Constraining Proliferation: The Contribution of Verification Synergies

by
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prepared for
The Non-Proliferation, Arms Control and Disarmament Division
Department of External Affairs, Ottawa, Canada

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The background graphic on the front cover represents the ongoing dialogue on arms control and disarmament issues in Canada and between Canadians and the world community.

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List of Abreviations

ABM	Antiballistic Missile
ADI	Air Defence Initiative
ALCM	Air-launched Cruise Missile
ALPS	Accidental Launch Protection System
ASAT	Anti-satellite
ATBM	Anti-tactical Ballistic Missile
ATTU	Atlantic-to-the-Urals (Zone)
BCC	Bilateral Consultative Commission (Threshold Test Ban Treaty)
BMD	Ballistic Missile Defence
BW	Biological Weapon/Warfare
BTWC	Biological and Toxin Weapons Convention
CBM	Confidence-building Measure
CCE	Consultative Committee of Experts (ENMOD Convention)
CD	Conference on Disarmament
CDE	Conference on Disarmament in Europe
CFE	Conventional Forces Europe
CFE 1A	Conventional Forces Europe Follow-on Agreement
CoCom	Co-ordinating Committee for Multilateral Export Controls
COMINT	Communications Intelligence
CORRTEX	Continuous Reflectometry for Radius versus Time Experiments
CPC	Conflict Prevention Centre
CSBM	Confidence- and Security-building Measure
CSCE	Conference on Security and Co-operation in Europe
CTB	Comprehensive Test Ban
CW	Chemical Weapon/Warfare
CWC	Chemical Weapons Convention
ELINT	Electronic Intelligence
ENDC	Eighteen-nation Disarmament Committee
EOD	Externally Observable Difference
EPCI	Enhanced Proliferation Control Initiatives (U.S.)
FROD	Functionally Related Observable Difference
FSU	Former Soviet Union
GPS	Global Protection System
GPS	Global Protection System
GSE	Group of Scientific Experts
HEU	Highly -enriched Uranium
HUMINT	Human Intelligence
IAEA	International Atomic Energy Agency
ICBM	Inter-continental Ballistic Missile
INF	Intermediate Nuclear Forces
ISMA	International Satellite Monitoring Agency
ITM	International Technical Means
JCG	Joint Consultative Group (CFE Treaty)
JCIC	Joint Compliance and Inspection Commission (START Treaty)
LIDAR	Light Detection and Ranging
LTBT	Limited Test Ban Treaty
MASINT	Measurements Intelligence
MBFR	Mutual and Balanced Force Reduction

MIRV	Multiple, Independently Targeted, Re-entry Vehicle
MTCR	Missile Technology Control Regime
MTM	Multilateral Technical Means
NACC	North Atlantic Cooperation Council
NATO	North Atlantic Treaty Organization
NBC	Nuclear, Biological, Chemical
NIM	National Intelligence Means
NMD	National Missile Defence
NNWS	Non-Nuclear Weapons States
NORAD	North American Air Defence
NPT	(Nuclear) Non-Proliferation Treaty
NRRC	Nuclear Risk Reduction Centre
NTM	National Technical Means
NWS	Nuclear Weapons States
OPANAL	Organization for the Prevention of Nuclear Weapons in Latin America (Treaty of Tlatelolco)
OPCW	Organization for the Prohibition of Chemical Weapons (Chemical Weapons Convention)
OSCC	Open Skies Consultative Commission (Open Skies Treaty)
OSI	On-site Inspection
OSIA	On-site Inspection Agency
PALS	Protection Against Limited Strike
PNET	Peaceful Nuclear Explosions Treaty
PPCMS	Portal and Perimeter Continuous Monitoring System
RADINT	RADAR Intelligence
SAIC	Science Applications International Corporation

SALT	Strategic Arms Limitation Talks
SAM	Surface-to-Air Missile
SAR	Synthetic Aperture Radar
SCC	Standing Consultative Commission (ABM Treaty)
SDI	Strategic Defence Initiative
SIGINT	Signals Intelligence
SLBM	Submarine-launched Ballistic Missile
SLCM	Sea-launched Cruise Missile
SNDV	Strategic Nuclear Delivery Vehicle
SNF	Short-range Nuclear Forces
SNI	Short-notice Inspection
SPOT	Satellite pour l'observation de la terre
SSBN	Submarine, Ballistic Missile, Nuclear
SSI	Suspect-site Inspection
START	Strategic Arms Reduction Talks
SVC	Special Verification Commission (INF Treaty)
TLE	Treaty-limited Equipment
TLI	Treaty-limited Item
TMD	Theatre Missile Defence
TOSI	Technical On-site Inspection
TTBT	Threshold Test Ban Treaty
UN	United Nations
UNSCOM	United Nations Special Commission
WEU	Western European Union

Abstract

While many studies have evaluated specific verification techniques, procedures or agencies, relatively little has been written about the multiplier effects associated with verification synergies. This study argues that the combination of separate aspects of arms control verification produces a whole greater than the sum obtainable from each of the separate parts. The term "synergies" encompasses the combinative effects arising between verification methods and techniques, between agreements or regimes, between implementing mechanisms and forums, between organizations and agencies within a country, between countries party to an agreement, and various combinations of these items. The resultant synergistic effects may be simultaneous or sequential.

This paper identifies many of these effects, using specific arms control examples, where appropriate, and with special emphasis on examples relating to non-proliferation. It also provides a basis for taking these synergies into account during the process of formulating and evaluating the effectiveness of the verification regimes of particular agreements and actions. The paper considers three forms of verification: co-operative, adversarial and coercive, as exemplified by the Conventional Forces in Europe (CFE) Treaty, the Chemical Weapons Convention (CWC), and the UNSCOM inspections in Iraq following the War in the Gulf, respectively.

Appendices A and B take a second approach, addressing the subject from a different perspective, using a high level of abstraction. Deriving a formal model of some aspects of verification synergies, a mathematical analysis is presented in Appendix A to demonstrate several underlying dynamics of the topic.

Résumé

De nombreux auteurs ont évalué des techniques, procédures ou organismes particuliers de vérification, mais très peu ont écrit sur les effets multiplicateurs de la synergie des divers aspects de la vérification. Dans le présent document, nous soutenons qu'ensemble, les volets de la vérification de la limitation des armements ont un effet plus grand que chacun d'eux pris séparément. Le mot «synergie» évoque l'effet issu d'une combinaison quelconque des éléments suivants : méthodes et techniques de vérification, accords ou régimes, mécanismes de mise en œuvre et tribunes de négociation, divers organismes d'un pays donné, et pays parties à une entente. Les effets synergiques peuvent être simultanés ou séquentiels.

Dans le présent document, nous cernons bon nombre de ces effets en employant des exemples particuliers afférents à la limitation des armements et en insistant surtout sur la non-prolifération. Nous formulons aussi des principes de base pour prendre en compte ces synergies pendant l'établissement et l'évaluation des régimes de vérification découlant d'une entente ou d'une mesure donnée. Nous nous arrêtons à trois types de vérification : coopérative, antagonique, et coercitive. Et nous évoquons trois exemples à cet égard, à savoir, respectivement, le Traité sur les forces conventionnelles en Europe (FCE), la Convention sur les armes chimiques (CAC), et les inspections de la CSNU en Iraq après la guerre du Golfe.

