18 September 1990

CONF-9009295--1

DE91 004476

TAGS AND SEALS FOR ARMS CONTROL VERIFICATION*

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INTRODUCTION

Tags and seals have long been recognized as important tools in arms control. The trend in control of armaments is to limit militarily significant equipment that is capable of being verified through direct and cooperative means, chiefly on-site inspection or monitoring. Although this paper will focus on the CFE treaty, the role of tags and seals for other treaties will also be addressed. Published technology and concepts will be reviewed, based on open sources.

Arms control verification tags are defined as unique identifiers designed to be tamper-revealing; in that respect, seals are similar, being used as indicators of unauthorized access. Tamper-revealing tags might be considered as single-point markers, seals as two-point couplings, and nets as volume containment.

The functions of an arms control tag can be considered to be two-fold: to provide field verification of the identity of a treaty-limited item (TLI), and to have a means of authentication of the tag and its tamper-revealing features. Authentication could take place in the field or be completed elsewhere. For CFE, the goal of tags and seals can be to reduce the overall cost of the entire verification system.

TREATY REQUIREMENTS

Neither the INF Treaty nor the underground nuclear-weapons testing bilateral treaties have had a requirement for tags. As aids to limitations on the number of mobile missiles and to control their modernization and production, tags and seals have been proposed for START. If nuclear warheads were to be verifiabily removed from service and dismantled, tags and seals might be needed.

For proposed multilateral treaties, tags and seals might have a more widespread role; their value increases with the practical difficulties of accountability when a great many items must be verified. In verification of a CW Convention, seals could be important in assuring against prohibited uses of holding tanks, valves, containers, and facilities. The CFE treaty has the potential for the largest number of tags -- perhaps hundreds of thousands.

In the negotiations on reductions of Conventional Forces in Europe (CFE), on-site inspection provisions again played a major role in the design of the treaty provisions. Advances in tagging technology promise to enhance security under a second-stage CFE Treaty as well as to reduce the cost of verification.

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*Work supported by the U.S. Department of Energy, Technology Support Programs under Contract W-31-109-Eng-38.

NTM can track large concentrations of weapons but cannot verify compliance with ceilings.

Verification Requirements

CFE verification entails counting a large number of items; taking account of various sites and zones of deployment, storage, production, withdrawal, elimination; compliance with limits on holdings, observation of mobilization capability; and recognition of modernization.

Based on the preceding military objectives, certain functional principles can be identified. Of overriding concern is cost-effectiveness.

Strict complete initial item accountability. All agreed treaty-limited items might be subject to strict and complete initial accountability because: (1) any item declared in a treaty becomes as a matter of law subject to verification; (2) overall accountability is facilitated by having accurate verification from the moment the treaty enters into force; and (3) if accountability is not complete from the beginning, the process is not reversible when compliance questions arise. One must keep in mind the possibility of a follow-on CFE-II treaty with further verified reductions.

Timely verification. The time scale for verification is driven by mobilization potential and countermeasure reaction. The degree and rapidity of access, the thoroughness of data collected, and the speed of transmission and assimulation of data are key factors in the utility of verification.

Accurate and efficient accountability. Because of several factors -- the very large number of items that could be subject to declaration (200-300 thousand), the initial surge of withdrawal, and the subsequent stages of reduction -- accurate and efficient means of item counting will be necessary to keep verification costs low and minimize disputes over compliance.

Synergistic support for NTM. The intelligence resources of many treaty parties will continue to provide strategic information on overall conventional-force deployment activities. NTM data interpretation can be expedited and improved by ground verification, and conversely. OSI selection can be guided by data from NTM.

High cost-effectiveness in verification technologies. Technical means of augmenting verification must satisfy stringent tests in cost-effectiveness, especially when one must take into account the large number of objects and factors with military significance.

Limited redundancy through different approaches. It is an accepted principle in many fields to allow redundancy by similar or different means when the objectives are sufficiently important. There might be some situations in CFE verification where overlap in types of verification should be accepted. For example, is the cup half-full or half-empty? If 5000 out of 10,000 TLIs are eliminated, what is more important: verifying the elimination or verifying the residual? Verifying just one of these two aspects might be sufficient, but verifying both would give added confidence.

Strong reliance on human observation. The human being is a highly capable and discriminating sensor and integrator of various indicators (but with limited and short-term memory). Perhaps the most important aspect of inspection will be the observations and inferences drawn by qualified military personnel, particularly in terms of the less quantitative aspects of on-site inspection. In fact, one goal of technology will be to relieve the inspectors of certain routine steps so that they can concentrate on verification of qualitative aspects such as war-fighting capability and treaty circumvention.

