket is designed to fly to a height of 100km with a 175kg payload. However, a no-thrust phase between the burn out of the first stage and ignition of the second stage causes the test to fail. ISRO engineers introduce modifications in the rocket for further tests. In subsequent models, the first and second stages of the rocket are held together by metal struts and both stages are ignited on the ground to eliminate the no-thrust coast phase.

—Gopal Raj, "Early Initiatives in Liquid Propulsion," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), pp. 112-113.

1976

The following facilities are commissioned at the Static Test & Evaluation Complex (STEX) at the Sriharikota High-Altitude Range (SHAR) in Sriharikota (Andhra Pradesh):

- Static acceleration test facility;
- Vibration test facility;

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- Drop test facility; and
- Hot and cold chambers.

[Note: The STEX facility is completed in 1976 at a cost of 60 million rupees.]

—Department of Space (Government of India), *Annual Report: 1975-1976*, p. 24; Gopal Raj, "Developing Competence in Solid Propulsion," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), p. 88.

1976

The Indian Space Research Organization's (ISRO) Precision Equipment Division (PED) in Thiruvananthapuram (Kerala) commissions facilities for manufacturing polybutadiene-acrylic acid-acrylonitrile (PBAN) binder used in solid-propellants.

—Gopal Raj, "Developing Competence in Solid Propulsion," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), p. 91.

1976

The Indian Space Research Organization (ISRO) commissions plant (Reinforced Plastics Centre) to manufacture reinforced plastics.

—Department of Space (Government of India), *Annual Report: 1978-79*, p. 24.

1975-1976

Various sub-systems of the SLV-3 such as "stage motors, inter-stages, heat-shield, stage-separation systems, control and guidance systems, vehicle electronics, technology payload, and launch systems" progress from "design to development, fabrication and testing phases."

[Note: According to the Department of Space (DOS) annual report, the "stage proofmotor static test results indicate that the technology for propellants, insulation, igniter, and nozzle for all the stages have been developed."]

— Department of Space (Government of India), *Annual Report: 1975-1976*, pp. 19-20.

April 1975-March 1976

The Indian Space Research Organization (ISRO) launches a total of 94 rockets between April 1975 and the end of March 1976. The break up includes:

| Type | Number of Launches |
|-------------------|--------------------|
| Centaur IIB | 6 |
| M-100 B | 52 |
| M-100 | 1 |
| Menaka-II (MK-I) | 30 |
| Menaka-II (MK-II) | 4 |
| RH-300 | 1 |

—Department of Space (Government of India), *Annual Report: 1975-1976*, pp. 23-24.

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March 1975

After a third and final meeting, the Project Devil evaluation panel concludes that the Defense Research & Development Laboratory (DRDL) has made sufficient progress in hardware fabrication in the area of missile subsystems. The committee also finds that DRDL has accomplished the twin tasks of "hardware fabrication" and "systems analysis" in the design and development of ground electronics. However, more progress needs to be made in the area of liquid propulsion. The committee notes that the DRDL's philosophy of reverse engineering has taken precedence over the generation of design data. As a result, missile engineers have been unable to make much progress in overall systems analysis. The panel recommends that DRDL be allowed to proceed with Project Devil; the defense ministry accepts the panel's recommendations.

—A.P.J. Abdul Kalam with Arun Tiwari, "Creation," *Wings of Fire: An Autobiography* (Hyderabad: Universities Press (India) Limited, 1999), pp. 74-75.

February 1975

The Devil review panel holds its second meeting.

—A.P.J. Abdul Kalam with Arun Tiwari, "Creation," *Wings of Fire: An Autobiography* (Hyderabad: Universities Press (India) Limited, 1999), p. 74.

1 January 1975

The Scientific Advisor to the defense minister Dr. M.G.K. Menon appoints an independent review panel from Indian Space Research Organization (ISRO) under Dr. Brahm Prakash to conduct an external review of Project Devil. Committee members include A.P.J. Abdul Kalam, Dr. R.P. Shenoy, and Professor I.G. Sharma. The committee holds its first meeting on 1-2 January 1975.

—A.P.J. Abdul Kalam with Arun Tiwari, "Creation," *Wings of Fire: An Autobiography* (Hyderabad: Universities Press (India) Limited, 1999), p. 74.

1975

Indian Space Research Organization (ISRO) scientists and engineers continue to receive training in French and West German research establishments.

—Department of Space (Government of India), *Annual Report: 1975-1976*, p. 45.

1975

The Department of Space (DOS) reports significant advances in the development of telemetry and telecommand systems, tracking systems, and electronics production. A C-band radar with a tracking capability upto 2,500km is being installed at the Sriharikota High-Altitude Range (SHAR) in Sriharikota (Andhra Pradesh); a C-band transponder to operate with this radar has also been developed. The Indian Space Research Organization (ISRO) has also undertaken the production of various on-board systems for rockets such as transmitters, regulators and mixers for the Rohini and SLV-3 programs, and ground systems such as data amplifiers, time-code generators, and fire control panels.

—Department of Space (Government of India), *Annual Report: 1975-1976*, p. 18.

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1975

During 1975, the following facilities are commissioned at the Static Test & Evaluation Complex (STEX) at the Sriharikota High-Altitude Range (SHAR) in Sriharikota (Andhra Pradesh):

- Parts processing facility;
- Trimming and conditioning facility;
- Motor storage facility;
- Facilities for material handling; and
- Load cell calibrator.

[Note: The Department of Space (DOS) annual report notes that, "construction work on four numbers of single-component test stands to test different stages of SLV-3 and the test bay No.1 consisting of 25-ton and 100-ton thrust capacity test beds to accommodate the test stands has been completed and commissioned. These will meet the complete requirement of single component measurement programs for SLV-3. The fabrication work on two numbers of six-component test stands, with high and low capacities to test the motors and thrust vector control system of the first-stage of the SLV-3 and RH-560 has been completed. The construction work on the Spin Test Facility for testing the fourth-stage of the SLV-3...is nearing completion. To accommodate the six-component test stands and spin test stands, the test bay No. 2 consisting of 25-ton and 100-ton thrust capacity test beds has been constructed."]

—Department of Space (Government of India), *Annual Report: 1975-1976*, pp. 24-25.

1975

The Indian Space Research Organization (ISRO) expands the sounding rocket complex at the Sriharikota High-Altitude Range (SHAR) in Sriharikota (Andhra Pradesh) to flight-test the second and fourth stages of the SLV-3 and for qualifying its sub-systems. Construction begins on a satellite launch vehicle complex 4km south of the sounding rocket complex for the SLV-3. The facility will provide "complete support for vehicle assembly, check-out, and launching operations." It will consist of facilities such as "launch pad, block house, vehicle integration building, service building, pyrotesting building, and terminal building." The Department of Space (DOS) annual report states that progress has also been made in building telemetry, tracking, telecommand, range timing, radio communications, and computer & data processing facilities for tracking satellites and rockets at SHAR.

—Department of Space (Government of India), *Annual Report: 1975-1976*, pp. 26-27.

1975

Special environmental test facilities are installed at the Vikram Sarabhai Space Centre (VSSC) in Thiruvananthapuram (Kerala) to simulate conditions in space for satellites and test the upper stages and heat-shields of the SLV-3. The facilities include the commissioning of a 1.25m thermovacuum chamber, and the installation of a kinetic heat simulator to test SLV-3 heat shields. Ground environmental facilities such as thermal cycling chamber and humidity chamber are commissioned and used to test the fourth-stage motor cases of the SLV-3.

—Department of Space (Government of India), *Annual Report: 1975-1976*, p. 23.

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1975

India sets up a unit to manufacture and supply high-accuracy pressure transducers for the European Ariane launch vehicle project. The Pressure Transducer Unit (PTU) is located on the campus of the National Aeronautical Laboratory in Bangalore (Karnataka); the first batch of 70 21U transducers are fabricated and exported to France. Plans are made to expand production to include 21UR and 21NS transducers.

—Department of Space (Government of India), *Annual Report: 1975-1976*, p. 20; Department of Space (Government of India), *Annual Report: 1978-1979*, p. 21.

1975

According to Department of Space (DOS), the Indian Space Research Organization (ISRO) is making plans to develop launch vehicles that will be capable of placing communication satellites in a geostationary orbit. Studies are being conducted for estimating the "orbital capabilities of stage combinations of such a vehicle."

—Department of Space (Government of India), *Annual Report: 1975-1976*, p. 20.

1975

The establishment of the Rocket Propellant Plant (RPP) at the Vikram Sarabhai Space Centre (VSSC) in Thiruvananthapuram (Kerala) nears completion.

—Department of Space (Government of India), *Annual Report: 1975-1976*, p. 15.

1975

As part of the rocket development project, the Indian Space Research Organization (ISRO):

- Tests an RH-300 with the newly developed PP-10 propellant.
- Undertakes design of a stretched RH-560 single-stage rocket.
- Introduces design improvements in the Menaka-I (Mark I) and Menaka-II (Mark II) rockets.
- Completes project to indigenize the Centaur rocket production in India. The Centaur rocket is also used to flight-test the worthiness of SLV-3 sub-systems.

—Department of Space (Government of India), *Annual Report: 1975-1976*, pp. 18-19.

1975

Significant developments in aerospace-related materials technology include:

- Finalization of heat-treatment cycles for 15CDV6, techniques for the melting, casting, and rolling of maraging steel, and welding techniques for titanium alloy gas bottles.
- Testing of indigenously developed carbon fibers for ablative applications.
- Development of tungsten-based materials for jet vane applications.
- Development of nozzle throat inserts based on tungsten and molybdenum.
- Developments of catalysts for applications in control rockets and provide multi-start capability.
- Fabrication of two full-sized heat shields for the SLV-3.

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- Commissioning of a polar [filament] winding machine (PH-500), and a helical [filament] winding machine (H-1000) for winding pressure bottles and rocket motor cases, respectively. Design of a vertical nozzle winding machine (1,500mm diameter capacity) and a racetrack type filament-winding machine.

[Note: Gas bottles are used to store high-pressure gas. The high-pressure gas can be used to pressurize liquid-fuel tanks or to provide energy and means to move actuators and valves in both solid- and liquid-fuel rockets. Additionally pressure bottles are found in propellant storage tanks for attitude control thrusters.]

—Department of Space (Government of India), *Annual Report: 1975-1976*, p. 14.

1975

Captive tests of a flight-vehicle employing a three-ton-thrust, liquid-propellant engine using red-fuming nitric acid (RFNA) and aniline near completion. Research and development continues on gas generators, turbopump feed systems, flow-control systems, and thrust chambers for meeting the needs of future programs. Indian engineers and scientists also acquire technology and training related to high-thrust liquid engines through the Vikas project with France.

—Department of Space (Government of India), *Annual Report: 1975-1976*, p. 3, 20.

1975

In the field of solid and liquid propellants, the Indian Space Research Organization (ISRO):

- Flight-qualifies the newly developed PP-10 propellant for the RH-300 program.
- Casts the fourth stage motor of the SLV-3 using HEF-20 as a substitute for imported carboxyl-terminated polybutadiene (CTPB); the Vikram Sarabhai Space Centre (VSSC) in Thiruvananthapuram (Kerala) launches program to begin scaled-up production of HEF-20-based propellant and PP-10 propellant.
- Develops pyrotechnic devices including ignition and separation systems using Rohini rockets for the SLV-3 program.
- Sets up additional facilities for the development of polybutadiene-acrylic acid-acrylonitrile (PBAN) and a pilot plant for the production of poly-isobutylene.
- Finalizes engineering details for building an ammonium perchlorate (AP) plant in Alwaye (Kerala).
- Casts the three segments (each weighing 2.9 tons) of the SLV-3 first-stage proof motor and a 3.2-ton single-grain cast for the second-stage proof-motor. The first-stage motor (1m in diameter and 9m long) is successfully static-tested at the Static Test & Evaluation Complex (STEX) facility in SHAR, Sriharikota (Andhra Pradesh).
- Begins synthesis of methyl aziridinyl phosphine oxide and triepoxides which are used as curatives for CTPB/PBAN propellants
- Commissions key facilities at the Solid Propellant Space Booster Plant (SPROB) such as the propellant mixing stations, oxidizer grinding and blending stations; other facilities including those for casting, curing, and non-destructive testing are in the final stages of completion. The entire plant itself is expected to be commissioned within a few months.

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[Note: ISRO adopted the segmentation route in casting the SLV-3 first-stage motors because, until the commissioning of SPROB in 1976, it did not have a facility to cast large monolith solid motors.]

—Department of Space (Government of India), *Annual Report: 1975-1976*, pp. 13-14; Gopal Raj, "Developing Competence in Solid Propulsion," *Reach for the Stars: The Evolution of India's Rocket Program* (New Delhi: Viking by Penguin Books India, 2000), pp. 78-79.

Mid-1970s

The private sector match manufacturer Wimco begins supplying ammonium perchlorate (AP) to the Indian Space Research Organization (ISRO).

—Gopal Raj, "Developing Competence in Solid Propulsion," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), p. 97.

Mid-1970s

The Defense Research & Development Laboratory (DRDL) sets up a facility for manufacturing fiber-reinforced plastics for the Valiant's re-entry vehicle and imports a filament-winding machine from the United States for this purpose. [Note: Filament winding machines lay strong fibers coated with an epoxy or polyester resin onto rotating mandrels in prescribed patterns to create high strength-to-weight composite parts. The machines can be programmed in three or more axes for the purposes of positioning, wrapping, and winding fibers. Filament winding machines are typically used to make rocket motor cases, propellant tanks, and payload shrouds. The high-strength and low-weight of the resulting structures make increased missile ranges and payload rates possible.]

—Raj Chengappa, "The Devil's Workshop," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers India, 2000), p. 171; "Category II-Item 6: Composite Production," *Missile Technology Control Regime Annex Handbook*, pp. 6-1-6-2.

1974-1975

The Department of Space (DOS) annual report says that the three-ton thrust, liquid-fuel engine currently under development "for a test vehicle, will eventually be upgraded to meet the requirements of SLV-3 as a strap-on booster and as an upper stage." The three-ton thrust engine has five times as many injector elements as the 600kg-thrust engine. The asbestos-phenolic ablative lining first tried out in the 200kg- and 600kg-thrust engines is retained in the early trials of the three-ton thrust engine. It is later replaced by an improved ablative lining made up of silica fibers embedded in phenolic resin. Graphite is used to line the throat of the nozzle. The erosion of graphite by hot gases allows the engine to be fired for about 45 seconds. [Note: Ablative materials are used to withstand a combination of erosion, fusion, corrosion, or decomposition, leading to progressive degradation, and or loss of material as a direct consequence of exposure to hot propellant gas flow in the nozzle.]