Nous présentons, dans les annexes A et B, une autre démarche dans laquelle nous adoptons une toute autre perspective à un niveau très abstrait. À partir d'un modèle formel de certains aspects des synergies de la vérification, nous menons une analyse mathématique dans l'annexe A pour illustrer plusieurs des paramètres dynamiques sous-jacents du sujet.

Acknowledgments

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Disclaimer

The opinions expressed in this paper represent the personal views of the four authors, and should not be attributed to government agencies of Canada or the U.S., or to Science Applications International Corporation.

The authors have had to work at separate locations and, although the study team has read and discussed all of the sections, the contents of each section are the responsibility of the author or authors, as indicated.

Preface

In the aftermath of the end of the Cold War, it is clear that multilateral arms control, unilateral declarations and actions, and arms control by mutual example will be the predominant approaches in future arms control efforts, most notably with regard to constraining weapons proliferation. In this emerging context, the synergistic effects amongst methods of verification will become increasingly important in assuring cost-effective verification, as budgets and resources come under increasing restraint.

Discussions and research relating to verification have often focused on the evaluation and enhancement of specific verification techniques, procedures or agencies. There has been little written about the synergistic effects amongst various methods of verification — that is, the ways in which the operations and data from several sources can combine to produce a final result that goes beyond what could be achieved by each of the separate inputs alone.

Four distinguished scholars — two American and two Canadian — were invited to come together to explore these synergistic effects and to identify how they could be harmonized to enhance verification effectiveness, particularly in the context of curbs on proliferation. This report provides their comprehensive and ground-breaking overview of this subject.

Readers will note that two general analytical approaches are evident in the report. The first, which constitutes the main thrust of the report, examines the subject from a policy perspective, reviewing synergies as they appear in past arms control agreements, describing a variety of synergistic effects amongst methods of verification, and suggesting how these effects impact on the nature and scope of efforts to control proliferation. The second approach, represented by Appendices A and B, addresses the subject from a different perspective, using a high level of abstraction. Deriving a formal model of some aspects of verification synergies, a mathematical analysis is conducted in Appendix A to demonstrate several underlying dynamics of the topic.

This report follows an earlier one representing the results of a study by a combined team of American and Canadian scholars.* Like the former, it constitutes an important example of co-operative research in this important area of verification. It is being made available to researchers and specialists in the field in fulfilment of one of the objectives of Canada's Verification Research Program, which is to contribute to improved understanding of questions relating to verification in all its aspects.

* Sidney Graybeal, George Lindsey, James Macintosh and Patricia McFate, Verification to the Year 2000, Arms Control Verification Studies No. 4, Ottawa: External Affairs and International Trade Canada, 1991).

I Purpose and Scope of the Study

Patricia Bliss McFate

The end of the Cold War has signalled a new era in arms control. East-West confrontation is over, cooperation has begun, and the questions remaining center around how quickly steps can be taken to reverse the nuclear buildup, how to assure that excess nuclear weapons and materials do not find their way into rogue nations, how to eliminate a large stockpile of chemical weapons, and how to prevent the spread of conventional weapons to unstable regions of the world. While these are not small questions, the cooperative pursuit of solutions will make a significant contribution to the international efforts to constrain proliferation.

The end of the Gulf War presages a less fortunate future. It signals a period in which weapons of mass destruction and their advanced delivery systems are being developed indigenously or acquired by emerging weapons states in the Third World, stores of conventional weapons are being built up beyond the legitimate requirements of national defense, local disputes are spilling over into regional conflicts, and regional conflicts are threatening global stability and security. Constraining the proliferation of these **weapons of mass impact**, reducing regional confrontations, and encouraging reductions in military force levels will be major tasks ahead for Canada, the United States, and other members of the United Nations.

Future multilateral arms control agreements, export controls exercised by supplier groups and regimes such as the Missile Technology Control Regime, reciprocal actions, and unilateral initiatives will play major roles in the many efforts which will be required in order to reduce, cut, control, and deal with the consequences of a rapid increase in weaponry: **the proliferation of nuclear, chemical, biological and advanced conventional weapons and advanced delivery systems such as ballistic missiles, cruise missiles and modern aircraft.** Each of these approaches will require means for assuring compliance by all parties.

While many studies have evaluated specific verification methods, such as on-site inspection, little has been written about **the multiplier effects associated with verification synergies.** This study argues that the combination of separate aspects of arms control verification produces an effect greater than that of the components taken separately, or to put in the most simple terms, the sum of verification is greater than its parts. The term, "synergies," as used in this paper encompasses the combinative effects between verification methods and techniques, between agreements or regimes, between implementing mechanisms and forums, between organizations and agencies within a country, between countries party to an agreement, and various combinations of these items. The resultant synergistic effects may be simultaneous or sequential.

This paper identifies many of these effects, using specific arms control examples where appropriate. It also provides a basis for taking these synergies into account during the process of formulating and evaluating the effectiveness of the verification regimes of particular agreements and actions. The paper considers three forms of verification: cooperative, adversarial, and coercive, as exemplified respectively by the Conventional Forces in Europe (CFE) Treaty, the Chemical Weapons Convention (CWC), and the UNSCOM inspections in Iraq following the War in the Gulf.

Underlying this paper are the following premises. Arms control, in a variety of forms, will remain a fundamental approach to international security. Verification or some form of explicit and agreed-upon "confirmation" will be required for regimes and approaches aimed at constraining the proliferation of weapons of mass destruction and their advanced delivery systems. Finally, the need to constrain proliferation and to control and resolve regional conflicts will necessitate more adversarial verification regimes and coercive regimes, such as mandatory inspections and embargoes encompassed in resolutions of the United Nations Security Council.

II Key Findings

Patricia Bliss McFate

The context of a changing world in the period 1992-2002 will affect future arms control agreements and their verification regimes.

- Arms control, in a variety of forms — multilateral, bilateral, unilateral, global, regional — will remain a fundamental approach to international security. However, the context in which future multilateral arms control will have to operate will be a disorderly, unstable world with little wars and emerging proliferators.
- The War in the Persian Gulf was reflective of the regional instabilities associated with the proliferation of weapons of mass destruction and their advanced delivery systems and conventional weapons over and above the needs of legitimate defense.
- UNSCOM inspections in Iraq have served to underline that in the future, some countries will be prepared to cheat on their obligations associated with non-proliferation.
- The list of countries developing or acquiring chemical and/or biological weapons for future use will increase despite the Chemical Weapons Convention (CWC) and the Biological and Toxin Weapons Convention (BTWC). The countries developing nuclear weapons for the first time will be a small number of pariah states. Ballistic missiles will proliferate, as will advanced conventional weapons, for reasons of regional instabilities in the Third World as well as economic motives on the part of the suppliers.

Concerns over proliferation of weapons of mass destruction and their advanced delivery systems and sophisticated conventional weapons will change both conceptual and programmatic aspects of verification.