There continues to be an attitude expressed for CFE that only militarily significant violations need be detected. Many outside the negotiations disagree with this view, and the four reasons often cited are:

1) Even if the violations are not militarily significant, but they are deliberate, the earliest possible tip-off is needed in order to recognize the symptoms and to institute the earliest possible remedies.

2) Detection of small-scale violations will discourage cheating that is disguised as minor anomalies. What better way is there to increment deployed forces than to put up and maintain a smokescreen of small discrepancies, with each detected discrepancy being able to mask several more real illegal increases?

3) Political confidence, in this and in other pending negotiations is enhanced by day-to-day and long-term demonstration of strict compliance. The design of verification regimes that convey this approach is likely to encourage signing and ratification of such treaties.

4) It is axiomatically better to resolve discrepancies as they occur rather than to wait until they become militarily significant.

Burdensharing. Costs of verification will have to be borne by the parties to the treaty in some agreed manner. With a drawdown in troops occurring, no doubt considerable weight will be given to uniformed inspectors as a key means of apportioning cost with minimal impact on national budgets.

Because major armament platforms are to be reduced in number and controlled in deployment, a significant role for tamper-revealing tags might ensue. The key roles for such tags would be to assist in inventory and location of items of account during baseline and drawdown phases. Some straightforward, concurrent means of keeping track of objects eliminated or retained would increase confidence in compliance.

The foundation of a cost-effective framework for CFE could be self-applied tagging of all TLIs to gain rapid and accurate accountability. Rapid accountability expedites the inspection process and allows more items to be checked in a given inspection period; accurate accountability supports effective verification and avoids unwarranted compliance disputes. The result is reduced cost of verification, improved accuracy in item counting, and enhanced security.

A constraint on tagging is the notion of "parsimony". The most demanding extension of this notion is the requirement of developing a tag that can be applied during the baseline period by the party to be inspected without witness by other treaty parties. A statement of this requirement has been given by two former officials of the Western European Union, who gave as examples the unique pattern of an optical fiber seal which is formed when sealing the tag to the TLI, or a tag consisting of a "fingerprint" of part of the TLI itself.

The baseline period after a treaty goes into force could be more effectively utilized by each side in inventorying its own equipment and in applying the tags. During this period each side will probably uncover anomalies in its inventory that are better straightened out through this registration process that would result in a revised MOU.

Requirements for tags are stringent since a large number of tag failures would undermine confidence in treaty compliance. Each tag must uniquely identify one weapon. Tags must be resistant to counterfeiting and be tamper proof and very difficult to remove from a weapon once they are attached. But because of the distribution and numbers of TLIs to be tagged, the tags must be easy for inspectors to read under field conditions. Exposure of the tags to operational and environmental stress is likely to be much more severe than that for strategic weapons.

Conventional weapons deployed in Europe are subjected to a variety of weather conditions. Tanks are routinely driven through water, mud, sand, forests, gravel and even salty water from winter roads or the ocean. Troops are not noted for handling weapons with special care. Thus tags must be rugged enough so that they will not fail under extremes of vibration, abrasion, temperature or humidity. Because so many TLIs will be tagged, tags will need to last for at least a decade, and they should be as inexpensive as possible if the costs of monitoring the treaty are to be manageable. Tags for strategic weapons are likely to be in a protected environment.

In assembling a list of specific requirements at this stage in time it is difficult to make note of all needs to be met by tags and even more difficult to assess their relative priority. Although setting requirements is primarily a function of the user-community, the following qualities would appear to have some bearing on the selection of a tagging approach.

1. Identifiability. Inherent capability to identify either individual items or a class of TLIs as required.

2. Counterfeit resistance. Resistant to efforts of tag replication.

3. Transfer resistance. Tag cannot be readily (without detection) transferred by cutout or removal of the substrate.

4. Operational ruggedness. Withstand an operational environment that places all exposed surfaces at risk to damage in the field.

5. Environmental survivability. Able to cope with realistic deployment conditions from the Atlantic to the Urals, north and south.

6. Human tolerance. Resistant to human misuse, abuse, or error.

7. Field verificability and rapidity. Easy and rapid verification in the field.

8. Application by inspected party. Inspected party can apply tags without inspectors as witnesses.

9. Economical in outlay. Low-cost tags because of the many potential items of account.

10. Economical in overhead. Low personnel overhead costs for application, maintenance, and verification of tags.

11. Inventory assistance. Capable of assisting the computerized functions of baseline and drawdown inventories in both speed and accuracy.

