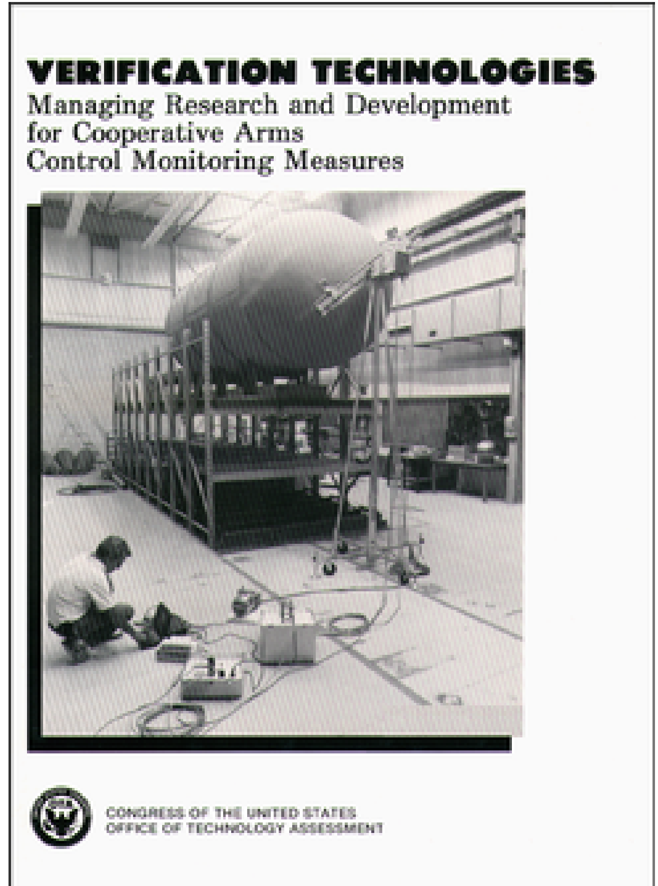
Verification Technologies: Managing Research and Development for Cooperative Arms Control Monitoring Measures

May 1991

OTA-ISC-488

NTIS order #PB91-197913



Recommended Citation:

U.S. Congress, Office of Technology Assessment, *Verification Technologies: Managing Research and Development for Cooperative Arms Control Monitoring Measures,* OTA-EK-488 (Washington, DC: U.S. Government Printing Office, May 1991).

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Foreword

Cooperative monitoring measures, including on-site inspections, are now a regular feature of international arms control agreements. The Intermediate Nuclear Forces (INF) Treaty, the Threshold Test Ban Treaty, the Conventional Forces in Europe Treaty, the prospective Strategic Arms Reduction Talks (START) Treaty, and the proposed Chemical Weapons Convention all contain such measures. This new element of arms control verification is likely to be a part of any future arms control arrangements in which the United States becomes involved. How well prepared are we for this new era?

The Senate Foreign Relations and House Foreign Affairs Committees asked OTA to undertake an assessment centering on the technologies and techniques of monitoring the START Treaty. (The first report of this study, focusing on the START Treaty, was delivered in the summer of 1990.) In its request, the Foreign Affairs Committee also called on OTA to address the ". . . newer technologies that can be brought to bear on such cooperative verification measures as manned on-site inspections, manned perimeter and portal monitoring, and unmanned on-site monitoring. " The committee added that "it would be useful to place these technologies in the broader context of verification technologies and methods.'

This report is one of OTA's responses to the latter request: it examines the management of the research and development process from which the new technologies are emerging. (Another response to the committee request, to be completed in May 1991, will take the form of a report analyzing at length one potential cooperative monitoring measure, aerial surveillance.) Partly as a result of the way in which the research and development process is managed, the allocation of research resources appears to be geared to meeting short-term needs and solving isolated problems, rather than to pursuing long-term goals and developing integrated verification regimes for the future. Our report identifies a range of organizational options that might help improve the balance of research emphasis.

In preparing this report, OTA sought the assistance of many individuals and organizations (see ''Acknowledgments"). We very much appreciate their contributions. As with all OTA reports, the content remains the sole responsibility of OTA and does not necessarily represent the views of our advisors or reviewers.

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NOTE: OTA appreciates and is grateful for the valuable assistance and thoughtful critiques provided by the advisory panel members. The panel does not, however, necessarily approve, disapprove, or endorse this report. OTA assumes full responsibility for the report and the accuracy of its contents.

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Acknowledgments

OTA gratefully acknowledges the assistance of individuals in the following organizations for their help in supplying information or in reviewing drafts of this report (the contents of the report, of course, remain the responsibility of OTA):

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U.S. Arms Control and Disarmament Agency
U.S. Department of Energy, Office of Arms Control

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Summary

In 1986 and 1987, the Soviet Union for the first time signed arms control agreements instituting on-site inspections as a means of monitoring treaty compliance. Previous decades of Soviet resistance had led to U.S. pessimism that extensive on-site inspections would ever be feasible. Accordingly, as U. S. agencies entered the Intermediate Nuclear Forces (INF) and Strategic Arms Reduction Treaty (START) negotiations, they had sponsored relatively little external research into on-site monitoring systems. Policymakers devised verification regimes for these treaties, then turned to the technical research community for quick development of new monitoring devices and systems as needed.

OTA's review of the INF and START cases suggests that:

- the policymakers' work might have benefited from the results of earlier, external research if it had been done; and
- the technical research community might have been better prepared to respond to policymakers' and negotiators' needs if its own research programs had been prioritized by the requirements of likely overall verification regimes.

U.S. technical research for cooperative arms control verification regimes has been piecemeal rather than synoptic, and oriented to the near term rather than the long term. When unilaterally gathered intelligence was almost the sole means of arms control monitoring, this approach seemed to suffice. (Note: This report addresses only issues related to research on cooperative monitoring techniques, not on National Technical Means (NTM); secrecy requirements impose this major omission.)

Three conditions suggest a need for more systematic, long-term research on cooperative verification methods:

- the likelihood that additional arms control agreements with cooperative verification measures will be negotiated;
- the likelihood that some of these agreements will involve numerous nations, some of which will not have access to NTM but will still want assurances of mutual treaty compliance; and
- the possibility that, as in the recent past, the United States will find itself negotiating arms control provisions that only shortly before seemed politically improbable.

A more systematic program of long-term analysis and research could improve support for future arms control negotiations. It could develop priorities for continuing research on technologies for various monitoring measures. It could help assess potential monitoring problems and identify promising technical solutions for further research. It might also help identify additional arms control measures made feasible by new monitoring techniques.

The United States lacks a synoptic, long-term program of research on cooperative measures of arms control verification in part because there is no one in charge-no one whose job is to make such a program happen. Two agencies, the Department of Energy (DOE) Office of Arms Control and the Defense Nuclear Agency (DNA) manage the bulk of research on technologies for cooperative verification measures. In 1990 DOE spent about $130 million,[1] mainly at its national laboratories; DNA dispersed about $35 million, including $14.5 million from the U.S. Army, to the DOE national laboratories, to private contractors, and to other government agencies, Today, numerous Government agencies participate in interagency committees to coordinate arms control research, but none has overall authority.

Options for alternative organizational arrangements include:

- make some incremental changes for better research focus;
- designate a lead agency for planning verification research;
- channel all or most research funds through one of the currently participating agencies to the others;
- create a new verification research ' 'czar' to direct the multi-agency research program;
- create a new arms control agency with primary responsibility and authority for all types of arms control research, planning, negotiation, and implementation.

Each of these options has advantages and disadvantages requiring careful consideration.

[1] About $75 million of this was devoted to the monitoring of nuclear tests, which left about $55 million for all other current and future types of arms control monitoring.

The Current U.S. Research and Development Program for Cooperative Verification Technology

Introduction

Late in August 1987, U.S. inspectors entered Soviet territory to inspect a Soviet ground force exercise involving 16,500 troops and 425 tanks. The Soviets had agreed to such inspections by signing the 1986 Document of the Stockholm Conference on Confidence- and Security-Building Measures and Disarmament in Europe. In December 1987, the United States and the Soviet Union agreed to five additional types of on-site inspection when they signed the INF Treaty (eliminating intermediate-range nuclear missiles in Europe).