—Gopal Raj, "Early Initiatives in Liquid Propulsion," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), p. 112; Thiokol Propulsion, "Nozzles," *Rocket Basics: A Guide to Solid-Propellant Rocketry*, www.thiokol.com, p. 23.

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1974-1970

July-December 1974

The Indian Space Research Organization (ISRO) and French space agency CNES sign an agreement to allow India to acquire French Viking liquid-fuel engine technology. Under the agreement, Indian engineers will work alongside specialists from the French firm SEP and provide hundreds of man-years of effort towards developing the Viking engines needed for the Ariane rocket. In return, Indian engineers will acquire the capability to build Viking engines in India. [Note: As a result of this agreement, within five years, India acquired the technology to build high-thrust, turbopump-based liquid-propellant engines. ISRO not only acquired the drawings and technical documentation for the engine, but since Indian engineers worked in tandem with their French counterparts, it also acquired critical know-how for the design principles for such engines. ISRO sent approximately 50 engineers to work on the Viking program in France. Under the contract Indian engineers were supposed to provide 75 man-years to SEP; the remaining 25 man-years could be used by ISRO to develop competence in areas of its choice. By the end of 1980-81, Indian engineers contributed nearly 135 man-years of work. Although ISRO budgeted 27 million rupees for the Viking program in 1974, total costs had escalated to 40 million rupees by 1980-81.]

—Gopal Raj, "Early Initiatives in Liquid Propulsion," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), pp. 122-124.

July 1974

Second meeting of the ISRO-CNES joint commission (the Indian Space Research Organization and French space agency). The two working groups meet to discuss satellite launch vehicles (SLVs) and communication satellites.

—Gopal Raj, "Early Initiatives in Liquid Propulsion," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), p. 122; Department of Space (Government of India), *Annual Report: 1973-1974*, p. 44.

July 1974

The Aeronautical Development Establishment (ADE) in Bangalore (Karnataka) tests an air-launched supersonic expendable drone in an attempt to develop an unmanned aerial vehicle (UAV). The project is named "Missile Target" and is released over a test-range to simulate an aerial threat to train gun and missile crews. The vehicle is auto stabilized and uses a canard configuration. [Note: Unmanned aerial vehicles (UAV) are "typically air-breathing vehicles which use aerodynamic lift to fly and thereby perform their entire mission within the earth's atmosphere. The most common mission for UAVs is reconnaissance. They are usually powered by small turbine or piston engines that drive either free or ducted propellers. UAVs tend to fly at relatively slow speeds of 360 to 540km/hr, usually for several hours....UAVs...can fly at altitudes ranging from very low, nap-of-the-earth trajectories to very high altitudes...UAVs are launched from many platforms, typically trucks, aircraft, and ships. They may fly autonomous preplanned routes and/or routes controlled by a human operator. After their mission is completed, they usually return to base to be used again.... UAVs are most typically used as reconnaissance platforms and thus carry electronic, video, or photographic payloads to gather or monitor data over unfriendly territory. They are designed to optimize time on station, which, for some systems, can be more than 24 hours. Because of their long-range, flexible payload, ease of acquisition, and reasonable cost, UAVs are potential delivery vehicles for weapons." It should also be noted that UAVs powered by piston or reciprocating engines fly at speeds substantially

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less (~150km/hr) than turbine-powered systems.]

—J. Jayaraman, "Technological Advances and Cost Effectiveness of Unmanned Air Vehicle Systems," in H.S. Mukunda and A.V. Krishnamurty, eds., *Recent Advances in Aerospace Sciences and Engineering: Volume II* (Bangalore: Interline Publishing, 1992), p. 165; "Complete Rocket and UAV Systems: Category I-Item 1," *Missile Technology Control Regime Annex Handbook*, pp. 1-5-1-6.

13 June 1974

Beginning of the flight qualification program for SLV sub-systems. A Centaur rocket is launched from TERLS carrying miniature rate-gyros, vehicle attitude programs, tone range receiver, and a scaled-down fiber-glass heat shield; the test is successful.

—Department of Space (Government of India), *Annual Report: 1974-1975*, p. 11.

18 May 1974

The Indian government announces that it has conducted a successful test of a 10-15kt nuclear device at the Pokhran test site in Rajasthan.

—"The New York Times Company: Abstracts," 19 May 1974; in Lexis-Nexis Academic Universe, <http://web.lexis-nexis.com>.

10 May 1974

The Defence Research & Development Laboratory (DRDL) conducts its first test of a liquid-fuel engine developed for the Valiant ballistic missile; the engine is tested for five seconds.

—Raj Chengappa, "The Devil's Workshop," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers India, 2000), p. 174.

April 1974

First test of a two-stage RH-560 sounding rocket. The RH-560 uses an aluminized polyvinyl chloride (PVC) propellant; the RH-560 is modeled on the French Dragon sounding rocket and carries an 86kg payload to a height of 280km. [Note 1: The Dragon sounding rocket is a two-stage vehicle. It uses a 560mm booster in the first stage to boost the Belier upper stage. The Dragon first flew in 1962 and can carry a 60kg payload to a height of 475km. The Indian Space Research Organization (ISRO) later used the RH-560 as a platform to test the SLV-3's guidance and control system. Note 2: Metals such as aluminum, beryllium, boron, magnesium, and zirconium are added to the solid-propellant grain or to liquid fuel to enhance propellant performance. For example, aluminum powder as a fuel additive makes up 5 to 21% by weight of solid propellant. Combustion of the aluminum fuel increases the propellant flame temperature by 526.85°C and increases specific impulse by as much as 10%.]

—Gopal Raj, "First Steps in Rocketry," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), pp. 41-43; Jonathan McDowell, "CNES Sounding Rockets," *History of Spaceflight*, 26 January 2000, <http://hea-www.harvard.edu>; "Category II-Item 4: Propellants," *Missile Technology Control Regime Annex Handbook*, p. 4-4.

1974

The Defence Research & Development Laboratory's (DRDL) budget increases nearly 40 fold, from 4 million rupees

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in 1972 to 160 million rupees in 1974.

—Raj Chengappa, "The Devil's Workshop," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers India, 2000), p. 166.

1974

The Department of Space (DOS) annual report states that a "substantial number of ISRO [Indian Space Research Organization] engineers and scientists have received training in France." Similarly, the training of ISRO personnel at the West German space agency DFVLR, which began in July 1973, continued in 1974. There have been two types of trainees. A group of 10 trainees (90 man- months) have been trained at the high-altitude test facilities at Lampoldshausan. Another group of 13 trainees (103 man-months) have received training in different fields including remote sensing techniques, microwaves, pulse code modulation (PCM) telemetry, and wind tunnel testing. Details for training programs in 1975 are being planned.

—Department of Space (Government of India), *Annual Report: 1974-1975*, p. 42.

1974

The Indian Space Research Organization (ISRO) commissions a 6,000-ampere modular industrial electrolytic cell with a capacity to manufacture 10 tons of ammonium perchlorate (AP) annually.

—Department of Space (Government of India), *Annual Report: 1974-1975*, p. 12.

1974

Work continues on facilities at the Sriharikota High-Altitude Range (SHAR) in Sriharikota (Andhra Pradesh). During 1974, the Indian Space Research Organization (ISRO):

- Completes a sounding rocket complex for flight-testing single- or two-stage sounding rockets up to a maximum diameter and weight of 560mm and 1.5-tons, respectively.
- Undertakes a project to expand the sounding rocket launch facility to include the launch of multi-stage combinations of RH-650 and RH-800 rockets.
- Makes progress in the construction of the SLV-3 launch complex.
- Continues development of ground support facilities such as telemetry systems, tracking and telecommand systems, computer and data processing facilities, rocket sled facility, and the static-test evaluation complex.

—Department of Space (Government of India), *Annual Report: 1974-1975*, pp. 20-25.

1974

Work begins on the installation of a special environmental test facility for satellites at the Vikram Sarabhai Space Centre (VSSC). The 1.25m-diameter thermovacuum chamber will be able to achieve a temperature range from -60°C to +120°C. Work is also in progress on a kinetic heating simulator for tests under combined environments of thermal and static loads as well as ejection tests. The climatic chambers are expected to be commissioned by March 1975.

—Department of Space (Government of India), *Annual Report: 1974-1975*, p. 19.

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1974

The Department of Space (DOS) annual report states that the Indian Space Research Organization (ISRO) has tested two operational models of the "miniature rate gyroscope." In addition, an operational model of the "free gyroscope" has been ground-tested while the first prototype of a "single-degree-of-freedom Rate Integrating Gyroscope (RIG)" is nearing completion. A "single-axis inertial-stabilizing platform" is being assembled and it will provide data and experience for developing "3-axis 4-gimballed inertial platforms required for SLV-3 missions." ISRO has also succeeded in assembling "the ground model of the onboard processor for SLV-3 (a 21-bit system using 4K word memory with 5 microsec cycle time)." In addition, the "system of the fin-tip control system for the flight control of the first-stage of the SLV-3 has been completed and the components such as servo-valves and actuators are under development." The report also notes, "transducers based on strain gauges and piezo-electric quartz cells are under pilot production...light-weight vibration pick-ups, universal thrust pick-ups, and semiconductor type pressure pick-ups have been developed."

—Department of Space, Government of India, *Annual Report: 1974-1975*, p. 14.

1974

During 1974, the Indian Space Research Organization (ISRO) launches a total of 102 rockets from the Thumba Equatorial Rocket Launching Station (TERLS). Here is the breakdown of these launches:

| Type | Number of Launches |
|-----------------------|--------------------|
| M-100 | 24 |
| Centaur II-B | 1 |
| Menaka-I test rocket | 12 |
| Menaka-II test rocket | 54 |
| RH-125 | 2 |
| RH-100 | 9 |

—Department of Space (Government of India), *Annual Report: 1974-1975*, p. 19.

1974

The Indian Space Research Organization's (ISRO) successes in rocket hardware development and fabrication include:

- Consolidation of all sounding rocket activities under the Rohini Sounding Rocket (RSR) program. Special sounding rocket launches for qualification of the SLV-3 project.
- Completion of feasibility study to boost the range and payload of the two-stage RH-300 rocket using aluminized polyvinyl chloride (PVC) and RCN propellants for the booster and high-energy propellant (PP-10) for the Centaur sustainer. This combination will enable a boosted RH-300 to reach altitudes of 150-200km.
- Two flight-tests of the RH-560 rocket using strip-wound motor chambers.
- Completion of structural qualification tests on the SLV-3 stage-four motors.
- Development of SLV-3 sub-systems.

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- Design and development of composite nozzles for SLV-3 stages.
- Progress in the development of a 3-ton-thrust bipropellant liquid-fuel engine. ISRO proposes to eventually upgrade the engine so that it can meet the requirements of the SLV-3 as a strap-on booster or as an upper stage.
- Tests of a three-quarter size second-stage motor for the SLV-3.
- Completion of system development and component fabrication of a Secondary Injection Thrust Vector Control (SITVC) system using strontium perchlorate.

—Department of Space (Government of India), *Annual Report: 1974-1975*, pp. 13, 17.

1974

In the field of aerospace materials technology, Indian space and defense agencies:

- Experiment with different grades of maraging steel on a laboratory scale. The Indian Space Research Organization (ISRO) collaborates with the Bhabha Atomic Research Center (BARC) and Defense Metallurgical Research Laboratory (DMRL) to develop titanium alloys. Evaluation trials are conducted on tungsten-molybdenum materials with applications in rocket motor thrust-vector control systems.
- Develop asbestos-phenolic composites for rocket nozzles. The Vikram Sarabhai Space Centre's (VSSC) fibre reinforced plastics division develops molded scaled-down heat-shields for the SLV-3. The VSSC also develops fiber-glass sounding rocket chambers, including 650mm-diameter SLV-3 stage-four motor cases. Phenolic-heat resistant materials for nozzles are successfully tested for the fourth-stage.

[Note 1: Maraging steels are steel alloys with strengths up to approximately 300,000psi in combination with a high fracture toughness. The term "maraging" is derived from the fact that these alloys exist as relative soft, low-carbon martensites (a solid solution of iron and up to one percent of carbon, the chief constituent of hardened carbon tool steels) in the annealed condition and gain high- strength from aging at relatively low temperatures. Maraging steel alloys were originally developed by International Nickel Company in 1959. Designation of each alloy refers to the nickel (Ni) content; for example, the four main grades are 25% Ni maraging steel; 20% Ni maraging steel; 18% Ni maraging steel; and 12% Ni maraging steel. The 18% Ni maraging steel is the most versatile and most widely used. Strength can be controlled by the aging treatments and hardener content (titanium, cobalt, molybdenum, and aluminum). Maraging steel is machined easily, has excellent weldability, and fracture toughness. The 18% Ni maraging steel heat treats at low temperatures, which is important in manufacturing very-large diameter motor cases.

Note 2: Tungsten, molybdenum, and alloys of these metals can be formed into missile parts by pouring them into a mold and subjecting them to high heat and pressure. Parts made from these materials are very hard, dense, and strong. They also have extremely high melting temperatures. Thus, finished parts are resistant to ablation in a high-heat and mass-flow environment such as those experienced in re- entry or in missile exhausts. These metals are used to manufacture re-entry vehicle nosetips, nozzle throat inserts, and jet vanes, which are used to steer engine exhaust.]

—Department of Space (Government of India), *Annual Report: 1974-1975*, p. 13; George P. Sutton, "Components

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of Solid Rockets," *Rocket Propulsion Elements: An Introduction to the Engineering of Rockets* (New York: John Wiley & Sons, 1986), pp. 326-327; "Category II-Item 8: Structural Materials," *Missile Technology Control Regime Annex Handbook*, pp. 8-7.

1974

The Indian Space Research Organization (ISRO) develops ISROPolyol as a substitute for the imported hydroxyl-terminated polybutadiene (HTPB). It also develops carboxyl-terminated polybutadiene (CTPB) for the third and fourth stages of the SLV-3. In addition, 10 chemical resins and adhesives are synthesized for various other "national agencies" under an import substitution program. [Note: HTPB is a binder and fuel used in solid-rocket motor propellant.]