12. Serviceability. Subject to minimal requirements in frequency and skill of field servicing of tags and their reading equipment.

13. Field testability. Can be tested in realistic field trials with high confidence in extrapolating to actual use on a large scale.

14. Long-term durability. Able to stand one or more decades of use in the field.

15. Availability. Available for negotiation and application on a timely basis.

16. Operational impact. Little impact on normal overhaul, cleaning, and painting operations.

17. Replaceability. Can be replaced in the field if necessary.

18. Amenable to remote verification. Compatibility with remote field verification to expedite and to reduce intrusiveness of verification.

19. Technology transferability. Technology not embargoed.

20. Locatability. Can be located on identical, conspicuous, and secure components of a treaty-limited item.

21. Technology transparency. Not limited by technology concerns over transfer or component transparency.

22. Intelligence susceptibility. No misuse of tags for purposes outside scope of a treaty.

23. Field authentication. Can be authenticated on a selected basis in the field with minimum difficulty and time.

To summarize the role of tagging, especially for CFE, the following features are highlighted:

Bar code registration. In order to provide accuracy, rapidity, simplicity, universality, and reliability to the accounting process standard, a recommended machine-readable method is the use of bar codes for registering and tracking TLIs. A human-readable number should also accompany each bar code for in-field confirmation. Bar codes can be applied as permanent or attached markers. There are some acceptable variants of bar codes such as the block-form varicode.

To better understand the role that bar-coded tags could assist in reducing the cost of verification, consider the use of the UPC (universal product [bar] code) in grocery stores: its role in reducing labor costs of checkout, reducing losses and disputes due to checkout error, expediting restocking, and providing an accurate inventory for audits. The bottom line is reducing the cost of operation and therefore increased profits.

Survivable tags. For any type of tag, locations must be chosen where operational and environmental damage risk is minimized and protection of the tag must be provided. Threaded bolts or riveted plates could be used where operational damage is possible. A mechanically attached bar code plate can act as a protective cover.

Selective authentication. The tamper-revealing aspects of tags could be authenticated during short-notice inspection by a process of selective sampling derived from statistical considerations. High confidence can be achieved by authenticating only a small fraction of the total number of tags (while reading all the bar codes). The bar code reading is much more rapid than the authentication process.

Unwitnessed application. Application of tags without an inspector being present is a tag concept feature that would allow significant reductions in cost for CFE. Some tags can be installed by and at the military unit level without inspectors present at the time. Authentication data would be sent to the central CFE organization where they would be kept on file and compared eventually with short-notice inspection results. For the CWC, it would be helpful to have either unwitnessed applications or removal of seals. For nuclear weapons and delivery systems, all tagging operations are likely to be closely watched.

Universal tagging. A tag concept that is durable and inexpensive enough to allow all TLIs to be uniquely identified is most desirable.

GENERAL FEATURES OF SURFACE, SUBSURFACE, AND ATTACHED TAGS

Proposed tags can be considered to be of two types: attached tags and intrinsic tags (see Table). Attached tags are devices which are manufactured elsewhere and attached to the equipment in the field. Intrinsic tags use some feature of the TLI itself as the unique marker. Attached tags range from very sophisticated electronic devices to simple epoxy paint with mica flakes suspended in it.

Intrinsic tags make use of unique features that belong to a treaty-limited item (TLI). Tagging a component that is part of or is the TLI is makes it difficult to circumvent the treaty.

Attached tags require some means of bonding a tag onto the surface of a TLI. Both the bond and the attached tag must each provide tamper-revealing features.

Two types of features can be considered intrinsic: those that are as-manufactured and those that are added. The as-manufactured features include metallic grains, precipitates, inclusions, oxides, voids, fibers, machining marks, and abrasions. Features deliberately added for enhancement of tagging include mechanical and etched markings, as well as particles and ions implanted within the surface.

An intrinsic tag may make use of surface roughness or subsurface features for its uniqueness. One of the advantages in principle of subsurface features is that they are protected by the surface from the external operational environment.

No matter what type of tag is used, there are four common practical installation imperatives: location, preparation, stabilization, and protection. The designated location for application -- exposed or sheltered from operational and environmental conditions -- will depend on the type of TLI, the sensitivity of its design, and the availability of suitable surfaces.