Until these breakthroughs, unilateral intelligence gathering (with some negotiated agreements on cooperative measures to facilitate the use of National Technical Means) was the United States' virtually sole method of arms control compliance monitoring. Decades of Soviet resistance led, understandably, to pessimism that extensive on-site inspections would ever be feasible. Accordingly, as they entered the INF negotiations, U.S. agencies had sponsored relatively little external research on on-site monitoring systems.[2]

Instead, these systems were developed as the negotiations proceeded. For example, INF negotiations began in 1980, broke off in 1983, and resumed in 1985. At the request of the Office of the Secretary of Defense (OSD), Sandia National Laboratories started studying the concept of a perimeter-portal monitoring system in late 1983, but did not focus on a particular design concept until late 1986; at that time, it was asked to build a full-scale demonstration complex (the Technical On-Site Inspection project) within a 3-month period. The United States and the Soviet Union signed the INF Treaty in December, 1987. The United States created its On-Site Inspection Agency (OSIA) in January 1988. The two sides did not sign the INF Memorandum of Agreement (MOA), which formalized on-site inspection procedures, until December 1989. Only during the 2-year period between the treaty signing and the MOA signing did the United States finish developing a radiation detection device called for in the treaty-a neutron-detecting mapper to help distinguish between the banned, three-warhead SS-20 and the permitted, single-warhead SS-25.[3]

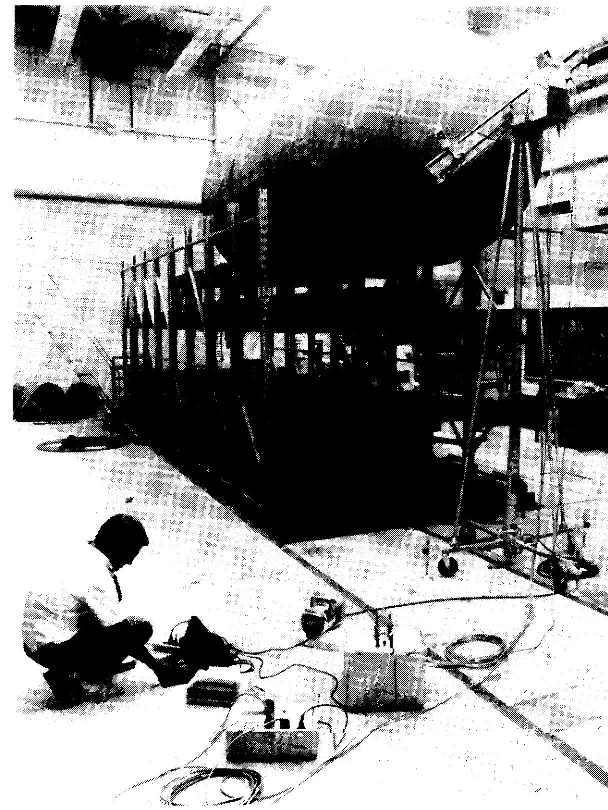


Photo credit: Los Alamos National Laboratory

The Los Alamos National Laboratory arms control verification simulation facility provides a testbed for monitoring instruments. Items shown include a mock-up of a Soviet missile transporter-erector-launcher (TEL) and a passive gamma ray imaging system. The TEL can be loaded with simulated single or multiple warheads. These warheads resemble real ones in shape, density, and radiation, and thus can be used to test a wide variety of proposed warhead monitoring instruments from various Department of Energy laboratories.

Thanks to modest DOE investments in longer term research and development (R&D) and to their

[2] One exception was for nuclear explosion detection and yield estimations. Another was for International Atomic Energy Agency nuclear material accounting safeguards.

[3] Sandia National Laboratories led a 12-month effort to the completion of this task. The device was to be used during on-site inspections at former SS-20 deployment sites. It should be noted that the device had to be approved by the Soviet Union and by U.S. export-control authorities; the specifications for such devices are often the subject of lengthy, detailed negotiations. Those negotiations for INF had not been completed by the time the treaty was signed.

existing technology base, the U.S. laboratories apparently responded well to the demands for inspection technology created by the INF Treaty. Nevertheless, by 1988 the Strategic Arms Reduction negotiations were moving ahead rapidly and, once again, verification technology research appeared to be working to catch up.

Before entering into an arms control treaty negotiation, U.S. planners decide in advance what arms control limits would serve U.S. interests; they then design a verification regime that would meet U.S. requirements. (In some cases, they might judge that compliance with a proposed arms control provision could not be acceptably verified and therefore that the measure itself would not serve U.S. interests.) Diplomats base their negotiating goals on these plans, adjusting goals and plans as negotiations unfold.

It is not always possible to precede arms control negotiations with thorough research on potential verification regimes.[4] The United States has frequently been engaged in arms control negotiations for which lengthy advance preparations had not been made: to wait for the completion of long-term planning would be to pass up the arms control opportunities these negotiations offer. Second, the U.S. Government is likely to remain one of distributed power centers, both within the vast bureaucracy that manages national security affairs and between the executive branch and Congress; therefore, a highly unified national planning process for long-term purposes is difficult to achieve without strong, high-level interest and leadership. Third, changes in Administration can disrupt the continuity of the process.

Nevertheless, the absence of long-term research has led in some cases to mutual dissatisfaction between the research and policy communities. The policymakers, bringing their requirements for new monitoring technology to the researchers, have found the researchers to respond on occasion with proposals that they deemed unusable or that were unnecessarily complex and costly.[5] Researchers, on the other hand, found themselves responding to short-notice demands to supply technical solutions to imperfectly specified problems. The INF and START cases suggest that:

- the policymakers' work might have benefited from the results of earlier, external research if it had been done; and
- the technical research community might have been better prepared to respond to policymakers' and negotiators' needs if its own research programs had been prioritized by the requirements of likely overall verification regimes.

U.S. technical research for cooperative arms control verification regimes has been piecemeal rather than synoptic, and oriented to the near term rather than the long term. When unilaterally gathered intelligence was almost the sole means of arms control monitoring, this approach seemed to suffice. Under today's circumstances, the Nation might be better served by a more comprehensive and far-sighted approach. What are these new circumstances?

First, the United States is likely to continue negotiating new arms control agreements (such as the Chemical Weapons Convention) that include on-site inspection (0SI) and other cooperative monitoring measures. These measures need to be carefully thought out if they are to be more than window-dressing. They will also be increasingly expensive (in dollars and in other ways) unless applied efficiently. Efficiency may include the application of some monitoring measures to more than one treaty.

Second, new multilateral, not just bilateral, arms control agreements will impose new requirements on verification regimes. For the United States, the major source of arms control compliance informa-

[4] For example, an interagency Consolidated Verification Group conducted extensive studies on possible monitoring measures and Proposal the verification regimes which have, to a great extent, been incorporated in the INF and draft START treaties. The studies were conducted and proposals developed even as negotiations were under way (in the mid-1980s)

[5] A participant in the policy process leading to the INF and START verification regimes argued the following to OTA:

> Design of verification regimes is a policy function which draws on technical monitoring capabilities and which deals with many factors (intrusiveness, costs, benefits, etc.) beyond the scope of the R&D community. Some of the national labs' analytical studies have been built in a vacuum; many contain some useful ideas but often reinvent the wheel or propose things that are and have been non-starters for various reasons well understood by the policy community.

On the other hand, the researchers' studies might be more relevant if they could take into account in advance all the constraints under which monitoring technologies would be expected to operate. In addition, policy planners usually address the design of verification regimes when negotiations are either imminent or in progress; some prior research might produce an information base from which they could draw when the time came.

tion will continue to be National Technical Means. But many future negotiated monitoring measures will have to be applicable in, and acceptable to, a variety of nations simultaneously. They will also have to provide some confidence in mutual compliance to countries without the considerable NTM resources of the United States and the Soviet Union. It is even conceivable that some day there will be an international verification agency, which would require multilaterally acceptable monitoring measures.[6]

Third, the recent past has shown that arms control measures thought to be beyond the horizon may move into serious negotiations faster than the U.S. Government anticipates. Unless long-term research has prepared potential responses to such contingencies, U.S. negotiators may have to improvise and put forward positions not as well considered as they might have been. Moreover, the very availability of new monitoring techniques may make it possible to consider arms control measures that previously would have been considered infeasible.

Under these new conditions,[7] U.S. interests would be served best by a research program that emphasized:

- *systematic* identification and analysis of potential arms control verification regimes (including both NTM and cooperative monitoring measures) and of how all their components can work together most efficiently;
- systematic analysis of how data from multiple sources can be fused into a meaningful picture (and of how data gathered for one treaty might contribute to monitoring compliance with others);
- design of *multilateral* monitoring systems that would both serve U.S. interests and increase the confidence of countries without U.S. NTM resources that all parties to an agreement are in compliance; and
- examination, on a *contingency* basis, of verification regimes for arms control measures not currently on the active agenda.

Such analysis could improve support for future arms control negotiations. It could develop priorities for continuing research on technologies for various monitoring measures. It could help assess potential monitoring problems and identify promising technical solutions for further research. It might also help identify additional arms control measures that could be made feasible by new monitoring techniques.

Given the lessons of recent experience, why does the United States still lack a synoptic, long-term program of research on cooperative measures of arms control verification? The short answer to this question is that there is no one in charge-no one whose job is to make such a program happen. A 1990 Administration report to Congress reveals the weaknesses and strengths of current executive branch arrangements for managing verification research.

The Current Program: Coordination v. Direction

Senators Jeff Bingaman and Pete V. Domenici attached to the FY 1989 defense authorization bill an amendment (Section 910) mandating a report to Congress that included a review of the relationship of the arms control objectives of the United States to the responsiveness of research and development of monitoring systems for verification. The deadline for that report was June 30, 1989; the executive branch delivered to Congress the 24-page document, informally known as the "Section 910 Report," on March 5, 1990.

During the period between the mandate for the report and its delivery, the National Security Council established a new working group to coordinate research and development in this area (for a listing of organizations to be coordinated, see box A). As the report explained,

> In general, with respect to coordinating development and utilization of technology for treaty verification, agencies successfully have worked together informally or through interagency working groups for INF and START and have accomplished coordinated technology development and utilization. This coordination will be further strengthened and for-

[6] For example, see A. Walter Dorn, "The Case for a United Nations Verification Agency," *IEEE Technology and Society Magazine, December* 1990/January 1991, pp. 16-27; and "Study on the Role of the United Nations in the Field of Verification,'' United Nations document A/45/372, Aug. 28, 1990, pp. 86-87.

[7] As of early 1990, the trends cited above could be called into question in the light of difficulties with the Soviets in implementing the Conventional Forces in Europe (CFE) agreements and in concluding the START Treaty. On the other hand, long-term planning and research are in preparation for contingencies, and neither can nor should be instantly adapted to near-term events.