—Department of Space (Government of India), *Annual Report: 1974-1975*, p. 12; "Category II-Item 4: Propellants," *Missile Technology Control Regime Annex Handbook*, p. 4-11.

1974

The Indian Space Research Organization's (ISRO) Propellant Fuel Complex (PFC) in Thiruvananthapuram (Kerala) becomes operational. Trial runs for the production of HEF-20 polyester VI-1, polyester PR-6, phenol formaldehyde resin, dicotyl adipate, perbenzoic acid, and polyurethane resin are successful. Special polyesters, formaldehydes, polyurethane resins, and other chemicals are produced in the complex in sample and production quantities for utilization in various rocket development programs.

—Department of Space (Government of India), *Annual Report: 1974-1975*, p. 12; Gopal Raj, "Developing Competence in Solid Propulsion," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), p. 90.

1974

India signs an agreement with France to supply transducers for the French Ariane program. The Vikram Sarabhai Space Centre's (VSSC) Pressure Transducer Unit (PTU) is expected to begin production by September 1975.

—Department of Space (Government of India), *Annual Report: 1974-1975*, p. 18.

1974

The Indian Air Force loses interest in the Devil program (reverse engineering of the Soviet SA-2 missile) and regards it as "technology gathering" project. The Air Force's waning interest is partly the consequence of the poor performance of the SA-2 in the 1971 Bangladesh War. An internal Air Force investigative committee concludes that of the 11 missiles fired during the war, almost all were directed towards the wrong target; the rest missed their targets completely. The Air Force's skepticism with the program is also linked to the Defense Research & Development Organization's (DRDO) failure to develop a powerful gas-turbine engine for the HF-24 Marut combat aircraft. The Air Force lobbies the government to purchase the solid-fuel Pechora surface-to-air missile (SAM), which is on offer from the Soviet Union. [Note: Development of the Pechora (SA-3) SAM began in 1956 at the Lavochkin OKB design bureau. The Pechora was designed to complement the SA-2 at low and medium altitudes; the first battery became operational in 1961. The Pechora is a two-stage weapon with a large solid-propellant booster and a smaller solid-fuel sustainer rocket motor. The booster is fitted with four large rectangular stabilizing fins. The main body is cylindrical in shape with four clipped delta shaped fins aft of the mid-point and four small

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delta moving control fins on the nose taper and four rectangular fins on the rear. The overall length of the missile is 6.1m, the diameter of the booster stage is 0.55m and that of the missile proper is 0.37m.]

—Raj Chengappa, "The Devil's Workshop," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers India, 2000), pp. 167-168; "SA-3 'Goa' Low to Medium Altitude Surface-to air Missile System, Tony Cullen and Christopher Foss, eds., *Jane's Land Based Air Defence 1992-93* (Coulsdon, Surrey), pp. 261-262.

1974

Due to faltering progress and insufficient interest in the Valiant program, the union cabinet requests that Dr. Nagchaudhuri explore whether the liquid-fuel engine developed for the Valiant can be used by the Indian Space Research Organization (ISRO) for the civilian satellite launch vehicle. During a meeting of the Defence Research & Development Laboratory (DRDL) and ISRO officials at the IISc in Bangalore (Karnataka), ISRO rejects the liquid-fuel engine, citing its own efforts in developing solid motors. The IISc's aeronautical department also appraises DRDL's efforts critically and cites instability problems in the Valiant's liquid-fuel engine. The Valiant program is subsequently terminated.

—Raj Chengappa, "The Devil's Workshop," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers India, 2000), p. 173.

December 1973

A French team from its space agency CNES tours Indian industrial establishments.

—Department of Space (Government of India), *Annual Report: 1973-1974*, p. 44.

Late 1973

The Indian Space Research Organization (ISRO) begins work on the design of various components, subsystems, and systems for the SLV-3.

—R. Nagappa, M.R. Kurup, and A.E. Muthunayagam, "ISRO's Solid Rocket Motors," *Acta Astronautica*, vol. 19, no. 8, 1989, p. 683.

June 1973

Due to intra-organizational differences, S.L. Bansal is removed from the Valiant program and appointed director of missiles at the Defense Research & Development Organization (DRDO) office in New Delhi.

—Raj Chengappa, "The Devil's Workshop," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers India, 2000), p. 172.

May 1973

First launch of a liquid-fuel rocket from The Sriharikota High-Altitude Range (SHAR) in Sriharikota (Andhra Pradesh). A 3.5-ton-thrust "clustered solid grain booster" is used for the rocket.

—Gopal Raj, "Early Initiatives in Liquid Propulsion," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), pp. 111-112; Department of Space (Government of India), *Annual Report: 1973-74*, p. 18.

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May 1973

Intra-organizational differences in the Defense Research & Development Laboratory (DRDL) hamper progress on the Valiant ballistic missile program. The leader of the Valiant team, S.L. Bansal, believes that the lab director V.S. Narayanan is far too focused on the Devil program.

—Raj Chengappa, "The Devil's Workshop," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers India, 2000), p. 172.

May 1973

The Indian Space Research Organization (ISRO) develops a 600kg-thrust liquid-fuel engine; the engine is based on a storable bi-propellant system using red-fuming nitric acid (RFNA) and aniline. Sufficient progress is made to build a flightworthy rocket stage based on liquid propulsion.

—Department of Space (Government of India), *Annual Report: 1973-74*, p. 18.

January 1973

First meeting of the ISRO-CNES joint commission (the Indian Space Research Organization and French space agency).

—Gopal Raj, "Early Initiatives in Liquid Propulsion," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), p. 122.

1973

Four fiber-glass motor cases for the fourth-stage of the SLV-3 are built by the Reinforced Plastics Centre (REPLACE) and pressure-tested. Qualification tests are planned to be completed by the end of 1974.

—Department of Space (Government of India), *Annual Report: 1973-1974*, p. 19.

1973

According to the Department of Space (DOS) Annual Report, the Vikram Sarabhai Space Centre (VSSC) is seeking design competence and pilot production of devices needed for:

- Instrumentation to evaluate the performance of propellants and rocket motors during static flight-tests;
- In-flight stabilization and control of rockets and satellites, and;
Control and guidance of multistage vehicles designed for orbiting satellites.

To achieve these goals, VSSC has developed a series of transducers to measure parameters such as thrust, acceleration, and pressure over a large range. Voltage and charge amplifiers to process the signals of these transducers and voltage-controlled oscillators to telemeter the measurements have also been developed. These instruments have been used in static and flight-tests of Menaka-I, Menaka-II, RH-125, RH-300, and RH-560 rocket motors and their propellants. VSSC has also standardized the design of inertial sensors such as "rate gyroscopes," "free gyroscopes," and "high-precision accelerometers." The inertial system under development will be used for "attitude reference" as well for the inertial measurement system of the SLV-3. A prototype system for "RH-300 roll-control, flight by fin-tip control" is under fabrication and an "electro-hydraulic fin- tip control system" for the RH-560 sounding rocket will be ready soon. Successful experiments have also been conducted with "strontium

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perchlorate as a secondary injectant for thrust vector control of rockets." An on-board digital computer has been designed for the control and guidance system of the SLV-3. The modular design of the computer permits its use with both the "stabilized-platform type" and "strapped-down type of inertial measurement systems." The ground model of this computer is nearing completion and preliminary experiments have been conducted to fabricate the computer using micro-electronic packaging techniques.

VSSC's Electronics Development Division has also developed the first phase of a PCM ground data recovery system. The division will supply a telemetry system to the SHAR, Sriharikota (Andhra Pradesh), which will have facilities to receive PCM and FM data from rockets and satellites.

[Note 1: A transducer is an electronic device that converts energy from one form into another; in a rocket, it produces an electrical signal proportional to a force or pressure input.

Note 2: An oscillator is an electronic device used for the purpose of generating a signal. Oscillators are found in computers, wireless receivers and transmitters, and audio frequency equipment. An oscillator employs a sensitive amplifier whose output is feedback to the input in phase. Thus the signal regenerates and sustains itself.

Note 3: Thrust vector controls (TVC) are used to achieve directional or attitude correction in solid rockets by vectoring or deflecting the thrust of the rocket motors. The two primary methods of producing lateral thrust with fixed nozzles include mechanical interference (MITVC) and secondary injection thrust vector control (SITVC). MITVC involves changing the direction of the supersonic gases at the nozzle exit plane by inserting a heat resistant body into the exhaust stream to deflect it. Devices used in this method include jet vanes, jetavators, and jet tabs. SITVC is accomplished by injecting fluid (liquid or gas) into the main exhaust stream of the rocket motor through ports in the expansion section of the nozzle. The motor's thrust is deflected by the force of the injected fluid and by the imbalance of pressure created in the nozzle.]

—Department of Space, Government of India, *Annual Report: 1973-1974*, pp. 16-17; Whatis.Com, <http://whatis.techtarget.com>; "Category II-Item 9: Navigation," *Missile Technology Control Regime Annex Handbook*, pp. 9-4, 9-7-9-8; Thiokol Propulsion, "Flight Direction Control," *Rocket Basics: A Guide to Solid Propellant Rocketry*, www.thiokol.com, pp. 25-28.

1973

The Indian Space Research Organization (ISRO) reports the following advances in the development of launch vehicle-related material technology, fiber-reinforced plastics, rocket hardware development and fabrication:

- Casting parameters and fabrication technology of high-strength magnesium alloys of the Az 92 series to build propellant tanks for control rockets and satellite components.
- Development of special-purpose polar, helical, and nozzle (filament) winding machines up to 1,000mm in diameter (one helical winding machine is supplied to an "outside research establishment").
- Development of rocket hardware such as motor cases, nozzles, fins, nosecones, and other structural elements like payload mounting, including experimental work in "explosive forming" technology to build 250mm-diameter hemispherical domes of aluminum alloy.

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- Expansion of the Rocket Fabrication Facility (RFF) at the Vikram Sarabhai Space Centre (VSSC) in Thiruvananthapuram (Kerala).
- Progress in substituting the nozzle and second stage of the Centaur rocket with indigenous ones.

[Note 1: Motor cases of a solid-propellant rocket serve as "a container for solid- propellant fuel" and "a vented pressure chamber in which the fuel is burned to provide forward thrust when expanded into the exit cone of the nozzle." The most commonly used materials used to build motor cases are ferrous alloys, including conventional "quench and temper" (hardened by heating and then plunging into liquid to cool quickly) steels and nickel precipitation-hardening alloy steels (e.g., maraging steel), nonferrous titanium alloys, aluminum alloys, and fiberglass reinforced plastics.

Note 2: The nozzle is the "device by which the internal energy of the exhaust gases is converted into kinetic energy, thereby producing thrust. For any given propellant system, the nozzle acts as a metering device to control the rate of gas flow, thus creating a predictable amount of thrust over a programmed time period. The energy conversion is accomplished by causing the gas molecules to accelerate to extremely high velocities as they leave the motor." The materials used in the fabrication of nozzles include structural materials (aluminum alloys and fiberglass- resin composites), adhesives, sealants and greases (zinc chromate, silicone grease), thermal insulators (composites of asbestos fibers and phenolic resins), coatings of refractory materials (e.g., zirconium dioxide), and ablative materials.

Note 3: A fin is an "aerodynamic appendage fixed to the body of a launch vehicle, typically at the base of the first stage, which provides stability during flight."

Note 4: The term "nose cone" refers to the "forward end of the rocket; the section which generally contains the payload."

Note 5: Explosive forming in metallurgy refers to "the use of explosives for controlled sheet metal forming." Although there are references to the process in the late 19th century, explosive forming developed in the United States during the 1950s with the growth of the aerospace industry. In explosive fabrication, "an explosive charge is detonated in the vicinity of the workpiece, as a result of which the metal is given very rapid acceleration over a very short period of time and is formed into a die shape, mainly as a result of its own kinetic energy. This process is normally used for the forming of a flat sheet or plate into a form die." Explosive forming is used for "performing operations on very large parts [of metal] where the forces required are beyond the capacity of most conventional presses...for forming sheet metal parts in different materials and to new shapes, and...to produce savings in the production of short-run items and prototype parts."

—Department of Space (Government of India), *Annual Report: 1973-74*, pp. 12-15; Thiokol Propulsion, "Cases," *Rocket Basics: A Guide to Solid Propellant Rocketry*, www.thiokol.com, pp. 14-16; Thiokol Propulsion, "Nozzles," *Rocket Basics: A Guide to Solid Propellant Rocketry*, www.thiokol.com, pp. 20-24; Mark Williamson, *Dictionary of Space Technology* (New York: Adam Hilger, 1989), pp. 121, 224; R. Davies and E.R. Austin, "Sheet Metal Forming: Explosive Forming," *Developments in High Speed Metal Forming* (New York: Industrial Press Inc., 1970), p. 184.

1973

The Indian Space Research Organization (ISRO) commissions a pilot-plant for the production of liquid propellants

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such as anhydrous hydrazine (10kg/day capacity). Production of unsymmetrical dimethyl hydrazine continues on a laboratory scale and the design and fabrication of a nitrogen tetroxide plant is completed. [Note: The hydrazine family of fuels is used in a wide variety of liquid-rocket engines requiring high performance and long-storage times. Hydrazine is most often used as a monopropellant (without an oxidizer) by decomposing it into hot gas with a catalyst. Nitrogen tetroxide is used as an oxidizer in liquid-rocket engines.]

—Department of Space (Government of India), *Annual Report: 1973-74*, p. 12; "Category 2-Item 4: Propellants," *Missile Technology Control Regime Annex Handbook*, pp. 4-3, 4-7.

1973

According to the Indian Space Research Organization (ISRO), the STEX complex at The Sriharikota High-Altitude Range (SHAR) is nearing completion. The facility's Static Test Stand, Spin Test Facility, Vibration Test Facility, Static Acceleration Facility, Drop and Destruction Test Facility, Extinguisher Well, Vertical Test Stand, Multipurpose Test Stand, and Instrumentation Facility, are in an advanced state of completion. Work is also continuing on setting up facilities for motor preparation, motor storage, mechanical maintenance, and administration.

—Department of Space (Government of India), *Annual Report: 1973-74*, p. 28.

1973

The Indian Space Research Organization (ISRO) says that it will begin constructing a Rocket Sled Facility at the Sriharikota High-Altitude Range (SHAR) shortly. The facility will simulate the conditions of rocket flight in a laboratory for the testing of rocket motors and other systems. The facility will consist of four to five kilometers of track over which a sled bearing the rocket booster will run; the track and allied structures will be designed to cater to velocities up to Mach 4. Instrumentations required to measure the different parameters will be deployed on the ground along with test vehicles.