Location. It is first necessary to designate and find the location on the TLI where the tag is to be installed. The designation might be embodied in a treaty MOU, based on the particular type and version of the TLI. One or more major components of the TLI might be subject to tagging, such as the turret, the tub, or the main gun a tank. Depending on these choices, the locations might be in exposed or sheltered locations. Once designated, the particular coordinates of the location must be found by those who are to install and read the tag.

Preparation. The surface at the location to be tagged will undoubtedly need some preparation, regardless of whether it is an attached or intrinsic tag. Intrinsic tags need reproducible surface conditions, and attached tags need surfaces to which they can adhere for many years. Moisture, grease, paint, and rust will have to be removed to reach bare metal (or other surface that does not deteriorate). Most likely a portable electric sanding drill will be needed, along with a wirebrush, sandpaper, and cleaning solvent.

Stabilization. Once a surface has been cleaned, it will be necessary to ensure that it does not revert to an unstable base. Attached tags would lose their adherence, and intrinsic tags would lose some of their signature capability. Stability can probably be obtained by preventing air and moisture from reaching the surface. Attached tags could do this with their adhesive, and intrinsic tags by covering the surface with a protective coating or cover.

Protection. At almost any location, whether exposed or sheltered, tags will require protection against operational conditions and abuse. At exposed locations, they will also need protection against the environment. If an attached tag is sufficiently self-protected against damage, it might not need additional protection; however, a tag that protrudes excessively from the surface is vulnerable to detachment by shear forces. An intrinsic tag will require some protective cover, which could be a thin polyvinyl or metal barcode adhesively and/or mechanically attached. Bare metal surrounding the

tag in excess of the tag area would probably be primed and painted again to the edges of the tag.

Intrinsic Surface-Roughness Tags for CFE

The intrinsic-surface tag has been evaluated for two types of application that involve the direct and indirect use of the scanning electron microscope. The direct approach involves bringing to the TLI a portable SEM, using it to make measurements of topology and morphology of the surface. Combining three-dimensional topographical with x-ray analysis of the surface composition provides highly detailed and unique characterization.

The indirect approach makes use only of the three-dimensional topography by examining a plastic-casting fingerprint taken of the surface. In this case the SEM could be a fieldable system brought to a site where all fingerprints are examined during the course of an on-site inspection, or it could be kept at the laboratories of each verification organization where the fingerprints are compared upon return of the inspection teams.

The concept of using surface-roughness features as a tag has been strongly urged in Europe. Based on extensive experience in on-site inspection and analysis of ways of improving OSI value to treaty verification, the Western European Union Agency for Control of Armaments has concluded that intrinsic surface features (roughness and grain structure) may be particularly useful for tagging CFE TLE. They consider intrinsic surfaces to be "practically invulnerable to evasion measures" and suggested urgent attention to such "viable" tagging.

SEAL TECHNOLOGY

Seals for arms control verification are likely to be based on the experience derived from domestic and international safeguards. However, the weapon treaties might need seals to be developed to meet more stringent goals. A CW Convention might require considerably more seals than utilized for the NPT. Thus, it would difficult in the field to have lengthy verification procedures or to carry an overly large data base. Some compromise in the steps that constitute field verification of integrity and identity might be required, with additional authentication to be carried out at headquarters.

For high-value weapons of mass destruction, the highest degree of seal authentication would be needed. Seals might be placed on nuclear weapons to be shipped for verified dismantlement. Considerable time might lapse between the placement of the seal on a shipping container and its witnessed opening at a dismantlement facility after transport. Such arms control seals are likely to be attached in addition to owner custody requirements.

A bolt-seal has been thoroughly proven after joint development centered at the Ispra Euratom Laboratory. The unique part of the seal consists of a metal stub that retains its integrity unless broken and that provides an ultrasonic signature of defects randomly introduced. It is used to seal batches of nuclear-reactor fuel bundles.

A nuclear-weapons seal should be designed to assure the verifying party that during transit to the portal the container could not be opened without revealing that the seal had been decoupled. Such a seal might have a standard of verification quality that exceeds that which is normally associated with domestic or international safeguards (Type E seals) for two reasons. First, the resources for defeating the seal available to a national party generally exceed those that are available to adversaries usually considered in design of a domestic safeguards seal. Second, weapons of mass destruction require a much higher level of assurance than normally associated within international safeguards on fissile materials.

Seals that might be improved to meet the more stringent arms-control verification standards include two particular types: fiber-optic seals (VACOSS and COBRA) that have light-transmitting cables which can be wrapped around a container and brittle-ceramic seals that have ultrasound-conducting cables which can be interrogated by acoustic methods. The fiber-optic seals have been developed by Sandia National Laboratory and the Euratom Joint Research Center; the ceramic ultrasonic seal is under development at Argonne National Laboratory.