Box A—U.S. Government Organizations With a Role in Verification Technology Development

Perhaps contributing to the 9-month delay in delivery of the Section 910 Report was the multiplicity of the government organizations which had to be consulted. The report identified the following as playing major roles in verification technology development:

- Department of Defense
  - Office of the Under Secretary of Defense for Acquisition
  - Office of the Under Secretary of Defense for Policy
  - Office of the Assistant Secretary of Defense for C^3I
  - Defense Technology Security Administration
  - Joint Chiefs of Staff
  - Defense Intelligence Agency
  - Defense Advanced Research Projects Agency
  - The Military Services (Army, Navy, and Air Force)
- Department of Energy, Office of Arms Control
- Department of State
  - Bureau of Politico-Military Affairs
  - Bureau of Intelligence and Research
- Arms Control and Disarmament Agency
- Intelligence Community

In 1989, the National Security Council created a Verification Technology Working Group as a forum for coordination among these groups.

realized through the Verification Technology Working Group (VTWG) of the Subcommittee on Verification and Compliance (SCVC) of the Arms Control Policy Coordinating Committee of the National Security Council (NSC).[8]

The Section 910 Report pointed out that, besides the coordinating groups established at the initiative of the executive branch,

> . . . Congress has mandated one formal mechanism to coordinate research and development applicable to arms control throughout the government. Under Section 31 of the Arms Control and Disarmament Act and Executive Order 11044 (Aug. 12, 1982), the ACDA [Arms Control and Disarmament Agency] Director is charged, with the advice and assistance of affected agencies, with ensuring the conduct of research, development, and other studies in the field of arms control and disarmament (including verification) and coordinating research, development, and other studies conducted in the field by or for other government agencies. The Arms Control Research Coordination Committee (ACRCC) was created in 1984 to coordinate research related to arms control. Chaired by ACDA, its members are the Office of the Secretary of Defense, Defense Nuclear Agency (DNA), the Joint Chiefs of Staff, the Departments of State and Energy, the Central Intelligence Agency (CIA), and the National Aeronautics and Space Administration (NASA).

Even by the report's description, this committee has done little to perform ACDA's congressionally mandated role, described as follows:

> The committee:
> —meets periodically to exchange information on current research, to consider steps to facilitate coordination of research, and to discuss future research plans;
> —encourages agencies to circulate final reports of contracted research on arms control to other agencies and to share briefings on such research; and
> —establishes and maintains a data base catalog (dubbed ACORN) listing past and ongoing research projects.

In fact, the ACRCC appears to meet rarely, and OTA found it to be unknown even to some of the principal officials involved in verification policy. (For a discussion of the ACDA verification research role, see box B.)

Other, lower level interagency working groups also play coordinating roles. For example, the Department of Defense (DOD) has a Verification Technology Research and Development Working Group ". . . to provide a forum for discussion of current and potential verification technology requirements. . . ."

The two principal agencies funding (non-NTM) verification technology research are the DOE Office of Arms Control and the Defense Nuclear Agency.[9] The DOE national laboratories execute virtually all

8 "Arms Control Policy and Verification Technology: Report to Congress Pursuant to Section 910, FY 1989 Department of Defense Authorization Act (Public Law 10W56), Mar. 5, 1990." Transmitted by the White House to the President of the Senate and the Speaker of the House on that date. The report as a whole is classified "secre~" but all passages quoted or cited here are marked as unclassified in the document.

9 Acting as executive agent for the Under Secretary of Defense for Acquisition, Directorate of Defense Research and Engineering, Deputy Directorate for Strategic and Nuclear Forces.

Box B—The Arms Control and Disarmament Agency Role

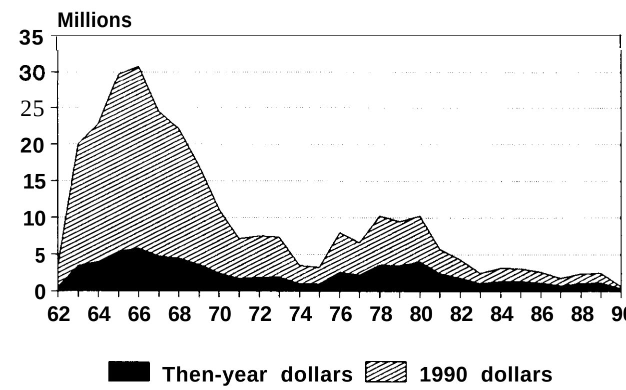
In March 1989, the ACDA Inspector General issued a report declaring that

> ACDA does not now play an active role in coordinating research conducted by these agencies. ACRCC [Arms Control Research and Coordinating Committee] meets only one or two times a year. . .ACDA has little, if any, influence over research priorities that maybe established by these other agencies.

ACDA's own funds for external research had declined over the years to less than $0.5 million annually (see figure 1). Even astute uses of these funds

> . . .do not come anywhere near giving ACDA the role in external research that the Congress may have originally intended when it asked the Director "to exercise his powers in such a manner as to insure the acquisition of a fund of theoretical and practical knowledge concerning disarmament.". . .To the extent that national security and foreign affairs agencies can persuade OMB [Office of Management and Budget] and their congressional committees that they need research money for arms control, ACDA's ability to coordinate arms control research will be correspondingly diminished. Given ACDA's small size and research budget (a condition likely to be continued unless the Administration and Congress shift research funds to ACDA from other agencies), there is no way that ACDA can influence to any significant degree the way other government agencies spend Federal research dollars.

Figure I—Arms Control and Disarmament Agency External Research Funds, 1962-90



ACDA external research funds have paid for research on all aspects of arms control, not just verification. As this graph shows, ACDA's ability to support external research on verification technology had become almost negligible by FY 1990. When then-year dollars (lower line) are adjusted for inflation (upper line), the real decline of ACDA external research becomes apparent.

SOURCE: U.S. Arms Control and Disarmament Agency and OTA, 1990.

It should also be noted that in the 1960s ACDA external research funds also financed academic and think-tank research on arms control. In later years, private foundations took up some of that effort. More recently, their support has declined as well. Thus universities find it increasingly difficult to find support for research in this area.

Soon after the transmittal of the Section 910 Report, ACDA announced the creation of a Chief Science Advisor's office. This office is to support arms control negotiations, oversee ACDA's external and internal research activities and operational analysis work, and carry out ACDA's coordinating activities with other research and development organizations in and out of government. According to ACDA's description of this office, it is to identify

> . . .promising technologies for development of techniques and instruments for use in cooperative measures to monitor arms control agreements, as well as innovative science and technology projects for possible ACDA sponsorship or support.

The office is also to support ACDA's Verification and Intelligence Bureau in the formulation of guidance for development of new National Technical Means collection capabilities.

The creation of this office in May 1990 seems to have been a response to the recommendations of the ACDA Inspector General. The office might strengthen ACDA's role in the interagency process described in the Section 910 Report. As of February 1991, however, ACDA had not yet appointed the Chief Science Advisor or staffed the office. (ACDA advised OTA that the delays were due to jurisdictional and funding questions within ACDA, but that these should be resolved soon.)

the DOE research, with some subcontracting to private fins. A handful of defense contractors, in addition to the DOE national laboratories, have so far carried out the DOD research. The two departments have agreed that DOE will sponsor basic research and development, while DOD will sponsor technologies at the test and evaluation stages.

Table 1 indicates the types of research and amounts of funding for FY 1990. (More detailed breakdowns of DOE projects are only available in classified form.) Note that for FY 1991, the DNA budget increased dramatically, from about $35 million (including $14.5 million from the Army) to about $107 million-with a proposed decrease to $83 million in FY 1992.

Table l—DNA and DOE Verification Technology Budgets

	Thousands of dollars
Defense Nuclear Agency, FY 1990:	
START	17,081
Including:	
Borescopes, videoscopes (for containers)	
Radiography	
Reflective particle tags	
Fiber optic tags (also DOE money)	
Seals on rocket motor casting, curing pits	
Ultrasonic tags	
Rapidly deployable portal-perimeter monitoring system (RDPPMS)	
Portal-perimeter continuous monitoring (PPCM)	
CONVENTIONAL FORCES EUROPE	1,035
Including:	
Tags (field demos)	
Treaty-limited equipment storage monitoring	
Sensors/human facility monitoring	
Inspection regime analysis	
CHEMICAL WEAPONS CONVENTION	14,500
(Funded by the Army, but administered by DNA)	
Including:	
Evaluate sampling methodology	
Trial inspections	
Field demonstration of available technologies	
Perimeter monitoring development	
Tagging development	
Chemical process database	
Analysis of manufacturing sites and equipment	
Evaluation of cheating scenarios	
THRESHOLD TEST BAN TREATY	2,685
(Nuclear test yield measurement)	
GRAND TOTAL (DNA)	35,301
Department of Energy, FY 1990:	
NUCLEAR TESTING	
Including:	
Underground, on-site	14,510
Underground, seismic	10,963
Nonseismic	2,667
Aboveground, satellite	43,160
Sample/debris	4,115
DIRECTED ENERGY	5,000
OTHER TECHNOLOGY	
Tags, demos, chemical detection, etc.	21,367
Radiation detection	12,915
ANALYTICAL SUPPORT	13,000[a]
PROGRAM DIRECTION	2,300[a]
GRAND TOTAL (DOE)	129,997

[a]OTA has arbitrarily assigned 50 percent of the budget for these functions to verification research.

SOURCES: Defense Nuclear Agency, 1991, and Department of Energy, 1990.