—Department of Space (Government of India), *Annual Report: 1973-74*, p. 28.

1973

Work on the telemetry system, tracking system, communication system, computer and data processing, closed-circuit TV and data link, range timing, and telecommand systems at the Sriharikota High-Altitude Range (SHAR) in Sriharikota (Andhra Pradesh) nears completion. The telemetry and tracking systems are developed in collaboration with the Thumba Equatorial Rocket Launching Station (TERLS), the Vikram Sarabhai Space Centre (VSSC) in Thiruvananthapuram (Kerala), the Bhabha Atomic Research Center (BARC) in Trombay (Maharashtra), the Tata Institute of Fundamental Research (TIFR) in Mumbai (Maharashtra), the Electronics Corporation India Limited (ECIL) in Hyderabad (Andhra Pradesh), and the microwave division of Space Applications Centre (SAC) in Ahmedabad (Gujrat).

—Department of Space (Government of India), *Annual Report: 1973-74*, pp. 23, 26-27.

1973

The Indian Space Research Organization (ISRO) reports that the Menaka-I sounding rocket, which is capable of carrying meteorological payloads to altitudes of 55km and higher, will become operational by the end of 1974. The largest sounding rocket of the series, the RH-560, is undergoing flight-tests and will have the capability of carrying a 90kg payload to an altitude of 320km. Progress has also been made in the development of rocket cases, pyrolytic

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graphite, spray coating of refractory materials, development of ceramic coatings, alloys for gyro applications and metallic magnets for control, guidance, and instrumentation. Special purpose machines such as polar, helical, and nozzle-winding machines up to 1,000mm diameter have been developed. [Note: Pyrolytic deposition is a high-temperature process used to deposit a thin, dense coating of metal or ceramic onto a mold or mandrel in order to form a part. It can also be used to coat another material in order to achieve strong adhesion and bonding between the coating material and the underlying surface. The purpose of these processes is to improve the ability of the coated and densified items to survive the extreme environments in which the critical rocket system parts operate.]

—Department of Space (Government of India), *Annual Report: 1973-74*, pp. 3-4; "Category II-Item7: Pyrolytic Technology," *Missile Technology Control Regime Annex Handbook*, p. 7-1.

1973

India's space program benefits from collaborative programs with France, West Germany, Japan, United Kingdom, United States, and the Soviet Union. Indian engineers undergo training in facilities offered by the French space agency, CNES, in the fields of satellite launchers and communication satellites. Indian Space Research Organization (ISRO) engineers also train in establishments of the West German space agency, DFVLR, in areas such as environmental simulation test facilities, pulse code modulation (PCM) on-board systems and ground operations, microelectronics and packaging, and remote sensing techniques.

—Department of Space (Government of India), *Annual Report: 1973-74*, p. 44.

1973

The Indian Space Research Organization (ISRO) reports that it launched 106 rockets from the Thumba Equatorial Rocket Launching Station (TERLS) in 1973. These included sounding rockets for scientific investigations, meteorological rockets, and flight- tests of rockets under development. Of these tests, 44 launches were conducted to evaluate the performance of rockets under development. [Note: During the period 1963-73, a total of 600 rockets were launched from TERLS for scientific and technological purposes.]

—Department of Space (Government of India), *Annual Report: 1973-74*, pp. 4, 11, 23.

1973

Indian Space Research Organization (ISRO) engineers begin work on the design, fabrication, assembly, and calibration of a three-ton-thrust liquid-fuel engine; the first test is completed with satisfactory results. Development of the turbopump unit, gas generators, and associated systems is planned. ISRO also initiates studies and design work to develop cryogenic engines in the future. A 500kg-thrust Lox-kerosene system is built in the Thumba Equatorial Rocket Launching Station (TERLS) area. In addition, engineers initiate studies on the design and development of pumps to meet the low-temperature requirements of cryogenic engines and turbine development for the turbopump feed system. A project is launched to design a 1,000kg-thrust Lox-kerosene engine.

[Note 1: The turbopump rocket feed system pressurizes the propellants by means of pumps, which in turn are driven by turbines. The turbines derive their power from the expansion of hot gases. Turbopump rocket systems are usually used in high-thrust and long-duration rocket units; they are lighter than other types for these applications. A gas generator is used as the source of hot gas (from combustion of propellants) for driving the turbines or turbopumps in a liquid rocket engine.]

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Note 2: Cryogenics refers to the science of low-temperature phenomenon. Cryogenic propellants are liquefied gases stored at very low temperatures, namely liquid hydrogen as the fuel and liquid oxygen as the oxidizer. Because of the low temperatures of cryogenic propellants, they are difficult to store over long periods of time. For this reason, they are less desirable for use in military rockets. Liquid hydrogen also has very low density and therefore requires a storage volume many times greater than other liquid fuels. Despite these drawbacks, the high-efficiency nature of liquid hydrogen-liquid oxygen makes these fuels desirable for use in civilian rockets; liquid hydrogen delivers a specific impulse about 40% higher than other rocket fuels.]

—Department of Space (Government of India), *Annual Report: 1973-74*, p. 18; George P. Sutton, "Liquid Propellant Rocket Fundamentals," *Rocket Propulsion Elements: An Introduction To The Engineering of Rockets* (New York: John Wiley & Sons, 1986), p. 153; George P. Sutton, "Liquid Propellant Rocket Engine Systems," *Rocket Propulsion Elements: An Introduction To The Engineering of Rockets* (New York: John Wiley & Sons, 1986), p. 243.

1972-1973

The Department of Space (DOS) announces plans to manufacture ammonium perchlorate (AP) in India and says that a cell for its manufacture will be commissioned soon. The process for manufacturing AP has been developed by the Central Electro-Chemical Research Institute (CECRI) in Karaikudi (Tamil Nadu). The experience gained from the operation of the pilot plant will be used to build a 150-ton per-annum capacity plant. [Note: Solid oxidizers provide oxygen needed to burn solid-rocket motor fuel. By carrying fuel and oxidizer together, the rocket does not depend on the atmosphere for oxygen. Ammonium perchlorate (AP) is an oxidizing agent used by most modern solid-propellant formulas. It accounts for 50 to 85% of the propellant by weight, depending on the formulation of the propellant.]

—Gopal Raj, "Developing Competence in Solid Propulsion," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), p. 97; Department of Space (Government of India), *Annual Report: 1973-74*, p. 12; "Category II- Item 4: Propellants," *Missile Technology Control Regime Annex Handbook*, pp. 4-10.

November 1972

The Indian Space Research Organization (ISRO) recognizes the need to follow up the SLV-3 with the development of larger and more powerful launch vehicles designed to place 800kg satellites in geostationary orbit. A study team of ISRO engineers recommends an integrated launch vehicle development program using a modular, building-block approach. Further studies are commissioned to obtain improved performance estimates and plan for technologies and facilities required for building such vehicles in the future. [Note: Geostationary refers to a satellite that travels about the Earth's equator at an altitude of 35,000km at a speed matching that of the Earth's rotation, thereby maintaining a constant relation to points on the Earth.]

—Department of Space (Government of India), *Annual Report: 1973-74*, p. 20.

October 1972

Design phase of the SLV-3 completed.

—Department of Space (Government of India), *Annual Report: 1973-74*, p. 19.

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June 1972

India's union cabinet makes a show of turning down the Defense Research & Development Laboratory's (DRDL) budgetary request of 160 million rupees to begin work on the Valiant and Devil missile programs. However, Prime Minister Indira Gandhi secretly sanctions funds for the projects using the prime minister's discretionary powers. Funding for the missile project is subdivided under various heads to disguise the true nature and scale of the missile projects.

— Raj Chengappa, "Not so Valiant," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers India, 2000), p. 159.

1 June 1972

The Indian government establishes an independent Space Commission and Department of Space (DOS). The Indian Space Research Organization (ISRO) is brought under DOS jurisdiction. The Space Commission is modeled on the Department of Atomic Energy (DAE). Professor Satish Dhawan is appointed chairman of the Space Commission, secretary for DOS, and chairman of ISRO. In 1972, ISRO has a budget of 100 million rupees and organizational strength of 3,000 people. [Note: The DOS is responsible for the execution of space activities in India through ISRO in the areas of space applications, space technology, and space sciences. The headquarters of DOS and ISRO are located in Bangalore (Karnataka) and provide overall direction to the technical, scientific, and administrative functions of the four ISRO centers: Space Applications Centre (SAC), Ahmedabad (Gujrat); ISRO Satellite Centre (ISAC), Bangalore; Vikram Sarabhai Space Centre (VSSC), Thiruvananthapuram (Kerala); and SHAR, Sriharikota (Andhra Pradesh).]

—Gopal Raj, "SLV-3: India's First Launch Vehicle," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), p. 62; Y. S. Rajan, "Management of the Indian Space Program," in R. Narasimha and A.P.J. Abdul Kalam, eds., *Developments in Fluid Mechanics and Space Technology* (Bangalore: Indian Academy of Sciences, 1988), p. 399; Department of Space (Government of India), *Annual Report: 1978-79*, pp. 4-5.

January 1972

Group Captain V.S. Narayanan is appointed director of the Defense Research & Development Laboratory (DRDL). Under his leadership, the DRDL launches "Project Devil," a project to reverse-engineer and produce the Soviet SA-2 surface-to-air missile (SAM) indigenously within seven years. Narayanan is also asked to set up the technological infrastructure to build a series of missiles. Plans for Project Valiant are kept secret. The DRDL's budget is increased to 160 million rupees, of which 50 million rupees are sanctioned for Project Devil for a three-year period. Of the 50 million rupees, nearly half is spent on imports. [Note: In developing missile systems, the DRDL adopted the philosophy of reverse engineering or "one-to-one substitution"; this was in contrast to the Indian Space Research Organization's (ISRO) strategy of "technology development" and "performance upgrading." The decision to reverse engineer the Soviet SA-2 SAM was regarded as a means to acquire detailed knowledge of all the design parameters of a proven missile and to establish the infrastructure for the development of modern missiles in India. The necessary infrastructure for designing, developing, testing, and building missiles was developed at the DRDL between 1972-1982. This included aerodynamic, structural, and environmental test facilities, liquid- and solid-propulsion test facilities, fabrication and engineering facilities, control, guidance, rubber, and computer facilities. It

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should also be noted that although the SA-2 is nominally a surface-to-air "defensive" missile, it can readily be transformed into a surface-to-surface system for "offensive" purposes.]

—Defence Research & Development Laboratory, "Historical Background," www.drdo.org; Raj Chengappa, "Not So Valiant," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers India, 2000), pp. 152, 159; A.P.J. Abdul Kalam with Arun Tiwari, "Creation," in *Wings of Fire: An Autobiography* (Hyderabad: Universities Press (India) Limited, 1999), p. 73.

1972

S. L. Bansal and his team of scientists and engineers propose a three-stage design for the Valiant ballistic missile. Stage one would be comprised of a cluster of four 30-ton liquid-fuel engines; stage two would be comprised of two engines for the coasting phase; and stage three would be comprised of probably one engine. The scientists hope to use a scaled-up version (by nearly 10 times) of the SA-2 liquid engine for the Valiant. Work begins on the design and development of the combustion chamber, injector, and nozzles for the engine. Indian missile scientists focus on developing a gimballed platform type of inertial navigation system. The Defense Research & Development Laboratory (DRDL) decides to import gyros and equipment to calibrate them from the United States. Some of the inertial guidance systems built in India are later tested on the Air Force's Canberra and Avro aircraft.

[Note 1: Liquid-propellant rocket engines burn fuel and oxidizer, which is fed to them in the proper ratio from tanks through pipes, valves, and sometimes pumps. These engines are far more complex than solid-propellant motors and contain many precision-machined and moving parts. Unlike solid motors, some liquid-rocket engines can be shut off and restarted, and some can be reused after refurbishment. Liquid-rocket engines are typically far more thrust-efficient than solid-rocket motors and are usually preferred for non-military missions. But they are difficult to manufacture, require more maintenance, and take longer to prepare than solid-rocket motors. Fuel and oxidizer can also be more difficult to handle and store because they are toxic, corrosive, or cryogenic. Once a command to fire a missile is given, the fuel and oxidizer tanks are pressurized. Fuel and oxidizer are forced into the injector head, where they are atomized by passing through small injectors, and mixed in the combustion chamber. Upon ignition, the hot, expanding gases rush out of the nozzle at very high velocity and give the missile thrust.

Note 2: Guidance systems are used to steer a missile along a trajectory or flight-path. Guidance sets are composed of assemblies of sensitive electronic and mechanical equipment. The heart of any guidance system is the inertial measurement unit (IMU), which contains the gyroscopes and accelerometers. Before launch, the guidance sets are calibrated and provided information on the missile's position, velocity, and orientation. After launch, the gyroscopes and accelerometers, or inertial instruments, sense missile accelerations and rotations, and convert them into electrical signals. A computational device converts these signals into deviations from the programmed part and issues commands to steer the missile back on course.

Note 3: In an inertial navigation system of the gimballed platform type, the "accelerometers are mounted in a gyro-stabilized, three-axis platform that isolates it from the vehicle angular motion and allows the accelerometer to operate in a very benign condition with the gyros providing [the] only measurement for any angular deviation from the stabilized condition."

—Raj Chengappa, "The Devil's Workshop," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear*

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Power (New Delhi: Harper Collins Publishers India, 2000), pp. 169-171; "Category I-Item II: Complete Subsystems," *Missile Technology Control Regime Annex Handbook*, pp. 2-11-2-12; Dr. N.C. Birla and B.S. Murthy, eds., "Inertial Guidance and Sensors," *Indian Defence Technology: Missile Systems* (DRDO, Ministry of Defence, December 1998), pp. 155-156.

1972

Professor Satish Dhawan consolidates the program management of SLV-3 and appoints A.P.J. Abdul Kalam as project director.

—Gopal Raj, "SLV-3: India's First Launch Vehicle," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), pp. 50, 54-57, 65-67.

1972

As part of the project to reverse-engineer the Soviet SA-2 surface-to-air missile (SAM), the Defense Research & Development Laboratory (DRDL) subcontracts the casting of the 350kg magnesium liquid-fuel engine frame to Hindustan Aeronautics Limited (HAL), Koraput division (Maharashtra); the casting of the solid-booster rocket is subcontracted to the Vishakapatnam-based Bharat Heavy Plates & Vessels Limited (Andhra Pradesh).