ON-GOING PROGRAMS

Programs for development of tag/seal technology are largely focussed at national laboratories in the United States and at the Joint Research Center at Ispra. The U.S. Department of Energy has funded most of the tag/seal development reported in this paper, much of the original work being conducted by Sandia National Laboratory under nuclear safeguards programs. The Defense Nuclear Agency is now undertaking test and evaluation of developed devices on behalf of the Department of Defense.

Under joint programs with Euratom and with other national organizations, the Ispra center has developed several seal concepts.

Dornier Aerospace in Germany has carried out an extensive analysis of tag applications and has applied for a patent on an electronic tag.

BENEFITS OF TAGGING AND SEALING

The benefits of tags and seals depend on the particular treaty. Seals are very important to the NPT, and will probably be equally important in a CWC and in a warhead dismantlement treaty. Seals might also have some limited use in START and CFE.

Tags are seriously considered for mobile missiles in START and have high potential for a warhead dismantlement treaty. The particular benefits of tags to CFE are listed below:

<u>All treaty-limited items can be accurately and inexpensively counted</u>

Accurate counting of all TLIs is important for compliance confidence and for avoiding uncertainties in the otherwise complex treaty bookkeeping. Because of the low cost of bar-code scanning systems, the overall cost of verification

will be reduced when compared to other means of accounting. Security is enhanced by ensuring that large deployments or activities could not be masked by the "noise" level of less accurate means of accounting. Some tags are so inexpensive that they do not serve as a fiscal barrier to effective verification.

No portal-perimeter monitoring is required

Portal-perimeter monitoring could be used for storage and production facilities in CFE, but with universal tagging of treaty-limited equipment, it would not be necessary. It would be incumbent on equipment custodians to attach tags on appropriate items of equipment before distribution from a production facility and to ensure that tags remain on equipment that is in storage. Short-notice inspections of deployed and stored items would be sufficient to check on inventory restrictions.

No inspection of production facilities would be needed. Tagging could reduce intrusiveness and save substantial costs because of the high cost of equipment and personnel for PPM. Although storage sites might be monitored, perhaps only minimal alarm systems need be installed. It is much less expensive to have an occasional inspection team drop by than to maintain a continuous presence. NTM can also keep a continuous eye on declared storage sites.

Zonal limitations can be easily and concurrently enforced

Computer-based data systems will be able to track deployment restrictions much more accurately and promptly when the entire population of TLI are subject to systematic statistical sampling. An inspector in the field only sees a small portion of holdings at any one time; NTM sees a broad picture with difficulty in ascribing specific items to particular locations. A computer-based registration system, which can have either real-time or post-inspection data processing, can check findings against the treaty numerical and locational restrictions and holdings for the entire distribution of forces if given accurate and periodic samples.

Movement of items can be inferred

If all TLIs are tagged, movements of TLI can be tracked to reveal possible deployment trends, irrespective of treaty limitations. Certain movements are legitimate within zones; other movements might be related to declared exercises; all of these activities are relevant to intelligence assessments.

Modernization can be noted

In concert with visual inspection, the pace of replacement or modernization can be followed if all items are required to have registrations once released from the production site. With 100% registration, some ambiguities regarding qualitative features can be avoided. In fact, increases in combat value can be more explicitly tracked if certain specific items are also tagged, such as tank turrets and gun breeches.

Operational aircraft can be counted

All aircraft must return to base at some time where they could be checked for proper tags just like all other TLE. Although this does not deal with the high instant mobility of airframes, their tag information coupled with registration of other forces will indicate patterns. It would be possible for short-notice inspections to occur in Europe within a few hours of declared intent, in fact in even less time by attached or roving inspectors.

No continuous presence at elimination facilities required

With universal tagging, it is not necessary to witness the destruction of weapons. When TLIs are destroyed, the treaty verification organization will be informed. Tags found during on-site inspection verification corresponding to items declared destroyed would constitute a discrepancy. Whether presence at elimination facilities will be required to verify actual destruction (in contrast to withdrawal from the ATTU) will be based on the actual treaty adopted. Short-notice inspections can be utilized to inspect marshalling yards at elimination facilities. In contrast to INF, the observation of CFE destruction is likely to be a continuous, uninformative, and boring process.

