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]

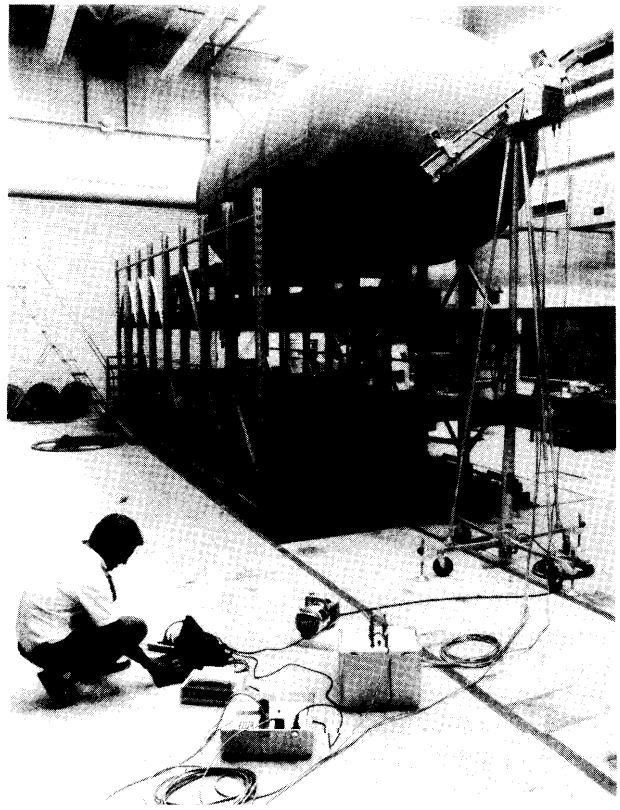


Photo credit: Los Alamos National Laboratory

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 farsighted 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

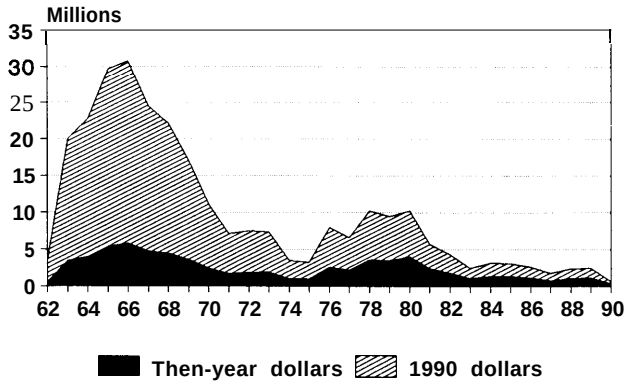
In March 1989, the ACDA Inspector General issued a report declaring that

> 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 l—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.

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,

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.

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.

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[1] Sometimes the targeted party wants to reveal accurate information, and may help the intelligence collectors of the other side get it. Thus, in past arms control agreements, the United States and the Soviet Union have agreed to forms of non-interference with NTM, 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.

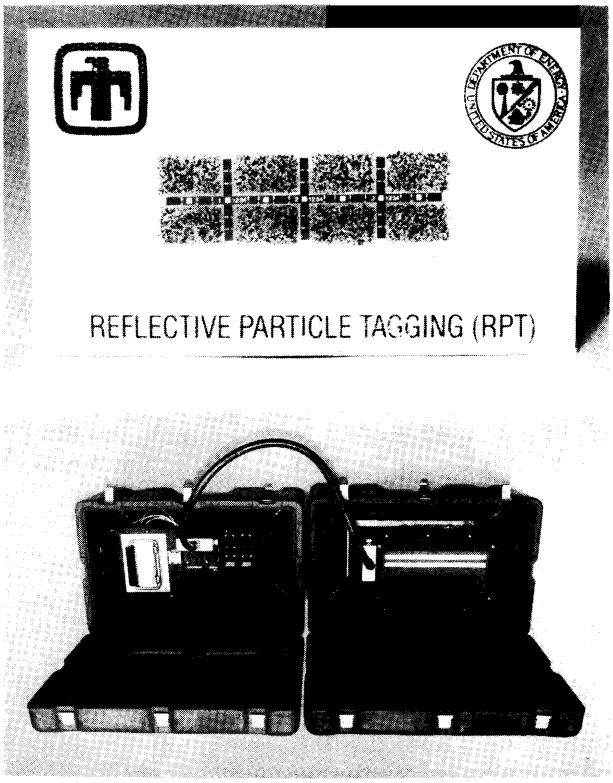

Photo credit: Sandia National Laboratories

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