—Raj Chengappa, "The Devil's Workshop," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers India, 2000), pp. 164-165.

1972

Professor Satish Dhawan initiates important organizational changes in the Indian Space Research Organization (ISRO). He unifies the Space Science & Technology Centre (SSTC) in Thiruvananthapuram (Kerala), the Rocket Propellant Plant (RPP) in Thumba (Kerala), Rocket Fabrication Facility (RFF) in Thumba, Propellant Fuel Complex (PFC) in Thumba, and the Sriharikota High-Altitude Range (SHAR) in Sriharikota (Andhra Pradesh) into a single entity-Vikram Sarabhai Space Centre (VSSC), with its headquarters in Thiruvananthapuram. Similarly, all of the space department's satellite applications facilities are consolidated under an umbrella Satellite Applications Centre (SAC), with its headquarters in Ahmedabad (Gujrat). Dr. Brahm Prakash and Professor Yash Pal are appointed directors of VSSC and SAC, respectively.

—Gopal Raj, "SLV-3: India's First Launch Vehicle," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), pp. 63, 65-66.

1972

The Defense Research & Development Laboratory (DRDL) begins to aggressively recruit scientists and engineers from India's academic institutions to participate in the Devil and Valiant missile programs. The laboratory's organizational strength expands from 400 employees to 2,500 by 1974. The Indian Institute of Sciences (IISc) in Bangalore (Karnataka) serves as a prime source for recruiting talented aeronautical engineers and scientists. Work begins on solid- and liquid-propulsion technologies and the development of infrastructural facilities for fabrication, static-testing, qualification, and propellant production.

—A. Subhananda Rao, "Development of Solid Propulsion Systems for Guided Missiles," in H.S. Mukunda and A.V. Krishnamurty, eds., *Recent Advances in Aerospace Sciences and Engineering* (Bangalore: Interline Publishing, 1992),

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p. 182; Raj Chengappa, "Not So Valiant," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers India, 2000), p. 161.

1972

Work begins on the construction of the STEX facility at the Sriharikota High-Altitude Range (SHAR) in Sriharikota (Andhra Pradesh).

—Gopal Raj, "Developing Competence in Solid Propulsion," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), p. 88.

1972

Development and completion of a pilot-plant production for solid propellants and related chemicals required for various stages of the satellite launch vehicle (SLV) and other medium-sized rockets at the Vikram Sarabhai Space Centre (VSSC). This includes the manufacture of polyurethane propellant for the RH-300 rocket, a monolithic version of the SLV-3 first-stage, polybutadiene-acrylic acid-acrylonitrile (PBAN) binder for the second-stage of SLV-3, and carboxyl-terminated polybutadiene (CTPB) propellant for the third and fourth stages of the SLV-3. The Indian Space Research Organization (ISRO) reports that the Propellant Fuel Complex (PFC) will produce a variety of polymeric fuel binders such as polybutadienes, polyurethanes, polyesters, plasticizers, and catalysts required for high-energy propellants. In addition, certain additives such as copper chromite are being produced on a small scale. Igniters and pyrotechnic devices developed in the pyrotechnic laboratory are successfully tested on the Centaur rocket. [Note 1: Polymers such as CTPB and PBAN are chemicals used as binders and fuel in solid-rocket motor propellant. Note 2: Additives are generally classified according to their function such as fuel, oxidizer, binder, curing agent, or burn-rate catalyst. Copper chromite is added as a burn-rate catalyst in solid propellants. Note 3: Igniters in a solid-propellant motor generate the heat and gas required for motor ignition. Igniters include the pyrotechnic, electrical, torch, hypergolic, and catalytic types. Among these, the pyrotechnic type is the most practical and widely used.]

— Department of Space (Government of India), *Annual Report: 1973-74*, pp. 3, 12; George P. Sutton, "Solid-Propellants and Combustion," *Rocket Propulsion Elements: An Introduction to the Engineering of Rockets* (New York: John Wiley & Sons, 1986), p. 294; Sutton, "Components of Solid Rockets," p. 317; S. Krishnan and R.D. Swami, *Copper Chromite Catalyst Qualification as Composite Solid Propellant Burning Rate Enhancer*, 47th AGM of Aerospace Society of India (IIT, Madras), 6-8 January 1996.

1971-1973

A total of 19 sounding rockets are launched from the Sriharikota High-Altitude Range (SHAR) between 1971-74. The Indian Space Research Organization (ISRO) plans to expand the complex by building a larger launch pad to handle launches of multistage rockets. Plans are also afoot to construct a launch pad to accommodate liquid-fuel boosters with up to 10 tons of thrust.

—Department of Space (Government of India), *Annual Report: 1973-1974*, p. 26.

30 December 1971

ISRO chairman Dr. Vikram Sarabhai dies of a heart attack. The director of the Tata Institute of Fundamental Research (TIFR) and secretary of the Department of Electronics, Dr. M.G.K. Menon, is asked to head the Indian

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Space Research Organization (ISRO) as a temporary arrangement.

—Gopal Raj, "SLV-3: India's First Launch Vehicle," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), pp. 59-61.

9 October 1971

The Sriharikota High-Altitude Range (SHAR) in Sriharikota (Andhra Pradesh) becomes operational with the launch of an RH-125 sounding rocket. A complex for flight-testing sounding rockets is completed and plans are made to augment the facility to launch multi-stage vehicles. The sounding rocket complex can launch single- and two-stage rockets with a maximum diameter of 560mm and weight of up to 1.5 tons.

—Department of Space (Government of India), *Annual Report: 1973-74*, p. 26; Gopal Raj, "SLV-3: India's First Launch Vehicle," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), p. 49.

April 1971

The Defense Research & Development Laboratory (DRDL) prepares a feasibility report on building a long-range ballistic missile, code-named "Project Valiant." The Indian government sanctions DRDL a few hundred thousand rupees to begin work on the project.

— Raj Chengappa, "Not So Valiant," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers India, 2000), p. 149.

1971

The Indian Space Research Organization (ISRO) sanctions the establishment of a Fibre Reinforced Plastics (FRP) division and Reinforced Plastic Centre (REPLACE) to manufacture composite materials for India's satellite launch vehicle (SLV) program. Indian scientists travel to Sud Aviation in France for a three month-long training program to learn techniques for making composite nozzles for the Centaur sounding rocket. They also travel to other establishments in Western Europe and the United States, including facilities of composite material manufacturers, to gain knowledge and information about composite manufactures. [Note: Composites are a "class of materials in which the fibers of a reinforcing material are set in the 'matrix' of another material." Composites and laminates are used to make "missile parts that are often lighter, stronger, and more durable than parts made of metal or other material. Composites and laminates can be used almost anywhere in ballistic missiles or unmanned aerial vehicles, including cruise missiles. Uses include solid rocket motor cases, interstages, wings, inlets, nozzles, heat shields, nosetips, structural members, and frames." Examples of composites are carbon composite, Kevlar composite, ceramic-matrix composite, and metal-matrix composite.]

—Gopal Raj, "Developing Competence in Solid Propulsion," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), pp. 102-103; Mark Williamson, *Dictionary of Space Technology* (New York: Adam Hilger, 1989), p. 65; "Structural Materials: Category II-Item 8," *Missile Technology Control Regime Annex Handbook*, p. 8-1.

1971

During a sabbatical at the National Defense College, New Delhi, the joint director of missiles in the Indian Air Force Group Captain V.S. Narayanan prepares a classified study on developing a range of missiles, including plans to

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upgrade the SLV-3 to an intermediate-range ballistic missile.

—Raj Chengappa, "Not so Valiant," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers India, 2000), p. 149.

1971

The Indian Space Research Organization (ISRO) sanctions the building of Solid Propellant Space Booster Plant (SPROB) in Sriharikota (Andhra Pradesh) for 80 million rupees. The proposed plant will be capable of casting solid-propellant grains up to two meters in diameter and weighing 10 tons. The 10-ton capability means that it will be able to cast the whole SLV-3 first-stage as a single grain, rather than in segments. The SPROB's production capacity is fixed at 500 tons annually, enough to produce more than 30 SLV-3 launchers. The solid-propellant plant and the static-test facility at Sriharikota are expected to cost 157 million rupees. [Note: According to Indian defense journalist Raj Chengappa, SPROB's "abnormally" large capacity is an indicator that Indian leaders probably intended to use it for military purposes. The SPROB now has the capability of producing single grains measuring 3m in diameter and capable of carrying 25-30 tons of propellant. Indian scientists claim that it compares well with other similar facilities in the world and India has developed solid-propellants that are very close to frontier technologies in properties such as "specific impulse, burn rate, density, and mechanical properties."]

—Gopal Raj, "Developing Competence in Solid Propulsion," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), pp. 77-79; "Annexure-I: Cost Estimates of the Space Research Programme," *Atomic Energy and Space Research: A Profile For The Decade 1970-80* (Atomic Energy Commission, 1970); M.R. Kurup, V.N. Krishnamoorthy, and M.C. Uttam, "Solid propellant technology in India," in R. Narasimha and A.P.J. Abdul Kalam, eds., *Developments in Fluid Mechanics and Space Technology* (Bangalore: Indian Academy of Sciences, 1988), p. 341; Raj Chengappa, "Not so Valiant," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins India Private Limited, 2000), p. 158; Department of Space (Government of India), *Annual Report: 1973-74*, p. 12.

1970-1980

The Defense Research & Development Laboratory (DRDL) develops a three-ton liquid-propellant engine for Devil missile's second stage. This three-ton class engine uses a propellant combination of "RFNA [red-fuming nitric acid] as oxidizer and G- fuel (Xylidene and Tri-ethylamine) as fuel. According to Defense Research & Development Organization's (DRDO) sources, this engine is designed for "fixed mode operation"; the engine's turbo pump is driven by a "monopropellant gas generator" and the "duration of operation is limited to 42 seconds." The Devil's second stage is not provided with any thrust-vector control mechanism.

—Dr. N.C. Birla and B.S. Murthy, eds., "Propulsion Systems," *Indian Defence Technology: Missile Systems* (DRDO, Ministry of Defence, December 1998), p. 99.

1970-1980

The Defense Research & Development Laboratory (DRDL) develops two solid boosters for the Devil surface-to-air missile. The salient features of these motors include:

- Use of double-base propellant with a specific impulse of 200 seconds.
- Propellant grains in multi-tubular configuration; these grains are free-standing without any inhibition.

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- Nozzles with variable throat area to facilitate operations in temperatures ranging from -40°C to +40°C without variation in burn time.
- Use of high-strength 15CDV6 steel for the motor casing.

These motors are flight-tested, culminating in the successful development of boosters for surface-to-air missile (SAM) applications. [Note: The term-specific impulse refers to the amount of thrust for the weight of fuel burnt.] —A. Subhananda Rao, "Development of Solid Propulsion Systems for Guided Missiles," in H.S. Mukunda and A.V. Krishnamurty, eds., *Recent Advances in Aerospace Sciences and Engineering* (Bangalore: Interline Publishing, 1992), p. 183; George P. Sutton, "Definitions and Fundamentals," *Rocket Propulsion Elements: An Introduction to The Engineering of Rockets* (New York: John Wiley & Sons, 1986), p. 21.

1969-1972

The Indian Space Research Organization (ISRO) develops a 200kg-thrust liquid-propulsion engine. Improvement in the quality of the ablative lining used in the engine (asbestos and phenolic resin) permits an increase in the duration of the engine firing from 10 to 45 seconds. The tests are carried out at the Rocket Propellant Plant (RPP) in Thumba (Kerala). [Note: Asbestos fibers and phenolic resins are composite materials that are used as thermal insulators between the nozzle ablative (erodible) and structural materials for the protection of the latter from high-temperature exhaust gases. They are also used for protection from aerodynamic heating.]

—Gopal Raj, "Early Initiatives in Liquid Propulsion," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), pp. 110-111; Thiokol Propulsion, "Nozzles," *Rocket Basics: A Guide to Solid-Propellant Rocketry*, www.thiokol.com, p. 23.

1970-1972

India approaches the United States and France for technical cooperation to build the STEX complex in Sriharikota (Andhra Pradesh). The United States rejects India's request. However, France agrees to assist India in designing and building the facility. The Indian Space Research Organization (ISRO) signs a technical cooperation agreement with the French company Société Européenne de Propulsion (SEP). An ISRO team travels to France for training. French scientists help their Indian counterparts design the various test facilities, including the critical six-component test stand. Most of the fabrication of parts for the facility is done in India. However, some of the critical machinery such as the 16-ton vibration table is imported from Britain.

—Gopal Raj, "Developing Competence in Solid Propulsion," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), pp. 87, 88.

1970-1971

ISRO's Propellant Engineering Division (PED) headed by V. Gowariker begins development of carboxyl-terminated polybutadiene (CTPB) resin for the SLV-3 upper stages. Due to difficulties in obtaining resin supplies from US companies, Gowariker's team decides to produce the resin indigenously. India's indigenous CTPB production process is proven on a lab-scale by mid-1971; the resin's chemical structure is slightly different from CTPB and the new resin is called High Energy Fuel-20 (HEF-20). HEF-20 is substituted for imported CTPB propellant formulations in the SLV-3's third and fourth stages. [Note: Carboxyl-terminated polybutadiene (CTPB) is a polymer used as a binder and fuel in solid rocket motor propellant. It is a liquid that polymerizes during motor manufacture to form

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the elastic matrix that holds the solid-propellant ingredients together in a rubber-like polymeric composite material. CTPB also burns as fuel and contributes to the overall thrust of the rocket motor. Polymers such as CTPB are used in the production of solid-rocket motors, hybrid-rocket motors, smaller rocket motors used to launch unmanned aerial vehicles (UAVs), and cruise missiles. These binding ingredients greatly affect motor performance, aging, storability, propellant processing, and reliability.]

—Gopal Raj, "Developing Competence in Solid Propulsion," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), pp. 89-90; "Category II-Item 4: Propellants," *Missile Technology Control Regime: Annex Handbook*, pp. 4-11-4-12.

December 1970

During a meeting with Dr. B.D. Nagchaudhuri in Hyderabad (Andhra Pradesh), Bansal rules out the possibility of building an 8,000km-range ballistic missile on grounds that India lacks the technological and organizational base to build long-range systems. He outlines the feasibility of building a 1,500km-range ballistic missile within six to eight years if given access to unrestricted manpower and finances. The successful development of a 1,500km-range missile is also considered overly optimistic.