- While verification regimes among developed, democratic nations will continue to be based on the assumption of an increasing degree of cooperation, verification regimes involving emerging weapons states may require adversarial or coercive verification.
- A verification regime dependent upon a high degree of cooperation could be dangerously vulnerable if international relations deteriorate.
- Monitoring arms control agreements will continue to be primarily a function of intelligence collection and analysis, utilizing national technical means, international technical means, multilateral technical means (NTM/ITM/MTM) and/or national intelligence means (NIM). NIM is defined as the sum of a country's intelligence collection and analysis capabilities.
- NIM, which includes HUMINT, collection by human sources and the analysis of open-source information such as media or commercial satellite photography, will be of increasing importance in this period of proliferation.
- Monitoring systems will be complemented by more cooperative measures.
- Verification based on OSI of **declared** facilities may make cheating considerably more difficult, but it does little to deter the use of covert facilities and activities for the development of weapons.
- Ineffectual verification regimes may produce a false sense of confidence which could be worse than no verification regime whatsoever, for example, a verification regime for the Biological and Toxin Weapons Convention (BTWC).
- Challenge or suspect site inspections may not detect a violation, but their existence can trigger a synergistic effect when combined with other collection methods. Furthermore, refusal of an inspection will reinforce suspicions of illegal activities which can focus other collection resources on that facility.
- In a cooperative environment such as the present relationship between the United States and Russia, elimination of short-range theater nuclear weapons might be accompanied by CBMs such as invitational inspec-

tions of facilities and data exchanges on production, deployment, and storage of such weapon systems.

- Future multilateral verification regimes will not resolve the classic arms control verification dilemma: how can a party have as much access to the other side's facilities as can be negotiated, while not compromising its own sensitive or proprietary facilities.

Synergies among verification methods, regimes, agencies, countries, regional groups, implementation bodies, and in the UN have not been sufficiently recognized and exploited.

Table 1 is based on the following findings.

- Data exchanges present highly useful information for enhancing monitoring capabilities, and information from NTM/ITM/MTM/NIM can be used to check some of these data.
- NTM/ITM/MTM have only a modest effect on notifications, but notifications have a substantial effect on monitoring capabilities.
- The synergistic effects between NTM/ITM/MTM and on-site inspections (OSIs) are high in both directions, resulting in enhanced verification and confidence in compliance with the agreement.
- Information from NTM/ITM/MTM can be of value in targeting aerial surveillance flights, and aerial surveillance flights can fill in gaps in NTM/ITM/MTM coverage.
- Confidence-Building Measures (CBMs) hold potential for synergistic effects with NTM/ITM/MTM/NIM.
- There are synergies among cooperative measures which should be recognized and taken into account.

Table 1:
Synergies Among Verification Methods

	NTM/ ITM/MTM	NIM	Data Exchange	Notifi-cations	OSIs	Aerial Inspections	Open Skies	CBMs
NTM/ITM/MTM	—	M	L	L	H	M	M	L
NIM	M	—	L	L	H	M	M	L
Data Exchange	H	H	—	L	H	M	L	L
Notifications	H	M	L	—	H	H	H	M
OSIs	H	H	H	M	—	H	M	M
Aerial Inspections	M	M	L	L	H	—	M	L
Open Skies	M	M	L	L	M	M	—	M
CBMs	L	M	L	L	L	L	M	—

Helps or Impacts Items Listed Vertically

Helps or Impacts Items Listed Horizontally

H = High Value Synergies
M = Medium Value Synergies
L = Low Value Synergies

- NIM can provide information for evaluating data exchanges and notifications; in turn, these methods of verification produce information which can serve as a check on the reliability of the sources for NIM.
- The synergistic effects between NIM and OSIs are very high; indeed, information from NIM can be used to trigger OSIs.
- NIM can provide clues about activities warranting closer examination by aerial inspection; aerial surveillance flights can detect suspect activities which can become the focus of NIM.
- NIM can also provide information which can be checked against the measures included under CBMs.

4 **Constraining proliferation requires analysis of the benefits associated with verification synergies.**

- Evaluation of the effectiveness of an arms control verification regime should take into account its verification measures individually and the verification synergies between measures and methods within the regime.
- Bilateral (United States-Former Soviet Union) verification has demonstrated the importance of national technical means (NTM); this argues for more sharing of data from NTM and the development of international technical means (ITM) or multilateral technical means (MTM).
- More cost-effective, simple, "low" verification technologies are needed, for example, development of movement detectors and sensors based on weapons signatures.
- The synergies among aerial surveillance, NTM/ITM/MTM/NIM, and cooperative measures should be exploited.
- A local or regional verification regime involving data exchange and OSIs would have synergies with the countries' NIM and with the NTM/ITM/MTM of other interested countries.
- Potential synergistic effects between arms control implementing bodies should be recognized and utilized; closer cooperation and exchanges of data should be instituted.
- The beneficial synergies from the activities of UNSCOM and IAEA should be considered in future situations requiring compliance with non-proliferation agreements.
- UNSCOM inspections have demonstrated the synergies associated with observations from satellites, aircraft, helicopters, and OSIs.
- In general, the multiplier effects associated with verification synergies need to be identified, analyzed, and taken into account in negotiating non-proliferation and other arms control agreements.
- Cooperation among participating countries in scheduling inspections and in combining the results of monitoring activities produces verification synergies.
- Verification of personnel limitations could be achieved by taking advantage of the verification synergies received when data on the complements of personnel associated with various items of equipment in standard units are combined with judgments formed during OSIs as to whether actual personnel strength matches the same standard.
- The flow of information associated with many arms control activities and verification methods gets impeded when it is compartmented into separate national and bureaucratic agencies. A central multinational agency could collect and analyze data obtained through verification of multilateral arms control agreements. While it might be subject to the dangers of bureaucratic resistance, conflict, and obstruction, such an agency could exploit opportunities for achieving verification synergies.
- With an increased focus on multilateral verification, countries will need to develop cost-benefit analyses in order to evaluate the verification regimes of multilateral

agreements developed to constrain proliferation. Analysis of costs should include resource costs as well as potential losses of sensitive and/or proprietary information; benefits should include assurance of compliance as well as confidence building through increased transparency. Determination of non-compliance will continue to remain a national prerogative; however, the call for international sanctions in the UN and other bodies may require the willingness to share reliable data on which non-compliance judgments were made.

Constraining proliferation is an international concern which needs "new thinking" and new initiatives.

- The role of the UN Security Council needs to be strengthened in order to constrain proliferation and resolve regional conflicts. More actions such as passing resolutions ordering mandatory inspections and embargoes will be required of the Security Council.
- Non-proliferation agreements should be viewed as major efforts to improve international security by setting norms of behavior.
- Non-proliferation strategy needs to address the "demand" as well as the "supply" side of the proliferation problem.
- Non-proliferation treaties must provide for challenge inspections of suspected activities on a timely basis, while meeting concerns about frivolous challenges, security risks, and economic espionage.
- The restrictive managed access approach negotiated for the CWC verification regime sets a precedent for more mandatory access which should be used to strengthen other non-proliferation agreements.
- The Missile Technology Control Regime (MTCR) should be re-negotiated as an arms control agreement with a verification regime which would strengthen its effectiveness.
- CWC verification could be further strengthened by the addition of aerial monitoring using several sensor technologies and including air sampling.
- Because the BTWC verification regime does not meet the criterion of effective verification, verification synergies will be of particular importance in improving its effectiveness.
- The United Nations should establish a body for acquiring, integrating, and analyzing information from a variety of sources to assist in verifying compliance with multilateral and regional non-proliferation agreements. An international data base management system should be developed that not only collects information, but identifies those pieces of information which signal the need for additional verification activities.
- The IAEA would benefit by having its own intelligence/information assessment unit based on some form of international technical means (ITM). ITM data could provide synergies with future IAEA "suspect site" inspections at undeclared facilities.
- The charter of UNSCOM should be expanded, for example, so that it can become an international inspectorate, or a new, comparable UN body should be created for monitoring regional arms control agreements.
- The United Nations should give serious consideration to establishing a new permanent body which would perform expanded functions of the IAEA and UNSCOM for current and future agreements constraining the proliferation of weapons of mass destruction and their delivery systems.