THE UTILITY OF TAGGING

The preceeding considerations indicate that the cost of tagging in arms control should not be considered in isolation -- but in conjunction with the utility tagging provides to the total verification system, thereby strengthening the effectiveness and reducing the cost of overall verification. Partial verification (not tagging some TLE) in order to save costs is based on mistaken impressions: cost savings incurred by tagging a smaller fraction of the TLE are trivial compared to the broader consideration of verification confidence for a given cost increment. On the contrary, the more comprehensive the tagging (at least for self-applied intrinsic tags), the higher the cost-effectiveness of tagging.

Usually the role of tagging is to enhance treaty verification effectiveness, especially for high valued weapons. For CFE cost is a high priority; in fact, the goal for tags and seals should be to help reduce the cost of verification, rather than add to the cost. Inasmuch as inspectors will have a limited time available at a site and will have a limited quota of inspections, tags and seals could:

1) help expedite inspection and reduce costly and misleading human error in the collected data;

2) let inspectors make better use of human faculties to observe qualitative features, such as equipment modernization, maintenance practices, and state of repair;

3) reduce the cost of the most expensive form of on-site verification, which would be continuous monitoring at storage, demilitarization, or production facilities -- by supplementing or obviating the need for sensors or humans on full-time duty.

PHYSICAL PRINCIPLES FOR INTRINSIC TAGGING (I)+

PHYSICAL PRINCIPLE	VERIFICATION CHARACTERISTICS				AUTHENTICATION		
	OPERATING MODE		APPLICATION SCOPE		LOCATION		
	ACTIVE	PASSIVE	UNIQUE	NON-UNIQUE	CONTACT	STANDOFF	DISTANT
ELECTRON MICROSCOPY		X	X		X		
PLASTIC CASTINGS		X	X				X
HOLOGRAPHAPHY		X	X			X	
OPTICAL MICROSCOPY		X	X			X	
ACOUSTIC*		X	X		X		X
RADIOLOGICAL**		X	X			X	

+ BASED ON A. KNOTH, DORNIER

* SUBSURFACE SIGNATURE

** ADDED SUBSURFACE FEATURE

PHYSICAL PRINCIPLES FOR ELECTRONIC TAGGING (II)+

PHYSICAL PRINCIPLE	VERIFICATION CHARACTERISTICS				AUTHENTICATION		
	OPERATING MODE		APPLICATION SCOPE		LOCATION		
	ACTIVE	PASSIVE	UNIQUE	NON-UNIQUE	CONTACT	STANDOFF	DISTANT
ACTIVE	X		X	X	X	X	X
STANDBY	X		X	X	X	X	
LASER INTERFEROMETRY		X	X			X	
MICROWAVE		X	X			X	
RADIO FREQUENCY		X	X			X	X

+ BASED ON A. KNOTH, DORNIER

PHYSICAL PRINCIPLES FOR TAGGING WITH ATTACHED COATINGS (III)+

PHYSICAL PRINCIPLE	VERIFICATION CHARACTERISTICS				AUTHENTICATION		
	OPERATING MODE		APPLICATION SCOPE		LOCATION		
	ACTIVE	PASSIVE	UNIQUE	NON-UNIQUE	CONTACT	STANDOFF	DISTANT
REFLECTIVE		X	X		X		
GEOLOGIC		X	X		X		
FLUORESCENT		X		X	X	X	
BIOLOGIC		X	X		X	X	
LAMINATED TAPE*		X	X	X	X	X	
METAL PLATE**		X	X	X			X

+ BASED ON A. KNOTH, DORNIER

* COULD HAVE MORE THAN ONE AUTHENTICATION FEATURE

** UNDERSIDE AUTHENTICATED BY ELECTRON MICROSCOPE

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SECOND WORKSHOP ON ARMS CONTROL VERIFICATION
VIENNA, AUSTRIA, 3-5 SEPTEMBER 1990

TAGS AND SEALS FOR ARMS CONTROL VERIFICATION*

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* WORK SUPPORTED BY THE U.S. DEPARTMENT OF ENERGY, TECHNOLOGY SUPPORT PROGRAMS UNDER CONTRACT W-31-109-ENG-38

OUTLINE OF PRESENTATION

- TREATY REQUIREMENTS
- THE POTENTIAL ROLE OF TAGGING IN CFE
- PROPOSED TAG TECHNOLOGIES
- PROPOSED SEAL TECHNOLOGIES
- APPLICATION TO VERIFICATION
- BENEFITS OF TAGS AND SEALS