Current Research Emphasizes Individual Technologies Over Systems Analysis

Establishing monitoring systems to verify compliance with agreements limiting arms is a complex process. The fact that such systems must operate within a negotiated international verification regime adds complexity. One way of managing the process would be to analyze individual monitoring methods or devices in their larger context. From such a systems-level point of view, the whole is not seen as just a sum of parts, but as an integral system of interacting smaller systems. For example, the monitoring regime for a particular arms control provision may be seen as comprising a set of monitoring measures employing a group of systems, each using various devices or techniques, which in turn derive from the application of scientific knowledge (i.e., basic technologies). See box C for a discussion of the difficulties of implementing comprehensive congressional oversight of both intelligence and cooperative elements of arms control monitoring. See box D for further description of monitoring regime system levels.

Most of the research supervised by DOE and DNA has centered on developing the technical elements of monitoring systems; much less has been devoted to overall system designs or “architectures," either for comprehensive monitoring regimes or for the sets of monitoring measures that make up such regimes. For example, the United States proposed at START that mobile missiles be tagged as a monitoring measure (see section on ‘‘Monitoring Systems‘‘ inbox D). Tags were to help inspectors distinguish between legal and illegal missiles. It was not until well into the negotiations (December 1989) that the United States was prepared to propose and demonstrate to the Soviets the specific tagging technology of its choice (reflective particle, or “glitter paint” tags). Even by that time,

Box C—Planning Intelligence and OSI Should Mesh, But Integrated Congressional Oversight Is Difficult

The U.S. intelligence community continues to gather and analyze the bulk of the information relevant to Soviet and other arms control compliance. At the same time, on-site inspection has added a new dimension to arms control monitoring. Ideally, these two ways of gathering information would operate in a perfectly complementary way, each collecting data inaccessible to the other, each supporting the other. In fact, such close integration is difficult to achieve. The problem is that, by necessity, the one way of getting information is highly secretive, the other relatively open.

Much intelligence gathering succeeds because the target government does not know or understand the sources and methods used: if it did, it could improve its ability to hide or falsify informational On-site inspection, on the other hand, comes about as the result of mutual agreement about the kinds of information to be gathered, the instruments to gather it, and the conditions of their use.[2]

The division between these two worlds of secrecy and openness creates problems for those outside the intelligence community (and its overseeing congressional committees) who attempt to assess U.S. monitoring programs. First, it is difficult to assess the verification value of additional increments of National Technical Means of verification (NTM)-partly because of the extreme secrecy surrounding NTM and partly because NTM systems will rarely serve verification purposes alone. Should any share of a system that would be acquired for intelligence be counted as an arms control monitoring cost? How should that share be determined? Without such an accounting, it is impossible to analyze the trade-off between the costs of various forms of on-site inspection and additional NTM expenditures.

Second, it is difficult to get net assessments of the gains and losses of sensitive information that come with on-site inspections. With an on-site inspection regime, the Soviet Union has the chance to gather more information about the U.S. military than they would otherwise; the United States, in turn, can get more information about the Soviet military than otherwise. Those negotiating inspection agreements with the Soviets count the potential losses of information to Soviet collection as part of the cost of the inspection regime. To the people whose facilities might have to undergo inspection, these potential losses pose both a risk to security and the concrete costs of trying to protect the information.

It may be that some in the intelligence community assess the potential benefits of getting more information about the Soviet military. Somewhere in the government, there maybe rigorous, all-source analysis comparing the values of the potential gains and losses. OTA was not privy to such analyses, nor is most of the Congress (outside the intelligence oversight committees) likely to be. Such analysis could support an evaluation of the ways that the overall security of the United States would be better off or worse off if particular kinds of inspection systems were employed. Because of the secrecy surrounding this issue, however, it is not likely to play a large role in arms control treaty ratification debates.

---

[1]Sometimes the targeted party wants to reveal accurate information, and may help the intelligence collectors of the other side get itThus, in past arms control agreements, the United States and the Soviet Union have agreed to forms of non-interference wiNTM, so that they may assure one another that they are complying with certain treaty provisions. Such cooperative measures are likely to be part of START as well.

[2]On the other hand, a legitimate inspector might engage in espionage, using clandestine methods to try to gather information beyond the types agreed on.

the focus of research had been on the tag and tag-reading mechanisms, not on the systematic use of the tags to assure that they would supply the desired information.

There is a marked contrast between the many millions of dollars spent each year on the analysis of new weapons systems (for example, Peacekeeper missile basing modes or Strategic Defense Initiative system architectures) and the relative absence of comparable contracted, or external, analysis of arms control monitoring regimes. Government working groups have conducted analyses in preparation for near-term negotiations, but this process has been apart from the technical research and development process, and has not addressed longer-term possibilities. Recently, a few million dollars per year of DOE verification technology resources have gone to analytic support to policymakers and negotiators. Much of this effort has been in the form of ‘‘quick-response’ support for ongoing negotiations.

Box D—Verification Technology System Levels

Complete Regimes

For a given arms control provision in a particular arms control agreement, the verification regime may comprise these elements:

- national technical means (NTM) and other intelligence methods capable of supplying information about compliance;
- cooperative measures enhancing use of NTM for monitoring compliance;
- other cooperative measures, including data exchanges and various kinds of on-site inspection or monitoring;
- institutional arrangements for implementing cooperative measures; and
- institutional measures for raising and resolving questions about compliance.

Monitoring Measures

Monitoring measures are the methods of gathering information that are part of the verification regime. An example of a monitoring measure would be continuous, on-site portal-perimeter observation (monitoring) of a mutually agreed-upon facility. Another might be observation of the destruction of treaty-limited items. Another would be the unilateral use of NTM. Monitoring measures must be implemented by means of specific monitoring systems.

Monitoring Systems

By a system, we mean a group of devices, processes, procedures, and people applied to a task. The technical elements of a verification regime will probably include various systems directed toward particular monitoring tasks or sets of tasks. An arms control monitoring system might comprise a set of intelligence assets applied methodically to, for example, watching for deployments of banned missiles. Another example would be the particular portal-perimeter continuous monitoring arrangement established under the Intermediate Nuclear Forces Treaty and operated by the United States at the Soviet missile plant at Votkinsk U.S.S.R. A third example would be the U.S.-proposed system of tagging mobile missiles under the Strategic Arms Reduction Talks agreement—a system whose elements would include not just the tags themselves and the methods of applying and reading them, but the times and places at which tags would be read, the personnel reading them, the transmission of the information gathered, the analysis of the information, and the process of drawing conclusions from it about Soviet treaty-related activities.

This report focuses on those systems which apply to cooperative monitoring measures, as opposed to those used in unilateral intelligence gathering. In a complete verification regime, the United States and the Soviet Union each would be likely to coordinate these two kinds of monitoring system.

Any monitoring system must include means of accumulating, sorting out, and combining the data it collects. The problem of how to make sense of and use monitored data is itself becoming an important topic of verification technology research and analysis.

Devices

A monitoring system will apply various devices to gather information relevant to compliance with arms control provisions. The most complex mechanism ever likely to be applied to arms control monitoring is the human being, with his or her acute senses and intelligence. The human observer may extend his or her powers with simple devices, like measuring tapes or binoculars. More complex devices, like cameras, computers, or remote sensors may not only extend the powers of human senses, but complement them by increasing the consistency of observations, providing continuous coverage, making an objective record of monitored information, and collecting data outside the range of human senses (e.g., detection of chemical traces or infrared imaging).

Basic Technologies

Basic technologies for arms control monitoring are the means that might be employed by devices for sensing or measuring phenomena. (They might also include methods of concealing phenomena from inspectors that the arms control agreement does not entitle them to.) Some of these devices may be simple adaptations of very old technologies (such as X-ray scanners). Others may be special applications of relatively new devices, such as chemical sniffers. Still others may be specifically researched and developed for particular arms control monitoring applications. Advanced scientific research may in some cases point the way to accomplishing monitoring tasks that seemed otherwise impossible. Nevertheless, it would be a mistake to think of research and development of verification technologies as a quest for ever more sophisticated, high-tech devices. Rather, the challenge is to find the most appropriate ones. See appendixes A and B for more on verification techology.

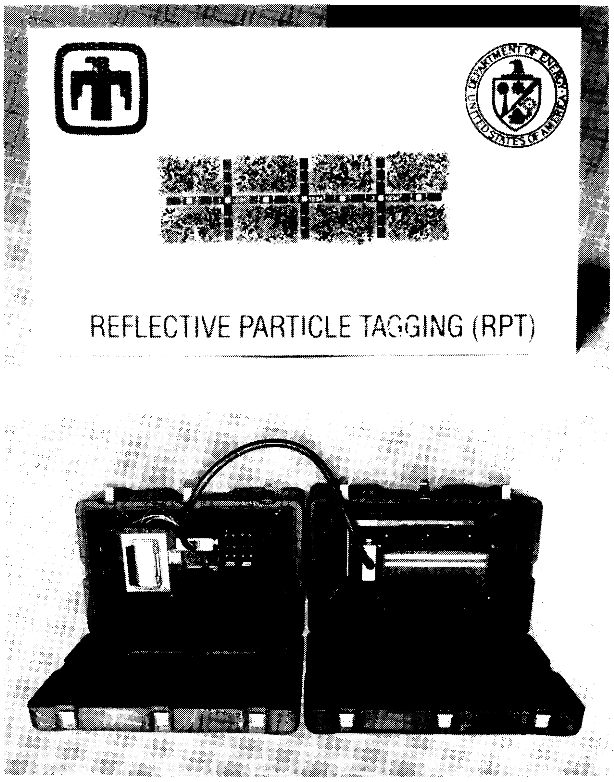


Photo credit: Sandia National Laboratories

The reflective particle tag (RPT), top photo, comprises a mixture of clear (acrylic) plastic material and reflective crystalline (micaceous) particles. The tag would be painted onto a treaty-limited item, such as a rocket motor, and cured with ultraviolet light. Light reflected from the tag forms a pattern that depends on the random locations and angles of the particles. Using instruments such as those in the bottom photo, arms control monitoring inspectors would record the unique pattern when they applied the tag. In subsequent inspections, they would again record the pattern and compare it to the original readings to ascertain that the tag is authentic. A treaty-limited item without an authentic tag would be a treaty violation.