III Introduction and Assumptions

Patricia Bliss McFate

The context in which arms control operates has changed: from bilateral issues to multilateral concerns, from fixed positions reflecting East-West alliances to fluid, ad-hoc coalitions based on shifting relationships. The United Nations — once abused as paralyzed by capricious states — is now energized by multinational mandates and an effective Security Council. Yet despite hopeful phrases such as "a new world order," the changing world remains disorderly and unstable with its little wars and emerging proliferators. Indeed, the concept of uncertainty seems to be replacing the concept of the threat.

In this world, with its regional tensions and the disturbing spread of weapons of mass destruction and their delivery systems, the next ten years will be a very uncertain period. The assumptions which follow speak to the period between 1992 and 2002 set the context in which verification synergies will be discussed. They are not necessarily listed in a priority order. They do not pretend to predict the unpredictable: no analyst would have been able to predict the date and the manner in which the Soviet Union would break up ten years before the event. Indeed, they assume that international events will continue to unfold without major "sea changes" such as that event.

Assumptions About Constraining Proliferation (1992-2002)

Weapons of Mass Destruction and Advanced Delivery Systems

1. The NPT will be extended indefinitely when it comes up for review in 1995, and its verification measures will be strengthened. The IAEA will use its authority to conduct "special inspections," i.e., suspect site inspections. The UN Security Council will consider strong sanctions against violators of the NPT and may be able to apply some pressure on the non-signatory states. With the momentum created by the inclusion of China, South Africa, and other states, and the already-agreed-upon entry of Belarus, Kazakhstan, and Ukraine as non-nuclear weapon states, the NPT will be successful in slowing nuclear proliferation, but it will be unable to stop it.

2. The Chemical Weapons Convention will enter into force, and it will be an agreement which serves the security interests of most countries. The degree to which the CWC verification regime provides effective verification will be seriously challenged; however, it will set a precedent for intrusive verification backed by UN Security Council pressures and actions.

    • Requirements to destroy CW stockpiles will stir national and international debates about cost, location of destruction facilities, and environmental standards for destruction.

    • The list of countries developing or acquiring chemical weapons for future use will increase despite the CWC; these countries will not necessarily be signatories of the CWC.

3. Similarly, some countries will develop biological weapons despite the BTWC, whether or not they are signatories of the BTWC.

    • The BTWC will remain inadequately verifiable, but additional confidence-building measures such as exchange of information and invitational inspections should increase confidence that the majority of the signatories are compliant with the convention. Verification synergies will be of particular importance in this area of arms control.

4. Many advanced countries, including the United States and Canada, will expand their programs in chemical and biological defences for troops and civilian populations in response to the proliferation of these weapons.

5. As called for in the START follow-on agreement, the United States and Russia will reduce their deployed strategic offensive

nuclear warheads and delivery systems to between 3,000 and 3,500 each. All MIRVed ICBMs will be eliminated and SLBM warheads reduced to 1700-1750. The number of warheads counted for heavy bombers will be the number of nuclear weapons they are **actually equipped** to carry.

- Further reductions are unlikely without the participation of the other declared nuclear powers.

- Follow-on START negotiations involving the five declared nuclear powers will be initiated, but the negotiations will be protracted. It will be extremely difficult to achieve agreed-upon levels of nuclear warheads and delivery systems which take into account current and future asymmetrical force levels and perceived requirements. While no formal agreements are likely to be reached in this time frame, reciprocal and unilateral actions by Russia and the United States resulting in further reductions are possible.

6. Thresholds of the TTBT and the PNET will be lowered, the quotas on nuclear tests in the United States and Russia will be reduced, and, before 2002, a global moratorium on nuclear testing will be in place. Fissionable materials will no longer be produced for weapons purposes in either country, but a surplus of such materials will be available. This surplus will lead to serious concern about possible illegal sales or diversions of weapons-grade materials. Serious negotiations on a CTB will be undertaken.

7. American-Russian consultations on a Global Protection System (GPS) will result in the establishment of a multi-national ballistic missile/space launch early warning center. Space -based interceptors will not be part of the system.

8. The ABM Treaty will be clarified, modified, and amended to permit effective theater missile defenses (TMD). TMD will be supported by space-based sensors. Even a Treaty-compliant ground-based national missile defense (NMD) for coverage of the United States may not survive defense budget cuts and political resistance.

9. Deployments of theater missile defenses (TMD) will be underway, but such deployments will not in themselves constrain proliferation of ballistic missiles. They will affect a country's possible employment of ballistic missiles.

Regional Concerns

The end of the Cold War resulted in many nations losing their status as "client states." These countries must reconsider their national security requirements, which will affect their efforts to acquire military weapons. Although the threat of a deliberate attack on any country from Russia has all but disappeared, Russia and other Republics of the former Soviet Union appear to be willing to sell advanced weapons, technology, and knowledge for economic reasons. This will further complicate efforts to constrain proliferation of weapons of mass impact and advanced delivery systems.

The post-war UNSCOM inspections of Iraq led the United States and Canada, among many other democracies, to place special efforts on those regions where the dangers of proliferation remain acute, notably, the Middle East, South-East Asia, and the Korean Peninsula. The following assumptions speak to regional concerns in the years 1992-2002.

10. Iraq will continue its clandestine programs to acquire nuclear weapons and to enhance its chemical weapons capabilities and advanced delivery systems. (Some believe that Iraq still possesses up to 200 SCUD missiles.) Permanent monitoring may be required to deter, and possibly detect, facilities dedicated to these programs. Iran will continue its small nuclear weapons program, with Chinese assistance in building a nuclear power plant. India and Pakistan will continue to pursue the nuclear option in a more

open manner, leading to the prospect of a nuclear arms race in South Asia. Israel will continue to develop nuclear weapons as deterrents against CW, BW, and nuclear use, as well as compensating for the advanced conventional weapons capabilities of Arab countries.

11. South Africa's nuclear rollback will be irreversible, as will be the rollback in Belarus, Kazakhstan, and Ukraine. Nuclear rollback is unlikely to succeed in other countries during this period, but stabilization of the status quo will take place.

12. Chemical weapons in the hands of Iran, India, Pakistan, Israel, Libya, and South Africa will be an international security concern.

13. India, Pakistan, and Israel will be pressured to join the NPT as non-nuclear weapons states following the example of South Africa. Pakistan may join if it is given strong security guarantees. Israel will await the results of the Middle East Initiative, but is unlikely to sign up. It is unlikely that India will agree to join because of its continued concerns regarding China.