UNIQUE IDENTIFIERS FOR ARMS CONTROL VERIFICATION

- TAGS, SEALS, NETS
- TAMPER-REVEALING
- DUAL FUNCTIONS
  - FIELD VERIFICATION
  - AUTHENTICATION

TREATY REQUIREMENTS

- INF, UNDERGROUND NUCLEAR TESTING (NO TAGGING REQUIREMENTS)
- START: MOBILES
- CFE: LARGE POTENTIAL
- NPT, CW: SEALS
- NUCLEAR-WARHEAD DISMANTLEMENT: TAGS/SEALS

VERIFICATION REQUIREMENTS

- COMPOSITE OF OSI, OSM, NTM, OS, AS
- STRICT COMPLETE INITIAL ITEM ACCOUNTABILITY
- TIMELY VERIFICATION
- ACCURAGE AND EFFICIENT ACCOUNTABILITY
- SYNERGISTIC SUPPORT FOR NTM
- HIGH COST-EFFECTIVENESS IN VERIFICATION TECHNOLOGIES
- LIMITED REDUNDANCY THROUGH DIFFERENT APPROACHES
- STRONG RELIANCE ON HUMAN OBSERVATION
- BURDENSHARING

THE ROLE OF TAGGING IN CFE

- SUPPORT DECLARATION, BASELINE, DRAWDOWN, AND RESIDUAL PHASES
- PROVIDE MULTINATIONAL LANGUAGE-INDEPENDENT SHAREABLE DATA
- REDUCE COST AND COMPLEXITY OF VERIFICATION
- COMPLEMENT OTHER MEANS OF VERIFICATION
    - OSI
    - OSM
    - UNATTENDED MONITORING
    - NTM
- HELP MAINTAIN VIGILENCE FOR MANY DECADES
    - IRRESPECTIVE OF CHANGING FORCES AND FORCE-STRUCTURE
    - IRRESPECTIVE OF CHANGING POLITICAL ALIGNMENTS

CFE VERIFICATION CHALLENGES

- COUNT TLE
  - LARGE NUMBER (100,000 CFE-I RESIDUALS EACH SIDE)
  - RELATIVELY SMALL
  - MOBILE AND TRANSPORTABLE
  - INDISTINGUISHABLE GROUPS
  - RUGGED ALL-TERRAIN
- COUNT ACCURATELY
  - FOR EFFECTIVE VERIFICATION
  - TO AVOID COMPLIANCE DISPUTES
- ACCOUNT FOR
  - DEPLOYED EQUIPMENT
  - CEILINGS AND SUB-CEILINGS
  - REGIONS AND SUB-REGIONS
  - STORAGE, PRODUCTION, WITHDRAWAL, ELIMINATION
  - NATIONAL, FOREIGN, AND ALLIANCE HOLDINGS
  - MOBILIZATION CAPABILITY
  - MODERNIZATION

VERIFICATION QUALITY

- DEPENDENCE ON TREATY
- MILITARY SIGNIFICANCE
- NATIONAL LEGAL REQUIREMENTS
- TRADEOFFS IN CONVENIENCE VS. TAMPER-RESISTANCE

SPECIFIC REQUIREMENTS

- TAMPER-REVEALING FEATURES
- LONG-TERM DURABILITY
- ENVIRONMENTAL SURVIVABILITY
- OPERATIONAL DURABILITY
- ECONOMICAL OUTLAY
- FIELD VERIFIABILITY
- SELF-APPLICATION
- ECONOMICAL OVERHEAD
- INVENTORY ASSISTANCE
- SERVICEABILITY
- FIELD TESTABLE
- NON-TRANSFERABLE
- HUMAN TOLERANCE
- OPERATIONAL IMPACT
- REPLACEABILITY
- REMOTE CAPABILITY
- UNIQUENESS
- LOCATABILITY
- TECHNOLOGY TRANSPARENCY

HIGHLIGHTED TAGGING FEATURES FOR CFE

- BAR CODE REGISTRATION
- DURABILITY
- SELECTIVE AUTHENTICATION
- UNWITNESSED APPLICATION
- UNIVERSAL TAGGING CAPABILITY
- BURDENSHARING
- SIMPLE USEAGE IN THE FIELD

TAGGING CONCEPTS

(PUT 3 TABLES HERE)

GENERAL FEATURES OF SURFACE, SUBSURFACE, AND ATTACHED TAGS

- LOCATION
- PREPARATION
- STABILIZATION
- PROTECTION

PROPOSED TAGGING TECHNOLOGIES FOR CFE

- LAMINATED TAPE
- INTRINSIC-SURFACE-ROUGHNESS FINGERPRINT
- DEEP-SURFACE MARKINGS
- WELD MACROPHOTOGRAPHY
- ELECTONIC IDENTIFICATION DEVICES