Two recent DOE-sponsored studies did take synoptic approaches to a verification regime. One was the "Conventional Forces in Europe (CFE) Verification Framework Study." This study developed an overall monitoring system, including data collection, data management and integration, and analysis, for the CFE Treaty. A study group representing four DOE national laboratories (with assistance from three others) began the project late in 1989. With an overall budget of about $1 million, the classified study was not yet delivered some months after the treaty was signed. The study may still prove useful for CFE follow-on negotiations. It may also establish a model for future contracted studies, perhaps undertaken earlier in the negotiating process.

Another DOE, multi-laboratory study in 1990 designed a possible verification regime for the Chemical Weapons Convention. That study should be delivered early in 1991. Negotiations on a Chemical Weapons Convention started in the U.N. Committee on Disarmament in 1969. In 1984, then Vice President Bush submitted a draft treaty which went onto become the basis for a' 'rolling text' **that** continues under negotiation today. The 1990 DOE study took this rolling text as the basis for the verification measures it analyzed. Although coming considerably after the submission of a U.S. draft treaty, this study could supplement executive branch studies and may still affect the current negotiations. It may also influence further development work in chemical weapons verification technologies now being conducted by the Army for the Defense Nuclear Agency and by others.

Current Research Emphasizes Near Term

Funding Constraints

In its discussion of the DOD's Verification Technologies R&D Working Group, the Section 910 Report said:

> the VTRDWG coordinates the efforts of the independent DOD agencies, DARPA, and DNA, and Military Service organizations tasked to develop technology and hardware to support INF implementation and the U.S. verification requirements for START, CFE, and CW. While ideally the VTRDWG would not only address near-term but also longer-term technology initiatives, the reality is that funding is inadequate to look beyond near- and mid-term verification requirements.

DOE, on the other hand, has sponsored some long-term research, though its verification technology research budget requests have been shrinking, and the budget has been maintained only with congressional intervention. (See box Eon the timing of verification research.) In addition, DOE-sponsored research is constrained by bureaucratic jurisdictional boundaries: DOE often attempts to refrain from appearing to develop its own 'policy' on arms control matters outside its jurisdiction.

Policy Constraints

The Section 910 Report pointed out that:

> . . .the relationship between verification policy and the technology development process varies in each of the time-frames. For quick-reaction needs, R&D

Box E—The Timing of Verification Research

An executive branch report to Congress pointed out that the technology development process has to respond in three timeframes:

Quick-Reaction Response (Need exists within 12 months.) This category entails applications engineering (i.e., detailed design of systems, acquisition of components, and demonstration projects) of actual systems to meet a known immediate or imminent treaty-implementation requirement (e.g., fielding of the portal-perimeter monitoring system). Responses rely on existing technology developed as apart of a strong and broad R&D base).

Near-Term Response (approximately 12 to 36 months). In this category, technology R&D responds to possible but not yet agreed verification requirements of negotiations in progress. This requires capitalizing on existing technology R&D with some modifications from research near completion (e.g., tagging technology). Technology has to focus on requirements based on plausible treaty outcomes as well as on current U.S. positions; as with the quick-reaction response, the emphasis is on providing specific responses to specific tasking.

Long-Term Research (approximately 3 to 10 years). Long term (sic) research is designed to develop a broad base of verification technology across the spectrum of arms control-not necessarily tied to any specific present or future treaty requirement but rather to more general verification policy requirements. R&D undertaken in this area entails investigating, developing, and testing promising concepts, technologies, and models. Such research may be generic, with applicability in more than one area of arms control (although it may be oriented toward a specific problem, for example, inspection of sensitive locations without revelation of highly classified or sensitive information not related to treaty compliance). It provides the basis for future quick-reaction and near-term responses.

SOURCE: Section 910 report, op. cit., footnote 8.

has to be directly responsive to policy concerns and more narrowly focused on specific solutions to known problems. For near-term response, R&D should be fully consistent with and directed toward current policy and negotiations, but within this framework, there often is more room for experimentation and initiative in the development of solutions to known problems. There is even greater room for initiative with long-term R&D, but again, U.S. arms control and national security policy goals define the direction of this R&D.

Note that even for the long term, the Administration stresses consistency of research with *existing* U.S. arms control and national security policy goals. This policy is understandable, in that policymakers do not want to appear to undercut their positions that certain arms control measures would not be in U.S. interests. Nevertheless, recent history shows that sometimes government positions change.[10] And when they do, the availability of contingency plans can give the policymakers a more informed set of choices.

Today, though, the vast majority of (nonintelligence) verification technology research funds are dedicated to the areas of arms control currently being pursued by the Administration: START, Conventional Forces in Europe, nuclear test detection and yield estimation (for Nuclear Non-Proliferation Treaty and Threshold Test Ban Treaty), and the Chemical Weapons Convention. Some of the technologies under development with these arms control agreements in mind someday may also be applicable to other arms control measures. Examples of generic monitoring systems now under research include: tags and seals, portal-perimeter continuous monitoring systems (permanent or ''rapid-deployment' '), and nuclear warhead detection or counting systems. In the absence of policy guidance, however, researchers will be unlikely to develop these systems into specific verification regimes for arms control measures currently not on the Administration's agenda.[11]

Conclusion: Organizational Options

Today, immediate policy needs (such as fleshing out details of verification measures already under negotiation), taken with available technologies, dictate the shape of quick-reaction and near-term research and development. How might the government set long-term research priorities? One can imagine at least six options:

1. **status quo:** continue current arrangements;
2. **incremental changes: add** some focusing procedures to current arrangements;

[10]For example, until 1990, the U.S. official position **at START** was **that mobile intercontinental ballistic missiles should be breed entirely.**

[11]Examples of such measures are the cessation of production of nuclear weapons fissile materials and the dismantlement of nuclear warheads. In the 1991 Defense Authorization Act, Congress directed the President to establish a technical committee to report on verification methods for those measures. It also authorized the Secretary of Energy to use DOE national security program funds ". . .to carry out a program to develop and demonstrate a means for verifiable dismantlement of nuclear warheads." U.S. Congress, *Congressional Record,* Oct. 23, 1990, p. H 12041.

3. **lead agency:** designate a lead agency from among those now involved in this research;
4. **funding agency:** give one of the agencies now involved not only a designated leadership role, but authority over most relevant research funding;
5. **czar: create** a new managing agency for all cooperative verification technology research; and
6. **new arms control agency:** revitalize or replace ACDA, creating an agency with increased arms control responsibilities, authority, and finding across the board, including research.

Each of these options has advantages and drawbacks.

Option 1: Status Quo

In recent years, the approach appears to have been one of ad hoc adjudication of competing research proposals, with allocation of resources guided by the following general principles:

- expect most research to address technical monitoring requirements defined in ways consistent with current policy expectations;
- support some research on generic techniques that may be applicable both to the current policy needs and to a range of future possible arms control monitoring tasks; and
- for the purpose of enriching the "technology base' from which solutions to future problems might emerge, permit a few researcher-initiated projects on technology issues of less apparent relevance to current policy.

Given the variety of bureaucratic interests with a stake in arms control verification, much of the necessary coordination will continue to be a matter of lateral negotiation among various agencies. With some stimulus from Congress, in the past couple of years the executive branch has taken steps to improve this coordination, for example by creating the National Security Council Verification Technology Working Group.

As shown above, this arrangement seems to be meeting short-term needs for cooperative verification technology development. On the other hand, it seems to be slighting needs for long-term research on comprehensive verification regimes and the technologies that might fit into them.

Even without strong Administration initiative, some options are open to Congress for encouraging a more coherent, longer-range research and development program in verification technology:

- direct and fund one or more agencies (e.g., ACDA, DOE Office of Arms Control) to sponsor additional long-term research on verification concepts and technologies for arms control measures not currently under active negotiation;
- in legislative oversight of verification technology research, require executive branch reports and testimony on the basis for proposed allocations of research resources;
- strengthen coordination among oversight committees dealing with various aspects of verification: House Armed Services, Foreign Affairs and Intelligence; Senate Armed Services, Foreign Relations, and Intelligence;
- during the ratification process for arms control treaties, require that the executive branch supply descriptions and results of systematic analyses of proposed verification regimes; and
- encourage ACDA to staff and support its Office of the Chief Science Advisor to more actively assert its legislatively chartered role in arms control research coordination.

Option 2: Incremental Changes

The executive branch could take steps to improve the coordinating process established during the preparation of the Section 910 Report.

A modest, but potentially useful first step would be to refine budgetary reporting on arms control verification. The Office of Management and Budget has now begun to require that agency budget submissions identify expenditures related to verification. A further set of subcategories could resemble those in DOD budgets: research, advanced development, procurement, and operations and maintenance. Breaking down budgets into such categories would make it much easier for both executive branch managers and congressional overseers to evaluate the content and direction of verification-related research and development. This kind of budget reporting would also ease evaluation of current arms control monitoring activities. Finally, it would permit better estimates of the potential costs of proposed verification regimes.