14. Instability in the Korean peninsula may be reduced by North-South Korean discussions and pacts, and perhaps by the death of Kim Il Sung, but it will not be eliminated. North Korea will continue to violate the NPT, but the costs in the form of UN and other sanctions associated with its clandestine program will be high. South Korea and Japan will have difficult decisions to make regarding their responses to a nuclear-armed North Korea despite continued U.S. security guarantees.

15. Latin America will consider the Tlatelolco Treaty of greatest importance; it will enter fully into force during this period, and the region will remain a nuclear weapons-free zone. Additional agreements will make Latin America a chemical and biological weapons-free zone. Argentina and Brazil may come into the NPT in this period.

16. The growing need for hard currency in the former Soviet Union and Eastern Europe will result in a thriving black market in nuclear materials and advanced technologies. Weapons sales will become a by-product of the free market in these countries.

17. Weapons of mass destruction will spread across the Islamic Crescent, across North Africa and through South Asia.

18. The Middle East will remain unstable in spite of the Middle East Initiative, and this instability will be related to the proliferation of weapons and their delivery systems.

19. Proliferation of sophisticated conventional weapons over and above legitimate defense requirements in unstable regional areas will be an increasing concern, particularly those which are dual-capable systems. The UN and other efforts may slow, but will not stop this proliferation because of the increased availability of such weapons and economic pressures to sell them. Efforts to constrain the proliferation of less sophisticated conventional weapons, such as tanks and artillery, will not be successful.

20. Terrorism on the part of indigenous separatist and insurgent groups will become a more serious threat to the world as these parties acquire a few weapons of mass destruction.

21. While ethnic tensions and territorial disputes will continue throughout many regions of the world, for example, within the borders of the former Soviet Union and in certain Eastern European countries, these quarrels will not constitute major threats to international security. They also will not involve the use of nuclear or biological weapons; some might involve a limited use of chemical weapons. There will be increased pressure upon NATO and other Western European countries to become involved. Local and regional confidence-building measures (CBMs) and arms control agreements will be explored to reduce the likelihood of these conflicts.

22. Ballistic missiles will continue to be weapons of prestige in the Third World. Their potential terrorist, deterrent, and military roles will be enhanced in the countries suspected of having chemical, biological, or nuclear warheads for the missiles.

    - International pressure will be brought to bear upon China and North Korea to curtail their continued sale of ballistic missiles.
    - Iraq will hold on to its hidden Scuds and will modify them to increase their range and improve their accuracy.
    - Other Arab nations will acquire ballistic missile capabilities.
    - Efforts to expand the INF Treaty into a global treaty banning medium- and intermediate-range missiles will be made, but they are unlikely to be accepted by some suppliers (China and North Korea) or some buyers (most Arab and Islamic nations).

23. Sales of space launch vehicles will permit Third World countries to acquire ICBM capabilities without having to develop the missiles indigenously. India will continue to develop intermediate-range ballistic missiles as "spin offs" from its space launch vehicle program. China already possesses intercontinental range ballistic missiles (ICBMs). It is unlikely that any Third World country other than India will be able to indigenously develop ICBMs in this period.

24. In spite of efforts on the part of the international community, complete and accurate reporting of weapons exports and imports is unlikely to be achieved.

25. Greater reliance will be placed on the United Nations Security Council and other international and regional security institutions to constrain proliferation.

26. By 2002, proliferation concerns over weapons of mass destruction and their advanced systems of delivery will come to focus more and more on a relatively small number of pariah states. Concerns regarding conventional weapons will encompass a much larger range of countries, and these concerns will be exacerbated by ethnic and regional conflicts. The United Nations and the CSCE will be called upon to mediate more "low intensity" conflicts.

Assumptions About Future Verification Requirements Related To Constraining Proliferation

1. **Military significance** will continue to be the criterion for effective verification, but it will be difficult to judge what constitutes military significance in the area of chemical or biological weapons when such weapons can be used for terrorist or deterrent purposes as well as for war-fighting purposes.* What constitutes military significance will vary with each agreement and with the views of the country making that judgment.

2. Distinctions will need to be made between cooperative and adversarial verification, that is, between verification regimes involving the democracies of the world which are tailored to assure compliance with the key provisions of an agreement and verification regimes involving certain weapons states which need to be tailored to deter or possibly detect non-compliance. Those distinctions will involve different approaches to verification methods; for example, implementation of invitational and cooperative on-site inspections will be quite different from implementation of challenge and suspect-site inspections. Coercive verification — the control of arms and forcible disarmament brought about by UN resolutions, sanctions, and embargoes — requires the most stringent, intrusive form of verification, for example, inspections with no right of refusal.

* Verification regimes under the criterion of military significance are termed "effective" if they provide for the ability of a party or parties to detect actions on the part of another party which go beyond the limits of the treaty in any militarily significant way, and if they provide the ability to detect any such violation in time to respond effectively, thereby denying the other party the benefit of the violation.

3. National Intelligence Means (NIM), particularly HUMINT — the intelligence supplied by humans — will become a key element in monitoring future multilateral agreements. Collateral analysis of open sources, for example, media reports, will also make an important contribution.

4. Incentives to cheat and the costs of cheating will continue to be important in the analysis of verification regimes for agreements constraining proliferation. Crisis stability is enhanced when neither party has strong incentives to launch a first strike. Understanding the underlying motives may lead to measures beyond arms control which lessen the tensions leading to the development of clandestine weapons programs. Increasing the costs of cheating buys time for proliferation initiatives to work.

5. The question, "after non-compliance, what?" will need to be revisited. Enforcement of stiff international sanctions will be the most appropriate response, and this will need to involve the UN Security Council or other respected international bodies.

6. The role of the UN Security Council in providing security guarantees and meting out and enforcing sanctions will need to be strengthened.

7. A greater emphasis on regional and local arms control and confidence-building measures will produce a need to train and advise local parties in the use of verification methods such as on-site inspections and the collection and analysis of readily available open source data.

8. The lessons learned from the UNSCOM experiences in Iraq will constitute a two-edged sword. They will be valuable in designing future verification regimes for agreements designed to halt or at least slow the proliferation of weapons of mass destruction and their delivery means. However, these same lessons will be used by proliferators, such as North Korea, to tolerate inspections without revealing the true nature and scope of their illegal programs. "Red teaming" — role playing in which teams assume the parts of the other side — inspections might prove a useful exercise.

Assumptions About Future Verification Methods and Techniques

1. National technical means (NTM) will remain the foundation for verifying all types of **bilateral** arms control agreements involving the United States and Russia.

2. There will be increased pressures on the United States, Russia, and other developed countries to share data from NTM, and there will be more efforts to develop international technical means (ITM) or regional technical means for purposes of verifying multilateral agreements.

3. Many Third World countries will have to rely solely on their NIM — their overall national intelligence means — in lieu of reliance on advanced satellite and other technical collection systems. If they feel that their national interests are at stake, they may exert pressure for an international body to perform on-site inspections, perform overhead surveillance, or carry out other verification tasks.

4. Data exchanges and notifications will make significant contributions to the verification of future agreements because they provide baseline information, much of which can be confirmed, because they promote transparency, and because their synergistic effects contribute to effective verification.