—Raj Chengappa, "Build an ICBM or I'll Shut Down the Lab," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers India, 2000), p. 131.

November 1970

Prime Minister Indira Gandhi assigns Dr. B.D. Nagchaudhuri to initiate a top-secret feasibility study for building long-range ballistic missiles. Nagchaudhuri directs S. L. Bansal, head of Defense Research & Development Laboratory's (DRDL) rocketry division, to constitute a core group to prepare plans for building an 8,000km-range ballistic missile capable of carrying a 500kg payload within four years.

—Raj Chengappa, "Build an ICBM or I'll Shut Down the Lab," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers India, 2000), pp. 129-131.

1970

First test of the Menaka-II sounding rocket. [Note 3: Menaka-II is a two-stage, solid-motor rocket capable of carrying a 5.5kg-payload to an altitude of 75km.]

—Gopal Raj, "First Steps in Rocketry," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), p. 41.

1970

India designs and tests a new RH-125 rocket with polyvinyl chloride (PVC) as the propellant. The new rocket weighing 32kg can carry a 7kg payload to a height of 10km.

—Gopal Raj, "First Steps in Rocketry," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), pp. 40-41.

1970

Indian Space Research Organization (ISRO) decides to build a four-stage satellite launch vehicle (SLV) with a capability to place a 40kg satellite in a 400km near-circular earth orbit. The design and development of the

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vehicle's four stages is broken up into four subprojects and assigned to individual project leaders. V. Gowariker is selected to head the Design Project Stage-1 (DPS); A.E. Muthunayagam for DPS-2; M.R. Kurup for DPS-3; and A.P.J. Abdul Kalam for DPS-4. The development of the SLV-3 is expected to cost 35 million rupees. [Note: ISRO opts for an all-solid four-stage rocket, as it has more experience with solid fuels. Further, the Indian SLV is modeled on the US Scout rocket, which has an all solid-fuel configuration. Since the Scout has flown successfully in the past, and knowledge of its dimensions and design parameters are available publicly, Indian scientists believe that a four-stage solid-fuel vehicle is feasible.]

—Gopal Raj, "SLV-3: India's First Launch Vehicle," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), pp. 50, 54, 55-57; "Annexure-I: Cost Estimates of the Space Research Programme," *Atomic Energy and Space Research: A Profile For The Decade 1970-80* (Atomic Energy Commission, 1970).

1970

France offers to license the production of SSIIBI anti-tank missiles to India. India accepts the French offer and sets up Bharat Dynamics Limited (BDL) in Hyderabad (Andhra Pradesh), to produce 1,000 SS11B1 anti-tank missiles annually for a period of 10 years. The Defense Research & Development Laboratory's (DRDL) anti-tank missile project ends in failure; almost half of DRDL's scientists are recruited to join BDL. [Note: Bharat Dynamics Limited (BDL) was incorporated in 1970 by signing a comprehensive license agreement between M/s Aerospatiale (Nord Aviation) of France and the Government of India for technology transfer to manufacture SSIIBI-a first-generation anti-tank missile. BDL was nominated as the prime production agency with a capital outlay of 50 million rupees.]

—Raj Chengappa, "Build an ICBM or I'll Shut Down the Lab," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers India, 2000), p. 142; *69th Report: Bharat Dynamics Limited*, Parliamentary Committee on Papers: Rajya Sabha, 13 March 1999.

1 July 1970

Dr. B.D. Nagchaudhuri is appointed scientific advisor to the defense minister.

—Raj Chengappa, "Build an ICBM or I'll Shut Down the Lab," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers India, 2000), p. 132.

Early 1970s

The West German space agency Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt (DFVLR) agrees to help the Indian Space Research Organization (ISRO) in the design of a high-altitude test (HAT) facility to simulate the near vacuum conditions in space. This facility will be used to test the performance of a satellite launch vehicle's upper stages. [Note: Environmental test facilities such as high-altitude facilities (HAT) are used to expose rocket or missile components, subsystems, and entire vehicles to the low pressures, high and low temperatures, vibrations, and acoustics of powered flight in order to measure the responses. The data generated are used to confirm the correct designs and ensure flight worthiness. High-altitude testing is simulated by sealing test objects into rugged pressure chambers, which are then evacuated with vacuum pumps. Flight temperatures are simulated inside thermally insulated chambers equipped with heaters and refrigeration equipment. These chambers are equipped with vibration equipment designed to replicate specific vibration and acoustic environments. Vibration equipment are motor-driven tables capable of providing amplitude-frequency spectra to the levels required for a

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complete rocket system, subsystem, or component required during powered flight. Acoustic chambers use a combination of electrostatically or electromagnetically driven horns, like loudspeakers to provide a spectrum of sound pressures like those generated by a rocket motor exhaust and very high-speed aerodynamic flight.]

—Gopal Raj, "Developing Competence in Solid Propulsion," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), p. 88; "Category II-Item 15: Test Equipment," *Missile Technology Control Regime Annex Handbook*, pp. 15-9-15-10.

1970

Work begins on expanding the Rocket Propellant Plant (RPP) in Thumba (Kerala) to meet the demands of the satellite launch vehicle (SLV) program. Facilities are built to mix and cast larger quantities of propellant. In addition, ovens are acquired to "cure" the bigger solid-propellant motors. The total cost for building and expansion is estimated at 15 million rupees. Dr. Vikram Sarabhai also approves V. Gowariker's proposal to build a Propellant Fuel Complex (PFC) at the site to be used for scaling up studies to demonstrate production on an industrial scale as well as to manufacture polymers for use in the rocket program. [Note: The production equipment and infrastructure necessary to produce solid-rocket propellant are complex and specialized. Facilities and equipment are necessary for preparing the various propellant ingredients, mixing and handling the propellant, casting and curing the propellant inside the motor case, and other specialized processes such as pressing, machining, extruding, and acceptance testing. Solid propellant is produced by one of the two processes, either batch mixing or continuous mixing. Most rocket programs use the batch process to make solid-rocket motor propellant. The individual propellant ingredients such as the binder, oxidizers, metal powder, stabilizers, curing agents, and burn-rate modifiers, are mixed in large mixers to form a viscous slurry. The slurry is poured or cast into the rocket motor case, in which a mandrel creates a hollow chamber running down the center of the motor. The loaded motor case is placed in a large oven to cure the propellant. During curing, the slurry is transformed into a hard rubbery material, or propellant grain. The rocket motor with the cured propellant is then cooled, the mandrel removed, and any final trimming finished. Finished motors are usually X-rayed to ensure that propellant grain is homogenous, bonded to the case, and free of cracks.]

—Gopal Raj, "Developing Competence in Solid Propulsion," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), pp. 83-84; "Annexure II: Provisions Included in the IV Plan (1969-74) For Space Research," *Atomic Energy and Space Research: A Profile For The Decade 1970-80* (Atomic Energy Commission, 1970); "Category II-Item 5: Propellant Production," *Missile Technology Control Regime Annex Handbook*, pp. 5-2-5-3.

1970

India's space profile for the decade 1970-80 states that special attention will be paid toward developing sophisticated control and guidance systems for multistage satellite launch vehicles (SLVs). This includes the "...design of optical, magnetic, and inertial type sensors and control components of electro-mechanical, magnetic, pneumatic and hydraulic types and associated special electronics." In addition, "...fibre glass, strip-wound, and helically welded rocket motors as well as special materials for aerospace use are required to be carried from pilot plant to the stage of large scale fabrication." Indian Space Research Organization (ISRO) budgets 25 million rupees for the development of inertial and in-flight guidance systems and onboard miniaturized computers for rockets.

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—"Space Research," *Atomic Energy and Space Research: A Profile For The Decade 1970-80* (Atomic Energy Commission, 1970), p. 31; "Annexure-I: Cost Estimates of the Space Research Programme," *Atomic Energy and Space Research: A Profile For The Decade 1970-80* (Atomic Energy Commission, 1970).

1970

According to India's space profile for the decade 1970-80, the launch of the SLV-3 will be followed by the development of a more powerful satellite launch vehicle between 1975-79. The new vehicle will be capable of placing a 1,200kg satellite into synchronous orbit at 40,000km.

—"Space Research," *Atomic Energy and Space Research: A Profile For The Decade 1970-80* (Atomic Energy Commission, 1970), p. 28.

1970

India launches a total of 205 sounding rockets between 1964-70 and plans to launch an additional 75 such rockets in 1970.

—"Space Research," *Atomic Energy and Space Research: A Profile For The Decade 1970-80* (Atomic Energy Commission, 1970), p. 29.

1969-1965

1962-1970

As part of the project to build anti-tank missiles, Defense Research & Development Laboratory (DRDL) acquires facilities for machining, tool making, injection, molding, assembly, inspecting, carpentry, and electroplating. These facilities give India the technological capability to fabricate prototypes of gyroscopes, actuators, silver oxide-zinc batteries, booster and sustainer motors, air-frame hardware such as fiberglass wings, ground-launcher mechanisms, and wire spool winding and reeling mechanisms, for first-generation anti-tank missiles. Between 1968 and 1970s, DRDL produces nearly 40 missiles a month for in-house testing and user trials.

—Dr. N. C. Birla and B. S. Murthy, eds., "Fabrication and Manufacturing Technologies," *Indian Defence Technology: Missile Systems* (DRDO, Ministry of Defence, December 1998), p. 77.

1962-1970

The propulsion system of the anti-tank missile is static and flight-tested extensively between 1962-70. Defense Research & Development Laboratory (DRDL) conducts 476 static and 500 flight-tests. Five percent of the propulsion units burst in the air due to "sustainer propellant defects." These defects are attributed to the lack of foolproof non-destructive testing (NDT) techniques. [Note 1: Static rocket system test (with complete propulsion system on test stand) refers to: "(a) simulated rocket operation for proper function, calibration, ignition, operation, usually without establishing full combustion, and (b) complete propulsion tests under rated conditions, off-design conditions, with intentional variations in environment or calibration." Note 2: Flight-tests refer to the "test of a rocket system on a specially instrumented flight-test range with a special test vehicle or production vehicle." Static and flight-tests on rocket systems are usually performed to "research the development of or improvement of a new rocket engine or motor; evaluate the suitability of a new or modified rocket engine or motor for a specified

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application; and evaluate production and quality assurance of a rocket system." Note 3: Non-destructive testing (NDT) refers to the "examination of an object with technology (e.g., radiography, ultrasonic, magnetic particle crack detection) that does not affect the object's future usefulness. NDT provides an excellent balance between quality control and cost-effectiveness. The term 'NDT' includes methods that can detect internal or external imperfections; determine structure, composition, or material properties; and measure geometric characteristics. NDT is used in all phases of a product's design and manufacture, including materials selection, research and development, assembly, quality control, and maintenance."]

—A. Subhananda Rao, "Development of Solid Propulsion Systems for Guided Missiles," in H.S. Mukunda and A.V. Krishnamurty, eds., *Recent Advances in Aerospace Sciences and Engineering* (Bangalore: Interline Publishing, 1992), p. 183; George P. Sutton, "Rocket Testing," *Rocket Propulsion Elements: An Introduction to The Engineering of Rockets* (New York: George Wiley & Sons, Inc.), p. 344; "What is NDT?" *American Society for Nondestructive Testing*, www.asnt.org.

1969-1970

India invites French and American companies to set up the Solid Propellant Space Booster Plant (SPROB) at Sriharikota (Andhra Pradesh). However, after an extensive tour of facilities in the United States and France, Indian scientists and engineers decide to purchase the equipment from the suppliers directly and build the facility themselves at a fraction of the price quoted by the US and French companies.

—Gopal Raj, "Developing Competence in Solid Propulsion," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), p. 85.

1969-1970

Indian Space Research Organization (ISRO) decides to build a Solid Propellant Space Booster Plant (SPROB) to cast large solid-propellant motors and a Static Test & Evaluation Complex (STEX) in Sriharikota (Andhra Pradesh) to test solid motors. These facilities are planned to meet the needs of the satellite launch vehicle (SLV) and other bigger launchers. ISRO also decides to expand the Rocket Propellant Plant (RPP) in Thumba (Kerala) and set up a Reinforced Plastic Centre (REPLACE) at Vattiyookavu near Thiruvananthapuram (Kerala) to develop advanced composite materials for upper rocket stages. The solid-propellant plant and static test facility are estimated to cost 157 million rupees. [Note 1: Static test facilities are used for testing the stage motors of launch vehicles and subsystems in order to study their performance characteristics and qualify them for flight environments. Note 2: Composites and laminates are used to make missile parts that are often lighter, stronger, and more durable than parts made of metals or other materials. Composites and laminates can be used almost anywhere in ballistic missiles or unmanned aerial vehicles (UAVs), including cruise missiles. Uses include solid rocket motor cases, interstages, wings, inlets, nozzles, heat shields, nosetips, structural members, and frames.]

—Gopal Raj, "Developing Competence in Solid Propulsion," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), pp. 77-79; "Annexure I: Cost Estimates of the Space Research Programme (1970-80)," *Atomic Energy and Space Research: A Profile For The Decade 1970-80* (Atomic Energy Commission, 1970); "Category II - Item 8: Structural Materials," *Missile Technology Control Regime Annex Handbook*, p. 8.

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15 August 1969

Department of Atomic Energy (DAE) creates the Indian Space Research Organization (ISRO) as the apex body to govern India's civil space program.

—Gopal Raj, "SLV-3: India's First Launch Vehicle," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), pp. 50-51.

1969

The Indian Army opposes Defense Research & Development Laboratory's (DRDL) anti-tank missile project. As a result of new technological developments, the Army changes its General Staff Qualitative Requirements (GSQR) and demands that DRDL extend the range of the missile from 1.6km to 3km; the new specifications also require that the hand-held missile currently under development be capable of being mounted and fired from a mobile-launcher.

—Raj Chengappa, "Build an ICBM or I'll Shut Down the Lab," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers India, 2000), p. 142.

26 February 1969

India launches its first indigenously built Centaure sounding rocket. The rocket is launched from the Thumba Equatorial Rocket Launching Station (TERLS); it carries a 31kg-payload and reaches an altitude of 145km. The Centaure's motor casings and other metal parts are fabricated at the central workshop of the Bhabha Atomic Research Centre (BARC), Trombay (Maharashtra).

—Gopal Raj, "First Steps in Rocketry," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), p. 38.