A second incremental step would be to further formalize the interagency coordinating process. The interagency committee (currently the NSC Verification and Compliance Subcommittee's Verification Technology Working Group) could be assigned to produce decision papers for the NSC.[12] These papers might propose verification regimes for particular potential treaties and then propose research programs to support the regimes. The Arms Control and Disarmament Agency might chair such studies. The studies themselves might be initiated by requests from the NSC or any of the agencies in the group. Because the studies would result in proposals for action to be authorized by the NSC, the affected agencies would have a strong incentive to play an active role. This decision-paper process might be most applicable to near- and mid-term needs for coordinating verification technology development with negotiating plans.

A third step would be to delegate the preparation of long-term research and development plans to a single agency, perhaps ACDA. The plan would not prescribe U.S. policy, but would look to preserving and creating future options. It could identify weaker areas of current research and point out areas where successful technology development might open up new arms control opportunities. Individual agencies would still be left to carry out (or ignore) their elements of the plan. But the availability of an annually updated plan would assist higher-level executive and congressional overseers in making their decisions.

Option 3: Lead Agency

A modest centralization of the current arrangement would be to designate one of the current research-sponsoring agencies as lead coordinating agency. This step would have to go beyond simply having the lead agency chair coordinating committee meetings. It might include directing the agency to conduct planning research and propose the primary, government-wide research agenda in this area. Table 2 lists some candidates for lead agency, along with pros and cons for each.

A significant drawback of this option is that without the authority to determine how money is actually spent, such a lead agency could not enforce a coherent R&D program. Rather, it is likely that the actual program would remain the product of a combination of bureaucratic competition and cooperation. There already appears to be some competition, for example, between DOE and DOD agencies for verification technology roles and missions.

A second problem facing any potential lead agency is that since current research, focusing largely on immediate and near-term needs, is already stretching budgets, a more robust long-term program will require more money. In the executive branch, this is likely to mean asking agencies to reallocate resources away from other, perhaps in their view, preferable missions. For example, for each of the past several years, DOE has declined to request real growth in its Verification and Control Technology budget line, while Congress has chosen to authorize more than DOE requested. In Congress, reallocations of appropriations can also be difficult. The amounts for plausible expansion of existing activities, however, would run to tens of millions, rather than billions, of dollars per year.

Moreover, there appears to be congressional interest in additional verification technology research. In its report on the FY 1991 defense authorization bill, the Senate Armed Services Committee said:

> The committee is disappointed that the Department of Energy has once again failed to adequately support the arms control verification research efforts of its laboratories in its fiscal year 1991 requests. The committee received testimony from both the Under Secretary of Energy and the directors of the Department of Energy laboratories that the requested funding is inadequate to support ongoing arms control negotiations and the requirements of recently concluded agreements. The Senate Select Committee on Intelligence has also recommended additional funding for this very productive research effort with a long track record of successes.

The committee then added $43.2 million to the DOE request for detection technology and directed

[12] The process might be analogous the joint DOD-DOE process for determining nuclear weapon acquisitions. The relevant agencies of the two departments participate in a liaison committee, the Nuclear Weapons Council Standing Committee, chaired by the Assistant Secretary of Defense for Atomic Energy. This committee issues requests for studies based on proposals by the member agencies. These studies produce decision papers for the departmental policymakers. One type of study ("Phase One' examines how perceived military requirements might be met by a range of technology options. The resulting decision papers then identify and propose the most promising choices for further research and development. A second type of study (''Phase Two' evaluates the choices available for developing a specific weapon.

Table 2-Candidates for Role of Lead Agency in Verification R&D

Agency	Pro	Con
Arms Control and Disarmament Agency	—Is the congressionally designated agency for this role —Plays important role in arms control negotiations —Is specialized for arms control tasks	—At present budget and manpower levels, lacks the personnel, expertise, funds, and authority to manage such a program —Is widely perceived to be incapable of assuming this role —As a small, independent agency, lacks intra-governmental clout of DOD, DOE
Office of Arms Control (DOE)	—Many years of experience managing DOE laboratory research on verification -Largest current budget for cooperative monitoring measures —Provides technical advisers to arms control negotiating delegations	—Lacks operational role in implementation of most arms control agreements -Other Departmental interests (e.g. in warhead testing and production) may appear to conflict with some arms control objectives
Defense NuclearAgency (DOD)	—Experienced as OASD Acquisition Under Secretary's manager of DOD verification research	—its Verification Technology Research Center has focused on near-term test and evacuation, not long-term research; -Other DOD interests (e.g., development and acquisition of new weapon systems) may appear to conflict with some arms control objectives —is removed from arms control policymaking arena
On-Site inspection Agency (DOD)	—As designated executor of U.S. on-site inspection activities, is the "customer" for products of cooperative verification research	—Too far removed from arms control policymaking arena —Too busy with current inspection tasks and planning to direct long-term research

the Secretary to submit a report within 45 days of passage of the bill describing each project to be funded. In the final authorization bill approved by Congress, however, the total DOE verification and control technology budget (of which detection technology is an element) exceeded the DOE request by only $30 million. This represented an 18-percent increase over the previous year's overall verification and control technology budget, as opposed to the 5-percent decrease requested by DOE. However, the $30 **million** was earmarked for the technology development portion of that budget, there representing a 29-percent increase as opposed to a requested decrease of 10 percent.

Option 4: Funding Agency

A more coherent, long-range program will likely require that the President not merely designate a lead agency, but that he assign it the authority and resources to do the job. Congress, in turn, would be called on to authorize and appropriate the resources.

Under this option, the same agencies now overseeing research would continue to do so, but their verification budgets allocations would be funneled through the lead agency. Since money now under the control of one department would effectively pass to that of another department, such a plan would no doubt lead to resistance. In addition, the same problems of identifying the appropriate lead agency as exist under Option 2 would also burden this option.

Option 5: Verification Research Czar

One way of sidestepping problems of bureaucratic resistance and inertia is to create a new organization, a ''czar' with the authority to focus government efforts toward a particular task. For example, President Reagan created the Strategic Defense Initiative Organization (SDIO) to centralize U.S. research and development of ballistic missile defense technology. Besides starting new research projects, the SDIO took over direct management of existing projects and supervised the continuation of others under the management of existing organizations. One could imagine a similar agency for verification research—though funded in the low hundreds of millions, rather than in billions of dollars.

Such a new agency can concentrate government attention on a problem, at least in the short run. In the long run, it has disadvantages:

- it adds a new layer of bureaucracy, but one without a solid base of experience and influence in the operations of the bureaucratic system;
- unless permitted to grow so large as to duplicate the staff resources of existing agencies, it may lack an adequate supply of in-house expertise; and
- the influence of the "czar" may last only as long as the President takes a direct and continuing interest in the mission.

Option 6: New Arms Control Agency

A more dramatic option would be to create a new agency-or to revitalize ACDA—with the bureaucratic and financial resources to execute a coherent arms control research program. Such an agency might also have substantial arms control action responsibilities (policy, negotiation and implementation[13]) that make it a key player. The rationale for creating this agency would be that arms control planning, negotiation, and implementation has become a larger element of U.S. national security policy than ever before, thus outgrowing previous organizational arrangements. Pulling most arms control activities together into one agency might lead to more coherent, comprehensive planning and execution of arms control policy. With respect to cooperative verification technology research, such a new organization would become the chief customer for the research product. It would have a direct interest in seeing that research met both near-term policy and long-term planning needs.

The ACDA charter licenses that agency as the focal point for U.S. arms control activities.[14] Moreover, the law lays special emphasis on the research function:

> . . the Director is authorized and directed, under the direction of the President, (1) to insure the conduct of research, development, and other studies in the field of arms control and disarmament; (2) to make arrangements (including contracts, agreements, and grants) for the conduct of research, development, and other studies in the field. . .by private or public institutions or persons; and (3) to coordinate the research, development, and other studies conducted in the field. . .by or for other Government agencies.[15]

With respect to verification,

> . . .the Director is authorized (1) to formulate plans and make preparations for the establishment, operation, and funding of inspection and control systems which may become a part of the United States arms control and disarmament activities, and (2) as authorized by law, to put into effect, direct, or otherwise assume United States responsibility for such systems.[16]

For many reasons, though, ACDA has not exuberantly carried out all the missions formally assigned to it. While it does continue to play a major (but not dominant) role in arms control negotiations, its roles in research and in implementation are minimal. Whether ACDA could be revitalized and expanded to take on a larger role, or whether it would have to be abolished and its successor created anew is an open question.

This option, the most drastic in the list, would be the most difficult to carry out. The Departments of Energy and Defense would lose money and person-

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[13]Some have suggested that it would be consistent with the arms control agency mission to place the On-Sit Inspection Agency under its jurisdiction. "If that were done [for ACDA]," wrote one reviewer of this report, ''the funds that OSIA receives for research, which are not inconsiderable, could be part of ACDA's budget and ACDA would have a better chance of managing the Administration's long-term research on arms control. " On the other hand, the OSIA will necessarily make considerable use of DOD personnel and logistical support; its access to these resources maybe more immediate if it remains a DOD agency.

[14]The congressional statement of purpose in the law establishing ACDA says:

> The formulation and implementation of United States arms control and disarmament policy in a manner which will promote the national security can best be insured by a central organization charged by statute with primary responsibility for this field. ..This organization must have the capacity to provide the essential scientific, economic, political, military, psychological and technological information upon which realistic arms control and disarmament policy must be based. It shall have the authority, under the direction of the President and the Secretary of State, to carry out the following primary functions:
>
> (a) The conduct, support, and coordination of research for arms control and disarmament policy formulation;
>
> (b) The preparation for and management of United States participation in international negotiations in the arms control and disarmament field;
>
> (c) The dissemination and coordination of public information concerning arms control and disarmament; and
>
> (d) The preparation for, operation of, or as appropriate, direction of United States participation in such control systems as may become part of United States arms control and disarmament activities.