5. On-site Inspections (OSIs) will also contribute to transparency of future multilateral agreements, and they will provide early warning of possible non-compliance. OSIs can also "trigger" the need for other verification methods. They will be important in the area of non-proliferation because they can provide tangible evidence, observed by all parties to the inspections, of non-compliance.

6. Invitational inspections will play a greater role in removing ambiguities and generating confidence in the agreements.

7. Intrusive on-site inspections will be necessary for assuring compliance by some countries with multilateral agreements designed to curb proliferation, for example, the Chemical Weapons Convention. However, OSIs will not be a sure means of detecting violations unless the other side makes a mistake or informants provide timely, needed information.

8. Confidence-building measures will become increasingly important and effective in their own right as well as in their contribution to verification synergies.

9. Open Skies and other forms of aerial surveillance will provide greater transparency, assuming effective implementation, and thus will contribute to regional stability and to monitoring arms control agreements. They also perform a triggering function.

10. Independent, commercial sources of data, for example, the SPOT satellite may become increasingly significant as sources for verifying data. Commercial satellite imagery of medium quality resolution will become an increasingly important monitoring tool.

11. Challenge inspections without right of refusal may need to be instituted in situations where there is a high probability of cheating.

12. Less expensive, simpler, sturdier verification technologies will be sought for use in on-site inspections and aerial surveillance.

13. There will be more applications of verification methods to peacekeeping tasks in unstable regions of the world.

IV Constraining Proliferation: Verification Regimes for Multilateral Agreements

Past Verification Regimes

Sidney N. Graybeal and Patricia Bliss McFate

The Antarctic Treaty, the earliest of the post World War II arms limitations agreements, was signed in 1959 by 12 nations. It is an agreement of major significance: it demilitarized a continent and assured its cooperative exploration by providing for information exchanges, notifications, and on-the-ground and aerial inspections. It is an example of a multilateral agreement which demilitarized a region (in this case a continent) in order to prevent tension rather than waiting to negotiate weapons reductions or eliminations after deployment occurred.

The Outer Space Treaty, negotiated to support a UN General Assembly resolution, was modeled on the Antarctic Treaty in that its provisions seek to prevent exploitation and international tensions before they exist by restricting certain military activities in outer space and on celestial bodies. The verification regime for the Outer Space Treaty permits OSIs with advance notice for safety purposes, on the moon and other celestial bodies, but not on the national territory of the signatories.

The Treaty for the Prohibition of Nuclear Weapons in Latin America — also known as the Treaty of Tlatelolco — seeks to avoid conflict by obligating 23 Latin American countries not to acquire or possess nuclear weapons, nor to permit the storage or deployment of nuclear weapons on their territories by other countries. This Treaty resulted in the creation of the first nuclear-weapon-free zone. Verification of the Treaty provisions require signatories to negotiate agreements with the International Atomic Energy Agency (IAEA) for application of its safeguards to their nuclear activities. A General Council also has the power of carrying out special inspections under certain conditions. Four countries (Argentina, Brazil, Chile, and Cuba) have yet to make the Treaty operative.

Another regional agreement, the Treaty of Raratonga, establishes a nuclear weapons free zone in the South Pacific. Like the Treaty of Tlatelolco, it relies on the IAEA to verify the non-diversion of nuclear material to nuclear explosives through the full use of its capabilities, including special inspections.

Since its entry into force in 1970, the Non-Proliferation Treaty (NPT), the cornerstone of international efforts to prevent the further spread of nuclear weapons, has been signed by over 150 parties. The IAEA and its safeguards system provide verification support for the Treaty. Signatories to the NPT, with the notable exception of Iraq and possibly North Korea, have made it the most widely adhered to arms control agreement in history.

The Seabed Treaty, following on the model of the Antarctic, Outer Space, and Latin American Nuclear Free Zone Treaties, seeks to prevent the introduction of international conflict and nuclear weapons into an area free of them. Verification of the Treaty is to be undertaken by parties to the agreement, using their "own means" of observation; with the assistance of other parties; or through appropriate international procedures within the framework of the UN. Limited OSIs on the seabed are possible, after certain procedural consultations take place.

Multimethod, interlocking verification procedures were adopted to ensure compliance with the Sinai I Agreement of 1974, the Sinai II Agreement of 1975, and the Egypt-Israel Peace Treaty of 1979. These methods included ground-based early warning systems, aerial and satellite reconnaissance, and on-site inspection undertaken by both third parties and the parties themselves. The verification system was technologically-intensive so that it could operate with a minimum of personnel without sacrificing effectiveness. The system was also flexible in that its mission could be modified to reflect inspection and compliance requirements in new agreements. The synergies associated with this multimethod verification system could well provide the impetus for future regional arms limitation agreements.

The U.S. Senate adopted a resolution in 1973 calling for an international agreement "prohibiting the use of any environmental or geophysical modification activity as a weapon of war." Following negotiations in the Conference of the Committee on Disarmament (CCD), a Convention on the Prohibition of Military and Other Hostile Use of Environmental Modification Techniques (ENMOD) entered into force in 1978. At present there are 56 signatories to the Convention. There is no formal verification regime associated with ENMOD beyond the call for exchanges of scientific and technological information and a provision for formal complaint in the Consultative Committee of Experts. The second ENMOD review conference (14-18 September 1992) included a discussion of the release of oil into the Persian Gulf and the ignition of oil-fires by Iraqi forces in Kuwait during the War in the Gulf. Verification of these incidents came from a number of technical and human sources: aerial surveillance, satellite surveillance, "on-site inspection," HUMINT, etc.

Representatives of the participating States of the Conference on Security and Cooperation in Europe (CSCE) negotiated the Vienna Document 1992, a set of confidence- and security-building measures (CSBMs) which follow on from a series of previous documents such as that from the Stockholm Conference of 1986. The Vienna Document calls for an annual exchange of information on military forces, data on and deployment of major weapon and equipment systems, and military budgets. CSBMs include consultations, voluntary hosting of visits, demonstrations of equipment, notifications prior to certain military activities, observations of certain military activities, and exchanges of annual military calendars. Verification assumes the use of NTM and NIM and allows for on-the-ground and/or aerial inspections using maps and charts, photo and video cameras, binoculars, hand-held passive night vision devices, and dictaphones. In addition to inspections, evaluation visits are permitted to observe active military formations and units in their normal peacetime locations, as well as air-base visits.

A Canadian arms control initiative, the UN Arms Register was adopted by the UN General Assembly in 1991. Under this agreement, signatories are called upon to provide data on their imports and exports of a variety of categories of conventional weapons. The Register is viewed as a CBM and the reporting is voluntary. Additional means to increase openness and transparency are being analyzed.

The Open Skies Treaty provides for short-notice surveillance flights by aircraft over an area from Vancouver east to Pavlovskoye (the former Vladivostok). Signed in March 1992 by 25 countries, the Treaty allows for adoption of its provisions by other signatories, including members of the Conference on Security and Cooperation in Europe (CSCE). The Treaty provides countries without sophisticated NTM with independent access to data on military activities. As a transparency measure, it contributes to regional stability by allowing countries the opportunity to monitor their neighbors, thus reducing concerns. Since aerial inspection has not as yet been made a part of the CFE treaty, Open Skies also can be viewed as an adjunct to the CFE verification regime; this relationship is discussed in the following section on "Open Skies and Aerial Surveillance."