February 1969

India commissions its Rocket Propellant Plant (RPP) at Thumba (Kerala). The first Indian Centaure rocket filled with propellant made at RPP flies on 7 December 1969.

—Gopal Raj, "First Steps in Rocketry," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), p. 38.

February 1969

India decides to build a second rocket launch station at Sriharikota (Andhra Pradesh). The launch station is to be built in three phases. In phase one, a sounding rocket launch facility will be built to conduct flight-tests of Rohini sounding rockets; in phase two, to be completed by December 1971, the range will be developed further for flight-testing larger multistage vehicles and the necessary tracking and telemetry systems will be made available for performance tests; in phase three, the various facilities required for handling the satellite launch vehicle such as the long-range tracking radars, high-power ground telemetry stations, computational facilities, and a communications and control center, will be built by 1973-74. The Department of Atomic Energy (DAE) budgets 27 million rupees for building the rocket launching station at Sriharikota. In addition, the total cost for building high-performance missile-tracking radars and pulse code modulation (PCM) communication systems for the decade 1970-80 is estimated at 37.5 million rupees. [Note 1: Telemetry refers to "information or measurements transmitted by radio-frequency waves from a remote source to...recording device (e.g., from a spacecraft to an

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earth station). A telemetry data stream is usually transmitted separately from any other communication channel, since it concerns only the status of the spacecraft subsystems. The data are used both to control the spacecraft and establish the performance of the subsystem equipment. Historically, telemetry has been allocated its own frequency band and been transmitted by dedicated subsystem equipment." Note 2: Telemetry, tracking, and command refers to a "spacecraft subsystem incorporating the three functions: telemetry, which is downlinked from the spacecraft to the ground; tracking, whereby an earth station tracks the telemetry carrier or a beacon carried on the spacecraft; and command, whereby instructions are uplinked from the ground to the spacecraft." Note 3: Pulse code modulation (PCM) is a digital scheme for transmitting analog data. The signals in PCM are binary. Using PCM, it is possible to digitize all forms of analog data, including full-motion video, music, voices, telemetry, and virtual reality.]

—Gopal Raj, "SLV-3: India's First Launch Vehicle," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), p. 49; "Space Research," *Atomic Energy and Space Research: A Profile For The Decade 1970-80* (Atomic Energy Commission, 1970), pp. 34-35; "Annexure I: Cost Estimates of the Space Research Programme (1970-80)," *Atomic Energy and Space Research: A Profile For The Decade 1970-80* (Atomic Energy Commission, 1970); "Pulse Code Modulation," *Whatis?.com*, whatis.techtarget.com/whome/0,sid9,00.html; Mark Williamson, *Dictionary of Space Technology* (New York: Adam Hilger, 1989), p. 341.

1964-1969

The Defense Research & Development Laboratory (DRDL) acquires the capability to fabricate a 500kg regenerative-cooling liquid-propellant engine using kerosene as fuel and red fuming nitric acid (RFNA) as oxidizer.

—Dr. N.C. Birla and B.S. Murthy, eds., "Fabrication and Manufacturing Technologies," *Indian Defence Technology: Missile Systems* (DRDO, Ministry of Defence, December 1998), p. 77; Dr. N. C. Birla and B. S. Murthy, eds., "Propulsion Systems," p. 92; Raj Chengappa, "End the Wink and Nudge Approach," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers India, 2000).

Late 1968

The Indian National Committee on Space Research (INCOSPAR) begins work on designing a bipropellant liquid-propulsion system with two propellants: aniline for fuel and red fuming nitric acid (RFNA) as an oxidizer. The first experiment with a liquid-propellant motor is designated LPM-0. [Note: A bipropellant rocket has two separate propellants, an oxidizer and a fuel. They are stored separately and not mixed outside the combustion chamber. Aniline is one of the more commonly used liquid fuels. Upon contact with RFNA, it ignites spontaneously. A fuel and oxidizer reacting in this manner are said to be hypergolic. Aniline is an extremely dangerous chemical, produces toxic side effects, and requires careful handling. RFNA is a commonly available nitric acid oxidizer favored for tactical missiles and is widely used in Scud-technology-based missiles. It is easily obtained because of the large quantities produced for explosives and fertilizers. However, RFNA is extremely corrosive and toxic and requires careful handling. This oxidizer has been successfully used with aniline giving up nearly 63.6% of its oxygen content for combustion.]

—Gopal Raj, "Early Initiatives in Liquid Propulsion," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), pp. 107-108; "Category II-Item 4: Propellants," *Missile Technology Control Regime Annex Handbook*, p. 4-7; George P. Sutton, "Liquid Propellant Rocket Fundamentals,"

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Rocket Propulsion Elements: An Introduction to the Engineering of Rockets (New York: John Wiley & Sons, 1986), p. 147.

1968

First flight-test of the Menaka-I sounding rocket. [Note: The Menaka-I is a solid-motor rocket capable of carrying a "dart payload" (copper chaff) to altitudes of 55km and higher.]

—Gopal Raj, "First Steps in Rocketry," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), p. 41; *Annual Report: 1973-74*, Department of Space (Government of India), p. 18.

1968

The joint director of missiles in the Indian Air Force Group Captain V.S. Narayanan proposes a project to reverse-engineer the SA-2 surface-to-air (SAM) within five years at a cost of 165 million rupees.

—Raj Chengappa, "Not So Valiant," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers India, 2000), p. 148.

1968

India's defense ministry forms a missile panel to draw up plans for developing missiles in India. The joint director of missiles in the Indian Air Force (IAF) Group Captain V.S. Narayanan and A.P.J. Abdul Kalam are inducted as members of the panel. The panel discusses plans for building long-range ballistic missiles. Narayanan makes a case for using the technology developed for the civilian satellite launch vehicle for missile-related research and development.

—A.P.J. Abdul Kalam with Arun Tiwari, "Creation," *Wings of Fire: An Autobiography* (Hyderabad: Universities Press (India) Limited, 1999), p. 53.

September-October 1968

Indian space and rocket engineers prepare a preliminary report on India's proposed satellite launch vehicle to place a 20-40kg satellite in a 400km orbit. Their report proposes that India build a four-stage, solid-fuel launcher, modeled on the US Scout rocket. Y.J. Rao is asked to prepare a more detailed study. He submits an additional four to six configurations, all of them involving solid-stages, differing only in their length and diameter. [Note: The US Solid Controlled Orbital Utility Test (SCOUT) rocket program was conceived in 1958 and emerged as a four-stage vehicle capable of being used as a sounding rocket or lightweight satellite launcher. Scout was manufactured by LTV Aerospace and was America's first solid-fuel rocket. Scout's first-stage motor was based on an earlier version of the Navy's Polaris missile motor; the second-stage was developed using the Army's Sergeant surface-to-surface missile; and the third- and fourth-stages were adapted from the Navy's Vanguard missile. The standard Scout launch vehicle is a solid-propellant, four-stage booster system, approximately 23m in length with a launch weight of 21 tons. NASA decided that all the four stages would be solid fuel, citing the relative simplicity and reliability of previously demonstrated technology. The Scout's first stage, called Algol, burned for 40 seconds and produced a thrust of 511kN. It was controlled by using moveable outer tips of four stabilizer fins in conjunction with four exhaust deflector vanes. The second stage was stabilized by hydrogen peroxide jets; it burned for 39 seconds and produced a thrust of 222kN. The third stage, Antares, burned for 39 seconds, was stabilized by hydrogen peroxide

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jets, and could produce 60.5kN of thrust. The fourth stage burned for 38 seconds, was spin-stabilized, and could produce a thrust of 13.34kN. The third and fourth stages were encased in a glass-fiber shield, which included a payload shroud and a device to spin-stabilize the fourth stage. The Scout was able to carry a 22.6kg payload on a ballistic trajectory to an altitude of 13,679km or alternatively a 68kg payload in low-earth orbit.

The Scout guidance and control system provides attitude reference as well as the control signals and forces necessary to stabilize the vehicle in pitch, yaw, and roll axes. Miniature rate gyros detect any deviation from the vehicle's programmed path and generate electronic signals. These signals, along with the "rate-of-movement" information are then fed into the appropriate stage control system. The original NASA Scout was modified for specific US Air Force applications under the designations Blue Scout I, Blue Scout II, and Blue Scout Junior. The Blue Scout II was also modified by NASA for use in the Mercury program and named Mercury-Scout.]

—Gopal Raj, "SLV-3: India's First Launch Vehicle," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), pp. 50-51; "NASA'S Scout Launch Vehicle," *NASA Facts Online* (NASA Goddard Space Flight Center), www.gsfc.nasa.gov; Cliff Lethbridge, "Scout Program Background Factsheet," *Spaceline*, www.spaceline.org.

30 August 1968

India successfully tests its first indigenous two-stage sounding rocket. The Multi-Stage Rocket Project started by A.E. Muthunayagam in 1968 consists of a modified RH-75 fitted on top of an RH-125. [Note: The RH-125 is a two-stage, solid-motor rocket capable of carrying a 7kg payload to a height of 10km. In contrast to the "double base propellant system used in the RH-75," the RH-125 uses a "PVC-based [polyvinyl chloride] plasticol system...which has higher energetics resulting in higher combustion temperature." Because the "cure temperature" of the PVC plasticol is around 170°C, it is "not amenable for case bonding...and the propellant [is] cast in a PVC restrictor tube." Both the "booster and upper stage motors [are] of the same diameter and separated in flight by atmospheric drag." Important inputs from the RH-125 program included "improvements in propellant formulation and processing, handling and charging of flexible propellant grains, and staging and separation techniques."]

—Gopal Raj, "First Steps in Rocketry," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), pp. 36-37, 40; R. Nagappa, M.R. Kurup, and A.E. Muthunayagam, "ISRO's Solid Rocket Motors," *Acta Astronautica* vol. 19, no. 8, 1989, p. 682.

August 1968

Indian space officials submit a report recommending Sriharikota for a new launch site. The location of the island on India's east coast and its closeness to the equator (Sriharikota is 13° north of the equator) are cited as some of its key advantages. The 1968-69 Department of Atomic Energy (DAE) annual report states: "Due to insufficient space at the Thumba range and due to limitations imposed by range safety conditions, a second rocket launching station is necessary to cope with the increasing rocket launching schedule...a station located on the east coast of India is necessary for facilitating a satellite launch. Sriharikota island situated north of Pulicat (Andhra Pradesh) has been found most suitable for this purpose."

—Gopal Raj, "SLV-3: India's First Launch Vehicle," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), pp. 47-48.

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Early 1968

Indian space officials begin searching for a suitable launch site for larger rockets along India's eastern coast. The Andhra Pradesh state government offers the island of Sriharikota, which is located 80km north of Chennai. Sriharikota is 170 square kilometers in area, has a coastline of 62km, and is 8km at its widest. It is sparsely inhabited by Yanadi tribals.

—Gopal Raj, "SLV-3: India's First Launch Vehicle," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), p. 47.

Early 1968

Dr. Vikram Sarabhai broaches Indian space scientists and engineers on the idea of conducting a feasibility study for developing a satellite launch vehicle (SLV).

—Gopal Raj, "SLV-3: India's First Launch Vehicle," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), pp. 46-47.

2 February 1968

Prime Minister Indira Gandhi dedicates the Thumba Equatorial Rocket Launching Station (TERLS) to the United Nations.

—Gopal Raj, "The Sarabhai Vision," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), p. 19.

1967

India purchases three squadrons of SA-2 surface-to-air (SAM) batteries from the Soviet Union for the air defense of New Delhi.

—Raj Chengappa, "Not So Valiant," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers India, 2000), p. 148.

1967-1969

Two rival teams of Indian scientists led by V. Gowariker and A.E. Muthunayagam compete to develop solid propellants for the Rohini sounding rocket program. Gowariker's group selects a solid-propellant formulation based on polyester; Muthunayagam's group bases its solid propellant around a natural rubber resin. The first RH-75 with the natural-rubber propellant, named the Dynamic Test Vehicle (DTV), is flight-tested in 1968. Gowariker's team tests its DTV on 21 February 1969. However, neither of these propellants is used in the Rohini program. Polyvinyl chloride (PVC) remains the mainstay of India's sounding rocket program until better solid propellants become available.

—Gopal Raj, "First Steps in Rocketry," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), pp. 36-37, 39.

20 November 1967

India launches its first sounding rocket, the Rohini-75 (RH-75). The "75" refers to the rocket's diameter in millimeters. The RH-75 has a length and diameter of 1m and 75mm, respectively. It uses Cordite, which is a double-base propellant; the rocket has a total launch weight of 7kg, of which the propellant comprises 2.5kg. The

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propellant burn time is 2-seconds and the rocket reaches a height of 7km. India's earliest efforts in the development of solid-propulsion technology are overseen by A.E. Muthunayagam. [Note 1: The development of a 75mm diameter rocket was taken up "for initial propulsion technology development demonstration. The diameter was chosen to use off the shelf items to the extent possible and minimize development time. Double-base, free-standing grains of 67mm were already under manufacture in [India]... The propellant grain was charged into the aluminum chamber and bonded in place with a polyester resin system." The RH-75 used a "metallic heat sink design" for the nozzle with "polycrystalline graphite for throat insert." The development of the RH-75 provided Indian rocket scientists and engineers with useful information on "design and performance, propellant charging techniques, test stand design and testing techniques, and flight testing." Note 2: Double-base propellants form a homogenous propellant grain, usually a nitrocellulose type of gunpowder dissolved in a gelatiniser or plasticizer such as nitroglycerin plus minor percentages of additives. Both the ingredients are explosives and function as a combined fuel, oxidizer, and binder.]

—Gopal Raj, "First Steps in Rocketry," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), pp. 32-34; George P. Sutton, "Solid Propellants and Combustion," *Rocket Propulsion Elements: An Introduction to the Engineering of Rockets* (New York: John Wiley & Sons, 1986), p. 292; R. Nagappa, M.R. Kurup, and A.E. Muthunayagam, "ISRO's Solid Rocket Motors," *Acta Astronautica* vol. 19, no. 8, 1989.