(22 U. S.C.A. 2551)

[15]22 U.S.C.A. 2751.

[16]22 U.S.C.A. 2574.

nel traditionally assigned to them. Even if those agencies parted horn-their resources willingly, the transitions could be awkward. From the standpoint of conducting international negotiations, the relationship between the State Department and the new **arms** control agency would be difficult to work out. In both the executive branch and Congress, there may be concerns that the new organization would become a vested interest in favor of evermore arms control, to the neglect of other national security considerations.

In sum, each option for reorganization has formidable drawbacks. Nevertheless, each seems to offer some improvement over the previous, more or less improvisational approach to verification research.

Appendix A: The Technology of Arms Control Verification

This report has addressed the "who" and the "how" of the management of U.S. verification technology research. This appendix discusses the "what' the kinds of research to be managed. The following sections identify some of the kinds of topics that could be productively investigated in a systematic, long-term research program. The ideas are illustrative, not exhaustive.

In considering research options, it is important to keep in mind that research and development of verification technologies is not simply a quest for ever more sophisticated, "high-tech" devices. Rather, the challenge is to find the most appropriate ones. The bottom line is in how effectively, and at what cost, technology is applied to do the job.

Future Verification Regimes

Long-term research on verification regimes would identify potential arms control measures that should be examined. For each of those, it might build a possible list of treaty-limited items. It could then explore features of the production, testing, deployment, maintenance, or destruction of those items that might most easily be monitored. Examples of potential arms control measures that are not now on the executive branch's active agenda, but might conceivably become so someday include:

- ban on multiple-warhead ICBMs,
- nuclear warhead accounting and elimination,
- control or ban on nuclear sea-launched cruise missiles,
- control or ban on other naval tactical nuclear weapons,
- other forms of naval arms limitations,
- cutoff of nuclear weapons materials production and controls on fissile materials, and
- limits on space weapons.

Like the Conventional Forces in Europe agreement or the Chemical Weapons Convention, some future arms control arrangements may be multilateral, rather than just U.S.-Soviet. Therefore, it may be important to devise verification regimes suitable for multilateral participation and less dependent on NTM.

Monitoring Measures

Long-term research on monitoring measures would specify the kinds of measures that might apply to the potential arms control provisions under consideration. At this stage of research, some monitoring measures 'would have broad enough application for more than one kind of arms control provision. Others might be specific to the particular features of one kind of Treaty-Limited Item (TLI) or another. Some of the research might involve analyzing the extendability of measures for current arms control monitoring to future types of arms control.

Examples of monitoring measures that might be improved with further research include:

- aerial surveillance (beyond Conventional Forces Europe agreement);
- unattended observation of TLI destruction;
- remote tag reading for later START I implementation, START II, and other arms control applications;
- portal-perimeter continuous monitoring[17] (beyond INF and START treaties); and
- design and operation of new weapons in ways that make them easier to monitor.

Monitoring Systems

The above sorts of monitoring measures will require detailed analysis of the specific ways they can be put into effect. This analysis would involve not only identifying the types of devices that might be deployed, but the integration of those devices into systems as well as strategies and tactics for operating the systems to maximum effect.

Examples of monitoring systems that might have future applications include:

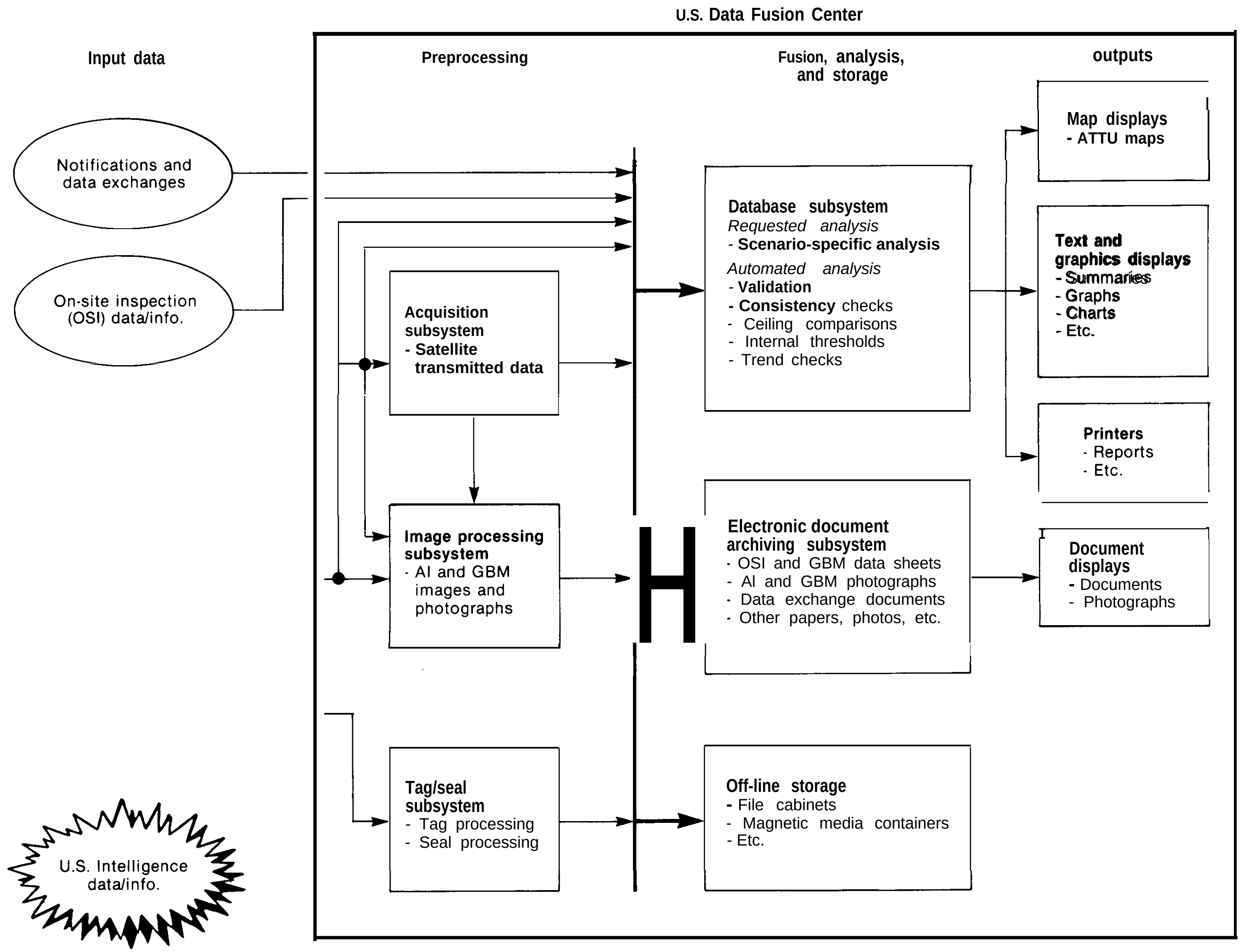
- aerial surveillance aircraft and sensor combinations and strategies for their use,
- portal-perimeter continuous monitoring systems specific to arms control measures beyond START, and
- data fusion systems to help pull together and interpret all the relevant information for arms control compliance assessments.

Technology Requirements

Analysis of potential verification regimes will take account of the existing base of ready devices

[17] Including study of possible penetration of perimeters, such as tunnels.

Figure 2-Schematic Diagram of a Proposed U.S. Data Fusion Center

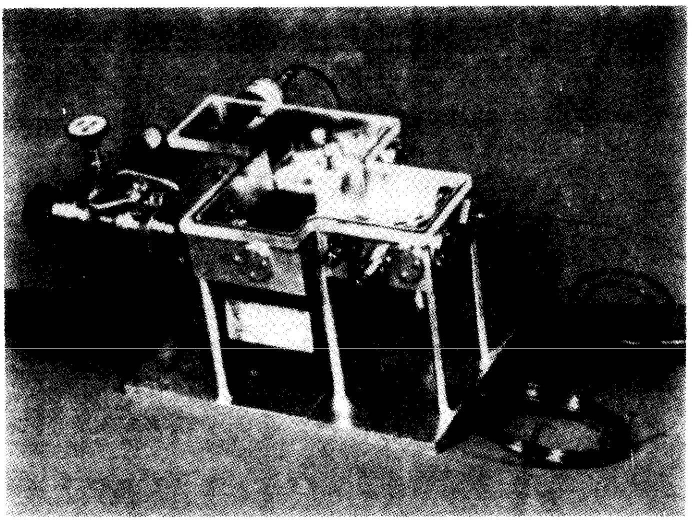


Data and information management for arms control monitoring

Researchers at Sandia National Laboratories have proposed a verification data fusion center. The system would assemble information from disparate sources, including news agencies, treat y declarations, on-site inspections, aerial inspections, or open literature sources. The system would store this data both in on-line computers for immediate access and in archives for cumulative interpretation and analysis. The goal would be to provide decisionmakers with concise, comprehensible, and timely reports on the information available about foreign compliance with arms control agreements.