Until the present time, verification regimes for multilateral treaties have stipulated CBMs and cooperative measures, while recognizing that some countries have sophisticated NTM. Thus far it is solely in the environmental area that the U.S. has agreed to open its archives of data compiled by reconnaissance means to scrutiny. Experts believe that information from intelligence platforms could aid scientists in their study of environmental changes. For example, reconnaissance aircraft take air measurements to track various types of military activity. These records might reveal levels of methane and carbon dioxide, as well as levels of chlorofluorocarbons; such measurements would be useful in determining the amount of global warming and the damage being caused to the earth's protective ozone level. Similar tracking by Navy vessels might yield information about ocean pollution and global climate change.

A major challenge to release of this information will be to balance a need for secrecy regarding surveillance capabilities with a scientific requirement for reliable and specific data. In June 1990, Senator Sam Nunn proposed using U.S. intelligence-gathering technology to address ecological problems which he called "a growing national security threat." In May 1992, a directive from President Bush ordered the Defense Department and the Central Intelligence Agency to "seek to make appropriate technology and data" available from military and civilian space-based systems. The Russian government has offered to make available photographic data from its satellite reconnaissance program through Soyuz Karta.

The Verification Regime for CFE
George Lindsey

The Treaty on Conventional Armed Forces in Europe had as its objectives the establishment of a secure and stable balance of conventional forces at lower levels; the elimination of disparities prejudicial to stability and security; and removal of the threat of massive surprise attack in Central Europe. Since it demands the removal, conversion, or destruction of many thousands of weapons, but also permits the retention of many thousands, verification presents very difficult requirements, exacerbated by the fact that many of the weapons limited by the Treaty cannot be distinguished from similar permitted "look-alikes" without careful close inspection. In addition to limitations on five categories of weapons, ceilings on military personnel have been added under the CFE 1A Agreement, although with very weak provision for verification, and with the limits not becoming mandatory until the weapon reductions have been completed. This should occur about forty months into the life of the agreement, which entered into force (provisionally) on 17 July 1992.

The arrangements for implementing and verifying CFE have been severely complicated by the breakup of the Soviet Union. In the area covered by CFE which was part of the USSR west of the Ural Mountains when the Treaty was signed in 1990, there are now eleven independent states.*

While there is to be no monitoring of weapon production or permanent stationing of inspectors, the provisions for exchange of detailed data regarding weapon and personnel inventories, and for on-site inspections of military sites, was more extensive than for any previous arms control agreement, bilateral or multilateral. A precedent was set by acceptance of challenge inspections of undeclared facilities (although allowing the inspected party to delay or refuse the inspection). On-site inspections are to be used to monitor holdings, reductions, and recategorizations of equipment at both operational and storage sites.

Aerial inspection for verification of CFE is to be negotiated at a later time, and should be distinguished from the "Open Skies" Treaty, which is at present restricted to a confidence-building measure and covers a different (larger) geographical area of application than CFE. For synergy and efficiency it would be desirable that the aerial inspections for CFE be harmonized with the arrangements for Open Skies.

There will be a definite hierarchy in the capability to monitor by use of NTM. The USA and Russia will be able to employ their high-resolution optical, radar, and ELINT satellites. France, Italy, and Spain will have the HELIOS military reconnaissance satellite, which will be somewhat less capable. The other parties will have access to space only through commercial satellites, whose resolution is inadequate to identify weapons of the size being limited in CFE.

Future arms control discussions in Europe may address technologies permitted for on-site inspections. One which shows promise depends on tags to be permanently attached to treaty-limited vehicles and guns, carrying a unique and non-alterable identification for each unit.

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* Russia, Ukraine, Belarus, Moldova, Georgia, Armenia, Azerbaijan, Kazakhstan, Lithuania, Latvia, and Estonia. All but the last three of these are now signatories of the CFE Treaty.

Tamper-proof seals, and various types of fixed remote sensing devices also offer useful potential. A critical factor for aerial inspection will be the types of sensors allowed.

Verification of CFE should profit from two kinds of synergy. One is the fusing of data obtained by a variety of methods (NTM, OSIs, data exchanges, eventually aerial inspection). Verification of personnel will be especially dependent on data exchanges and synergy available from comparison with the evidence collected regarding the TLE.

The other kind of synergy to be expected is the cooperation among participating countries in scheduling their inspections, and in combining the results of their monitoring activities. Three different levels of interested participants are present: national, alliance, and inter-alliance (or "treaty level"). At the alliance level NATO has established a Verification Coordinating Committee with a Verification Support Staff to distribute inspection quotas and coordinate a data base. CFE has a Joint Consultative Group, comprising all the parties, to promote the objectives and implementation of the provisions of the Treaty (although this has no specific task regarding verification).

In the future, negotiations in the Forum for Security Cooperation* will seek to "harmonize" the obligations under various CSCE agreements with those of the CFE Treaty. This harmonization process will have a significant impact on verification aspects of both processes.

Lessons Learned from Bilateral Regimes
Sidney N. Graybeal and Patricia Bliss McFate

While early multilateral agreements, such as the Antarctic and Outer Space Treaties, contain provisions allowing on-site inspection — but not on the national territory of the parties — verification of the ABM Treaty (1972) is solely by national technical means (NTM). The Soviet Union was unwilling to agree to inspections on its territory, and the United States agreed to this regime because the NTMs of the two countries were sophisticated enough to allow for adequate verification. The provisions of the agreement were designed to be consistent with verification by the NTMs.

The unique aspect of the ABM Treaty verification regime was that it prohibited each party from interfering with the NTM of the other party, and it prohibited the use of deliberate concealment measures which would impede verification by this method. The Treaty also states that "each Party shall use national technical means of verification at its disposal in a manner *consistent with generally recognized principles of international law*" (emphasis added). This statement recognizes that spies and espionage are not consistent with these principles and thus the non-interference clause does not endorse or protect such activities. The substantive content of these provisions were later incorporated into multilateral agreements, for example, the CFE Treaty (1990).

The Reagan Administration ushered in the era of intrusive verification, and the Bush Administration continued in that pattern. Despite the fact that there have been no militarily significant violations of the ABM Treaty, NTM by itself was not considered sufficient for effective verification of agreements related to nuclear forces. Therefore the INF, START, and TTBT/PNET agreements contain provisions for extensive data exchanges, numerous notifications, and intrusive on-site inspections in addition to NTM.

In June 1992, a mutual decision was taken by Presidents Bush and Yeltsin to cut Russian and American strategic nuclear forces significantly lower than START levels. The agreement which will be negotiated based on this decision will presumably rely for its verification requirements upon the stringent verification regime already negotiated for START. However, the mutual

* Established under the CSCE Vienna Document of 10 July 1992.

unilateral elimination of surface-launched short-range theater nuclear weapons proposed earlier by President Bush may mark a return to less verification, given great uncertainty about the initial baseline figures for deployed missiles of this type. There has been increasing concern, in the United States and Russia, about the economic burdens and the possible loss of sensitive information associated with highly intrusive verification. A compromise in the debate between advocates of modest and proponents of extensive verification might be the adoption of CBMs such as invitational inspections of facilities and further exchanges of data on production and deployment of weapon systems.