LIMITATIONS ON TAGGING TECHNIQUES

- CURRENT AVAILABILITY
- STATE OF DEVELOPMENT
- TIMELY PHASING
- FIELD TESTING EXPERIENCE
- PERCEPTIONS

VERIFICATION PROTOCOLS TO ASSIST IMPLEMENTATION OF TAGS

- TREATY PHASES
- PROOF OF ELIMINATION/DESTRUCTION
- VISUAL OBSERVATIONS DURING OSI/OSM
- FIELD VERIFICATION OF BAR CODE
- TAG AUTHENTICATION AT VERIFICATION ORGANIZATIONS
- DATA BASE
- DISCREPANCY RESOLUTION

PROPOSED SEAL TECHNOLOGY

- ROLE OF SEALS FOR VARIOUS TREATIES
- CUP SEALS
- BOLT-SEALS FOR NPT
- FIBER-OPTIC SEALS
- BRITTLE-CERAMIC SEALS
- IDENTITY AND INTEGRITY REQUIRMENTS
- FIELD AUTHENTICATION

ON-GOING PROGRAMS

- U.S. DOE OAC/OSS
- U.S. DOD DNA
- U.S. NATIONAL LABORATORIES
- WEU ACA
- JRC/ISPRA
- DORNIER AEROSPACE
- U.S.S.R.
- OTHER NATIONAL AND COMMERICAL

BENFITS OF TAGGING AND SEALING

- ALL TREATY-LIMITED ITEMS CAN BE ACCURATELY AND INEXPENSIVELY COUNTED
- PORTAL-PERIMETER REQUIREMENTS ARE REDUCED
- COMPLEX TREATY LIMITATIONS CAN BE EASILY AND CONCURRENTLY ENFORCED
- MOVEMENT OF ITEMS CAN BE INFERRED
- MODERNIZATION CAN BE NOTED
- NATIONAL AND MULTINATIONAL INTELLIGENCE COLLECTION IS SUPPORTED
- OPERATIONAL AIRCRAFT CAN BE COUNTED
- CONTINUOUS PRESENCE AT ELIMINATION FACILITIES IS MINIMIZED
- 100% VERIFICATION DURING BASELINE PERIOD IS NOT ESSENTIAL
- OVERALL COST OF VERIFICATION IS REDUCED
- ACCURACY AND EFFECTIVENESS OF VERIFICATION ARE ENHANCED

TAGGING CONCEPTS (I)

TAG TYPE	TAG						READER	
	SURFACE FEATURE		OPERATING MODE		APPLICATION SCOPE		LOCATION	
(SURFACE)	INTRINSIC	ATTACHED	ACTIVE	PASSIVE	UNIQUE	NON-UNIQUE	LOCAL	REMOTE
ELECTRON MICROSCOPY	✓			✓	✓		✓	
CASTINGS	✓			✓	✓			✓
HOLOGRAPHIC	✓			✓	✓			✓
OPTICAL MICROSCOPY	✓			✓	✓		✓	
ULTRASONIC	✓			✓	✓		✓	
LAMINATED TAPE		✓		✓	✓	✓	✓	

TAGGING CONCEPTS (II)

TAG TYPE	TAG						READER	
	SURFACE FEATURE		OPERATING MODE		APPLICATION SCOPE		LOCATION	
(ELECTRONIC)	INTRINSIC	ATTACHED	ACTIVE	PASSIVE	UNIQUE	NON-UNIQUE	LOCAL	REMOTE
ACTIVE		✓	✓		✓	✓		✓
STANDBY		✓	✓		✓	✓		✓
LASER		✓		✓	✓			✓
INTERFEROMETRY								
MICROWAVE		✓		✓	✓			✓
RADIO FREQUENCY		✓		✓	✓			✓

TAGGING CONCEPTS (III)

TAG TYPE	TAG						READER	
	SURFACE FEATURE		OPERATING MODE		APPLICATION SCOPE		LOCATION	
(PAINTS)	INTRINSIC	ATTACHED	ACTIVE	PASSIVE	UNIQUE	NON-UNIQUE	LOCAL	REMOTE
REFLECTIVE		✓		✓	✓		✓	
GEOLOGIC		✓		✓	✓		✓	
FLUORESCENT		✓		✓		✓	✓	
BIOLOGIC		✓		✓	✓		✓	

END

DATE FILMED

12/27/90