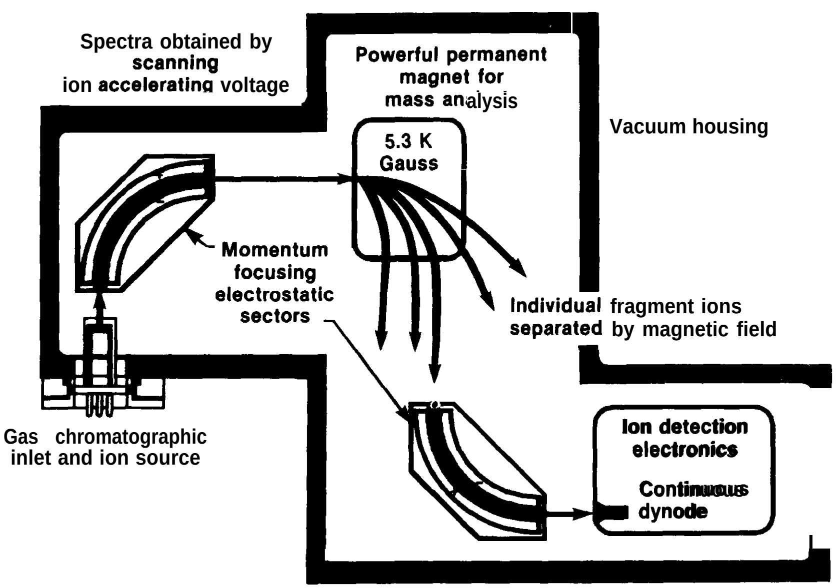
SOURCE: Sandia National Laboratories.

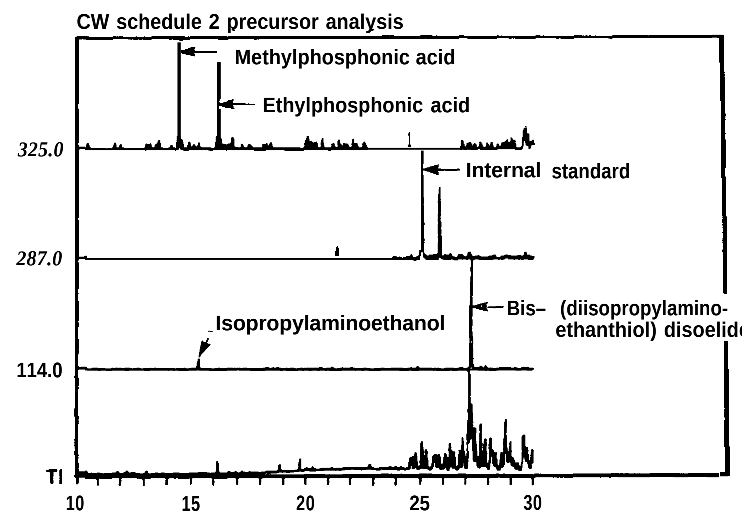
Figure 3--Portable High-Resolution Mini Gas Chromatograph-Mass Spectrometer



Lawrence Livermore National Laboratory is developing a portable, high-resolution gas chromatograph-mass spectrometer that may be used by inspectors monitoring compliance with the proposed international Chemical Weapons Convention. At a site suspected of manufacturing chemical weapons, this instrument might detect even minute traces of "precursor" chemicals that are combined to produce the prohibited poisons. First the gas chromatograph (the coiled tube leading into the device pictured at left) would separate a sample of air or water into different chemical components. These chemicals would be ionized and introduced into the mass spectrometer (device pictured at left, with schematic diagram below), which separates the ions according to differences in their mass. A resulting graph, shown below for a water sample containing a precursor chemical, would indicate the presence of ions of the compound of interest.

SOURCE: Lawrence Livermore National Laboratory.





and technologies available for development into ready devices. But the analysis will also suggest potential monitoring shortfalls and promising technologies that might help close the gaps. In this way, the analytic work would serve two purposes at once: first, serve as a planning base for future arms control negotiators; second, guide investments in technology research for future monitoring systems.

Appendix B: Systems Analysis and Verification Research

In its review of verification technology research, OTA found little large-scale systems analysis in comparison with that usually applied to weapons technology research (as in the case, for example, of SDI). This appendix illustrates one such kind of analysis, "network analysis" that could be applied to verification technology problems.

Introducfion: Judgments Under Uncertainty

Assessing the value of arms control provisions, regimes for verifying compliance, and specific monitoring systems for those regimes involves many complex judgments that must be made under conditions of uncertainty. Nevertheless, the Senate must implicitly or explicitly make such judgments (or accept the judgments of others) when it chooses or declines to ratify an arms control treaty. Both Houses of Congress acceptor reject such judgments when they choose to support or modify Administraion proposals for arms control verification technology research.

There is no way to eliminate all the uncertainties surrounding these judgments. No technical calculations can dispel uncertainties about future events or settle disagreements about the values to place on policy outcomes; therefore, calculations will not produce objectively "right" answers. Nevertheless, it is possible to apply analytic methods that clarify where the uncertainties lie and make more explicit the assumptions of those proposing different courses of action. Such methods may at least produce *better* answers than the unstructured playing of hunches. They may also lead to identification of areas of research that could reduce some uncertainties.

NetworkAnalysis of Evasion Strategies and Verification Measures

Analysts at Lawrence Livermore National Laboratory have suggested a method to ". . identify potential weaknesses in [an] overall treaty verification system, to highlight the evasion and breakout strategies least likely to be detected or deterred, and to determine the individual verification measures that offer the greatest benefit."[18] They propose a five-phase process of analysis, outlined below.

1. Identify Soviet Evasion Objectives

Determine how particular evasive actions might lead to a militarily significant advantage. If different objectives are possible, assign relative weights to them.

2. Develop Network Model of Evasion Strategies

A simpli.tied example of such a model is given in figure 4. Developing the model involves identifying steps that the Soviets would have to perform to achieve their objectives. Evasion strategies consist of sequences of steps that would lead to deployed weapons (or other treaty violations). The example the Liver-more analysts use is a network for the manufacture of small, single-stage ballistic missiles.

3. Estimate Evasion Probabilities

Estimate the probability that treaty evasions associated with each step in the network would be undetected by verification measures in force at that step. These estimates are by nature subjective judgments. Analysis of this kind forces the experts to make their judgments explicit. Agreement among experts would be desirable, but where disagreements exist, analysts can perform separate evaluations to show what differences those disagreements make. Moreover, additional technical research on specific verification measures may narrow the range of disagreements and increase confidence in judgments.

4. Determine Evasion Strategies Least Likely To Be Detected

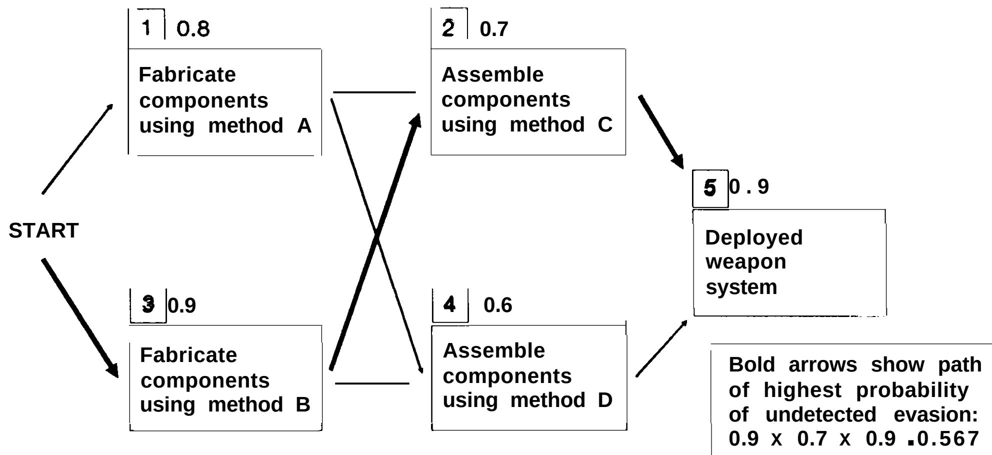
For each evasion strategy, multiply the probabilities of successful evasion of the individual steps.

5. Analyze Results and Perform Sensitivity Analysis

The advantage of **a systematic analysis like this is** that it clarifies the effects of varying assumptions, estimates, and strategies. For example, the analysis might show that a monitoring regime that had a relatively small chance of catching violations at each of several manufacturing steps would have a fairly high overall probability of detecting significant

[18] Thomas A. Edmunds and R. Scott Strait, *A Network Methodology for Evaluation of Treaty Verification Options* (Livermore, CA: Center for Technical Studies on Security, Energy, and Arms Control, Lawrence Livermore National Laboratory, September 1989), p. 1.

Figure 4--Network Representation of Evasion Strategies and Probabilities



Path	Undetected evasion probability	
o → 1 → 2 → 5	0.504	
0 → 1 → 4 → 5	0.432	
0 → 3 → 2 → 5	0.567	Highest probability of undetected evasion
o +3+4+ 5	0.486	

In this schematic diagram of possible paths to the deployment of a weapon system, each step has an estimated probability that it will go undetected. The likeliest evasion path is the one in which the multiplied probabilities of the steps come out the highest, in this case the path through steps 0,3,2, and 5. Note that efforts to reduce the probability of successful evasion at Step 3 to below O.8 could just induce the violator to use Step 1 instead, and therefore such efforts would not be worthwhile.

SOURCE: Adapted from Lawrence Livermore National Laboratory, 1990.

numbers of deployed weapons. Or, it might show that even greatly improving the chance of detection at one step might not be worthwhile, because it would simply cause the evader to choose an alternate step. Figure 4 illustrates this point.