1967

India obtains SA-2 surface-to-air (SAM) batteries from the Soviet Union. The missiles are deployed around New Delhi and several key airfields in northern India to provide air defense. [Note: The SA-2 is a guided medium- to high-altitude surface-to-air missile (SAM) designed to provide air defense against non-maneuvering targets such as bombers. Development of the SA-2 began in the Soviet Union in 1953 at the Lovochkin OKB design bureau, and the first missile batteries became operational in 1957. The original SA-2a was subsequently superseded in the 1960s and 1970s by the b/c/d/e/f models. The SA-2 is a two-stage missile with a large solid-propellant booster and a storable liquid-fuel sustainer rocket motor that uses red fuming nitric acid/kerosene fuel mix. The missile has a set of four cropped delta-shaped wings towards the midsection, a second set of small fixed fins at the nose, and a third set of slightly larger control fins at the tail. The SA-2a/b/c/d/e/f models vary from 10.6-11.2m in length, have a booster diameter of 0.65m, and launch weight between 2,287-2,450kg. The warhead weighs 195kg, 130kg of which is High Explosive (HE).]

—Raj Chengappa, "Not so Valiant," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers India, 2000), p. 148; "SA-2 'Guideline' Medium to High Altitude Surface-to-Air Missile System, Tony Cullen and Christopher Foss, eds., *Jane's Land Based Air Defence 1992-1993* (Coulsdon, Surrey), pp. 257-260.

Late 1960s

India decides to develop a family of sounding rockets with diameters ranging from 125mm-560mm with the capability of carrying 10-100kg-payloads to heights ranging from 80-350km.

—R. Nagappa, M.R. Kurup, and A.E. Muthunayagam, "ISRO's Solid Rocket Motors," *Acta Astronautica*, vol. 19, no. 8, 1989, p. 682.

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1965-1940

1965

The Indian government approves the establishment of the Space Science & Technology Centre (SSTC) in Thumba (Kerala) with the objective of building rockets, satellite payloads, as well as their instrumentation in India. The SSTC initially focuses on building sounding rockets and scientific payloads for the rockets. Dr. Vikram Sarabhai launches an aggressive program to recruit Indian scientists for the space program from the United States and Western Europe. Recruits include A.E. Muthunayagam, S.C. Gupta, M.K. Mukherjee, Y.J. Rao, D.S. Rane, M.C. Mathur, and V. Gowariker.

—Gopal Raj, "The Sarabhai Vision," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), pp. 17-18, 24-25.

1965-1969

As part of the contract with France's Sud Aviation to license produce Centaure sounding rockets in India, a small group of Indian scientists headed by M.R. Kurup is sent to France for training. The group is put through some courses in solid-propulsion and given practical training in the fabrication of the Centaure and in casting the polyvinyl chloride (PVC) propellant used in the rocket. Indian scientists are also given a tour of French solid-propellant facilities. Sud Aviation does not provide India with a turnkey facility for manufacturing the rockets. Instead, Indian scientists are given a list of the equipment and manufacturers to help them build the rocket-related facilities in India. The Centaure program helps India gain an understanding of the equipment, procedures, and safety precautions required to build large solid-propellant motors. It also exposes Indian scientists to the use of composite propellants, 15CDV6 steel, and sophisticated fabrication techniques, which are later used to build more advanced two-stage rockets. [Note 1: A solid rocket motor uses solid propellants to provide thrust to propel a vehicle. Although the terms "motor" and "engine" are generally interchangeable, propulsion devices using solid propellants are generally called "motors" and those using liquid propellants tend to be referred to as "engines." A typical solid motor is made up of the following components: a motor case containing the propellant grain, a surrounding insulating blanket or propellant liner, an exhaust nozzle, and an ignition system. In operation, solid motors are less complex than liquid-rocket engines. Note 2: Composite and composite modified double-base propellants are heterogeneous mixtures of fuels and small particulate oxidizers held together by a rubbery material referred to as the "binder." They provide a stable, high-performance, solid-propellant for rocket motors. Composite and double-base composite propellants are used to provide propulsive energy to rocket systems, kick motors for satellites, and for booster motors for launching cruise missiles, and unmanned aerial vehicles. These propellants are also used in tactical rockets.]

—Gopal Raj, "First Steps in Rocketry," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), pp. 37-40; Mark Williamson, *Dictionary of Space Technology* (New York: Adam Hilger, 1989), p. 284; "Category II-Item 4: Propellants," *Missile Technology Control Regime Annex Handbook*, p. 4-1.

1964-1965

India signs an agreement with Sud Aviation of France to build the French two-stage Centaure rocket in India under license. India simultaneously launches a program to build sounding rockets indigenously; Indian scientists begin

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experimenting with various solid-propellant combinations and embark on the Rohini (RH) sounding rocket program. They build simple motors, which are 50mm in diameter. The first Indian sounding rocket is named Rohini-00 (RH-00).

—Gopal Raj, "First Steps in Rocketry," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), p. 32.

1964

Defense Research & Development Laboratory's (DRDL) R. Gopaldaswami proposes building a three-ton-thrust liquid-fuel engine at a cost 183,000 thousand rupees. The Indian government sanctions the project. However, in the absence of any user requirements from the armed forces, the project turns into a competence-building exercise.

—Raj Chengappa, "Build an ICBM or I'll Shut Down the Lab," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers India, 2000), pp. 144-145.

1964

India signs an agreement with France to produce the Centaure sounding rocket under license in India. [Note: Centaure is a two-stage sounding rocket. The Centaure uses a 280mm Venus booster to boost a Belier second-stage. It can carry a 60kg payload to a height of 130km.]

—Gopal Raj, "The Sarabhai Vision," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), p. 17; Jonathan McDowell, "CNES Sounding Rockets," *The History of Spaceflight*, 26 January 2000, hea-www.harvard.edu; "From Belier to Eridan," *The Satellite Encyclopedia*, www.sat-net.com.

21 November 1963

India assembles and launches its first Nike-Apache rocket supplied by NASA. The rocket carries a sodium-vapor experiment provided by the French space agency CNES. American and French technicians oversee the launch. [Note: The Nike-Apache is a small rocket almost identical to the Nike-Cajun, with which it was interchangeable depending on the payload and the altitude desired. The Nike's Apache motor was manufactured by Thiokol Propulsion. The Nike-Apache was one of NASA's most common sounding rockets; it can lift a 45.4kg payload to an altitude of 160km. First test-firing from NASA's Wallops Island facility occurred on 25 May 1961.]

—Gopal Raj, "The Sarabhai Vision," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), p. 16; William R. Corliss, "Appendix A: Short Descriptions of Major Sounding Rockets," *NASA Sounding Rockets, 1958-1968: A Historical Summary* (Scientific and Technical Information Office, NASA, 1971), p. 82.

21 January 1963

Indian Minister of State for External Affairs Lakshmi N. Menon informs parliament that the government has decided to establish a sounding rocket launch station at Thumba (Kerala).

—Gopal Raj, "The Sarabhai Vision," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), p. 12.

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1962-1963

India sends a small group of scientists to NASA's Goddard Space Flight Center on Wallops Island for training in assembling, launching, and tracking sounding rockets. Indian scientists are trained in safety procedures, assembly of scientific payloads, and collection of scientific data radioed from the rockets during flight. The group of scientists includes R. Aravamudan, Pramod Kale, A.S. Prakasa Rao, B. Ramakrishna Rao, H.G.S. Murthy, A.P.J. Abdul Kalam, and D. Easwardas.

—Gopal Raj, "The Sarabhai Vision," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), pp. 14-15.

1962

Department of Atomic Energy (DAE) chairman Dr. Homi Bhabha persuades Prime Minister Jawaharlal Nehru to increase funding for Indian National Committee on Space Research (INCOSPAR).

—Raj Chengappa, "The Red Funnel," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers India, 2000), p. 90.

1962

Defense Research & Development Organization's (DRDO) Chief Controller Major General B.D. Kapur tours R&D centers, missile training sites, strategic air command bases, and NASA facilities in the United States. On his return trip to India, Kapur stops in Switzerland to meet representatives of the Zurich-based firm Contraves. India and Switzerland sign an agreement to develop an intermediate-range surface-to-air missile (SAM) under a program called "Project Indigo." However, the Indian government opts for the purchase of Soviet SA-2 SAM batteries and Project Indigo, a program to actually build a missile system, is cancelled.

—Timothy V. McCarthy, "India: Emerging Missile Power," in William C. Potter and Harlan W. Jencks, eds., *The International Missile Bazaar: The New Suppliers' Network*, (Boulder: Westview Press Inc., 1994), p. 202.

1962

The UN Committee on the Peaceful Uses of Outer Space passes a resolution calling for the creation of sounding rocket facilities in the equatorial region and southern hemisphere under UN sponsorship. India takes advantage of the UN resolution to start its own sounding rocket program to study the equatorial electrojet phenomenon. Indian National Committee on Space Research (INCOSPAR) signs an agreement with the US National Aeronautics and Space Administration (NASA) for help in assembling and launching sounding rockets. It also seeks NASA's help in training Indian personnel as well as establishing a sounding rocket launch center. Agreements are also signed with the French space agency, CNES, for the supply of radar and sounding rockets. [Note: Sounding rockets are rockets used to make observations anywhere within the earth's atmosphere. Sounding rockets derive their name from the nautical term "to sound," which means to take measurements. These rockets are divided into two parts: rocket motor and payload. Sounding rocket experiments provide information on the chemical composition and physical processes taking place in the atmosphere, natural radiation surrounding the earth, and data on sun, stars, and galaxies and other phenomenon. In addition, sounding rockets provide economic means of conducting engineering tests for instruments and devices used on satellites and other spacecraft prior to their use.]

—Gopal Raj, "The Sarabhai Vision," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi:

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Viking by Penguin Books India, 2000), pp. 9-10; National Aeronautics and Space Administration, "NASA's Sounding Rocket Program," www.wff.nasa.gov.

1962

India decides to build a sounding rocket range on the geomagnetic equator at Thumba, near Thiruvananthapuram (Kerala) to study of problems in aeronomy up to 200km. The planned program will be conducted with sounding rockets and the scientific results are expected to have a direct bearing on a better understanding of meteorology. [Note: "Aeronomy" refers to the study of the upper atmosphere, especially of regions of ionized gas.]

—"Space Research," *Atomic Energy and Space Research: A Profile For The Decade 1970-80* (Atomic Energy Commission, 1970), p. 27.

1962

Defense Research & Development Laboratory (DRDL) obtains 600,000 rupees to begin work on developing a wire-guided, solid-motor, anti-tank missile. Flight-tests of the 1.6km-range hand-held missile at Imarat Kancha, near Hyderabad (Andhra Pradesh) are hampered by the lack of adequate monitoring and tracking equipment.

—A. Subhananda Rao, "Development of Solid Propulsion Systems for Guided Missiles," in H. S. Mukunda and A. V. Krishnamurty, eds., *Recent Advances in Aerospace Sciences and Engineering* (Bangalore: Interline Publishing, 1992), p. 182; Raj Chengappa, "Build an ICBM or I'll Shut Down the Lab," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers India, 2000), pp. 141-142.

February 1962

Department of Atomic Energy (DAE) creates the Indian National Committee on Space Research (INCOSPAR) under the chairmanship of Dr. Vikram Sarabhai to oversee India's space program.

—Gopal Raj, "The Sarabhai Vision," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), p. 9.

February 1962

Defense Research & Development Laboratory (DRDL) is shifted to Hyderabad (Andhra Pradesh) to work on the design and development of missiles.

—Defence Research & Development Laboratory, "Historical Background," www.drdo.org.

1961

The Defense Research & Development Laboratory (DRDL) is formed as an extension of the Special Weapon Development Team (SWDT) on the campus of the Defense Science Laboratory (DSL), New Delhi. Group Captain V. Ganesan is appointed as its director in December 1961. Indian missile scientists are sent to the College of Aeronautics, Cranfield (United Kingdom) to attend a course on guided missiles.

—Defence Research & Development Laboratory, "Historical Background," www.drdo.org; Raj Chengappa, "Build an ICBM or I'll Shut Down the Lab," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers India, 2000), pp. 137-139.

1961

The Physical Research Laboratory (PRL) in Ahmedabad (Gujrat) becomes an autonomous institution under the

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Department of Atomic Energy DAE. The DAE routes funds for the space program through PRL until the formation of an independent Department of Space (DOS) in 1972.

—Gopal Raj, "The Sarabhai Vision," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), pp. 6-7.

1961

The Indian government assigns the subject of space research and the peaceful exploration of outer space to the Department of Atomic Energy (DAE).

—"Space Research," *Atomic Energy and Space Research: A Profile For The Decade 1970-80* (Atomic Energy Commission, 1970), p. 27.

16 October 1958

Indian Defense Minister V.K. Krishna Menon and his scientific advisor Dr. D.S. Kothari set up a guided missile study team under B.N. Singh at the Defense Science Laboratory (DSL) in New Delhi. The defense ministry sanctions 200,000 rupees to begin work on developing an anti-tank missile. For reasons of secrecy, the missile team is named Special Weapon Development Team (SWDT).

—Raj Chengappa, "Build an ICBM or I'll Shut Down the Lab," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers India, 2000), pp. 136-137.

1958

India's Union Cabinet approves the setting up of a missile study group under Defense Research & Development Organization (DRDO) to advise the armed forces on guided missiles. Prime Minister Jawahar Lal Nehru instructs the scientific advisor to the Defense Minister Dr. D.S. Kothari to ensure that foreign exchange outflow is kept to a minimum.

—Raj Chengappa, "Build an ICBM or I'll Shut Down the Lab," *Weapons of Peace: The Secret Story of India's Quest to be a Nuclear Power* (New Delhi: Harper Collins Publishers India, 2000), p. 136.

1 January 1958

India's Ministry of Defense (MOD) consolidates all defense-related research and development activities in the country by merging the Indian Army's Technical Development Establishment and the Directorate of Technical Development & Production with the Defense Science Organization into a new organization, Defense Research & Development Organization (DRDO). In 1958, DRDO is a small organization with 10 laboratories under its jurisdiction. Major General B.D. Kapur is appointed as its first Chief Controller.

—Defence Research & Development Organization, "DRDO: Genesis & Growth," www.drdo.org; Major General B.D. Kapur, "The Initiation of Defence Research Organization," *Building a Defence Technology Base* (New Delhi: Lancer International, 1990), p. 31.

1947

Dr. Vikram Sarabhai establishes the Physical Research Laboratory (PRL) in Ahmedabad (Gujrat) to pursue research on cosmic rays. The PRL later becomes the nucleus of India's civilian space program.

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—Gopal Raj, "The Sarabhai Vision," *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking by Penguin Books India, 2000), pp. 6-7.

15 August 1947

India gains independence from Britain.

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