One point which bilateral verification has demonstrated is the importance of NTM, and that, in turn, has argued for more sharing of data from NTM with other countries for purposes of multilateral treaty verification and/or the development of International Technical Means (ITM) or Multilateral Technical Means (MTM). In addition to the sharing of collected data, there is a serious need for data reduction and processing techniques in order to maximize the utility of the information. This is particularly true in the case of data from synthetic aperture radars (SARs). Another is that cooperative measures such as data exchanges and notifications not only promote transparency, but greatly enhance the effectiveness of NTM.

What has not been transferrable to multilateral arms control is the sophisticated verification technology developed by the United States and Russia. Given the concept of reciprocity, which leads to technology transfer concerns, and given the budgetary crises in a number of countries, which argue against indigenous development of such technology, negotiators of multilateral agreements may not be able to acquire the high technology needed for verification of treaty provisions.

Bilateral verification regimes have shown that perfect ("100 per cent") verification is not possible, and is not necessary to meet the criterion of military significance. These regimes did demonstrate the requirement for and value of forums for resolving compliance questions. In addition, many of the detailed on-site inspection provisions in bilateral agreements were applied to subsequent multilateral agreement, for example, CFE and CWC.

The final lessons to be learned from bilateral regimes is the need for data management systems to handle the increasingly complex and detailed information being reported, recorded, disseminated, and analyzed. Cost-effective, simple, unintrusive "low" verification technology which gets the expensive part of inspections, people, "out of the loop" is also needed.

Verification and Confidence-Building Regimes for Existing and Potential Agreements
Patricia Bliss McFate and Sidney N. Graybeal

Strengthening the NPT: IAEA Safeguards

The International Atomic Energy Agency (IAEA) developed a program of on-site inspections, audits, and inventory controls known as "safeguards" in the mid-1960s; the safeguards were designed to deter the diversion of fissionable materials, equipment, and components from peaceful uses to military purposes. "Full-scope" safeguards entail accounting and inspection measures on all of a nation's peaceful nuclear activities.

With the advent of the Nonproliferation Treaty (NPT), non-nuclear weapon states (NNWS) which become parties to the NPT accept safeguards worked out with the IAEA for the exclusive purpose of preventing diversion of nuclear energy from peaceful uses to nuclear weapons or other nuclear explosive devices. Nuclear weapons states (NWS) which are parties to the NPT agree not to provide special fissionable material or nuclear-related equipment to any NNWS for peaceful purposes unless the fissionable materials are subject to IAEA safeguards. NWS have agreed to place their nuclear facilities, except those with direct national security significance, under IAEA safeguards.

IAEA safeguards provide assurance to countries of their neighbors' peaceful intentions. However, the recent discovery of Iraq's nearly successful efforts to develop nuclear weapons has raised questions about the effectiveness of IAEA inspections associated with the NPT. During the period in which Iraq acquired equipment and components associated with its nuclear weapons program from outside suppliers, IAEA inspections neither uncovered the signs of Iraq's program nor did the inspections detect its use of calutrons and its misuse of a safeguarded research reactor. It should also be noted that intelligence bodies in the United States, Canada, and other signatories to the NPT were not aware of the true nature, scope, and development status of the Iraqi nuclear weapons program before the end of the War in the Gulf, and they only became aware of the true scope after the UNSCOM/IAEA inspections.

In 1995, the NPT parties will decide by a majority vote "whether the Treaty shall continue in force indefinitely, or shall be extended for an additional fixed period or periods." Prospects for a long-term extension depend upon arguments that the NPT is meeting its goals. It can be argued that two of the goals — to foster peaceful use of nuclear energy and to encourage nuclear arms control and disarmament — are being met. The third goal — to prevent the spread of nuclear weapons — will inevitably be evaluated in the light of activities in countries such as Iraq, North Korea, India, Pakistan, and Israel, and the sales of nuclear reactors and advanced delivery systems by China. A clear benefit of keeping the NPT in force indefinitely is that it establishes a norm, a standard of international behavior, backed up by a legal process, which leads countries to renounce the right to acquire nuclear weapons. The existence of the NPT has been essential to the efforts to bind three non-Russian republics of the former Soviet Union to adherence to a non-nuclear-weapon status. Because most signatories take this obligation seriously, the NPT is a source of international stability. Moreover, the legal foundation for global nuclear export controls resides in the NPT. NPT safeguards and inspections are the guarantee of this process, and they should be strengthened.

New steps must be taken to strengthen the IAEA's effectiveness in monitoring compliance with the NPT. These should include support of the IAEA's right to request special inspections at undeclared sites or locations. These suspect site inspections (SSIs) would not necessarily detect cheating, but they would make cheating more difficult and costly. The right to request SSIs would deter non-compliance, because a refusal to grant access would provide a clear signal of suspect illegal activities and would lead to the focusing of other collection assets on the activity or site. Thus, even though the SSI regime would not detect a violation, its existence could trigger a synergistic effect when it was combined with other collection methods.

Other changes need to be considered. For example, NPT parties could be required to declare and provide design information on projected nuclear facilities to the IAEA sooner than is presently the case. Timely reports to the IAEA about all nuclear-related sales and export denials by all IAEA members would also improve nuclear transparency. More extensive reporting to the IAEA on nuclear exports in general could also help establish a vital component of an early warning system — a system whose effectiveness would in large measure depend upon the synergistic effects among several monitoring methods and data exchanges. A return to the country officer approach might permit IAEA inspectors to serve as central points for the reception and evaluation of information relevant to a specific country.

Strong support by the UN Security Council of NPT goals is also essential. The Security Council needs to bring its considerable authority to bear upon potential violators of the NPT. The Council could declare that any violation of IAEA safeguards, the NPT, or any other legally-binding nuclear non-proliferation obligation would be considered a threat to peace and would require consideration of strong sanctions.

Elimination of Nuclear Weapons

The Russian Federation and the United States will be removing thousands of nuclear warheads from their inventories as a result of formal agreements, reciprocal actions, and unilateral steps. Reductions in the non-strategic nuclear force arsenals of the two countries fall into the second and third categories, having been called for in announcements made by President Bush and then President Gorbachev in September and October 1991 and by President Yeltsin in January 1992.

The reductions include elimination globally of all nuclear artillery rounds and nuclear warheads for short-range surface-to-surface ballistic missiles and withdrawal of non-strategic nuclear weapons from naval forces at sea and from naval aviation ashore. The United States will eliminate approximately 2100 land-based weapons; the former Soviet republics may eliminate more than 10,000 land-based weapons. An unspecified number of U.S. and former Soviet sea-based tactical nuclear weapons will be eliminated; the remainder will be stored. Verification of compliance with these actions was not mentioned in the statements; it can thus be assumed that NTM alone will constitute the method of verification.

Dependence upon NTM to monitor "mutual-unilateral" arms reduction statements has raised questions in the United States related to the issue of clandestine storage, rather than destruction, of the former Soviet holdings. It is true that monitoring the elimination of tactical/theater nuclear weapons systems will pose verification problems given their very small size, inherent mobility, and dual-capability. In addition, questions can be raised concerning verification of the disposition of the nuclear warheads and the nuclear materials from dismantled warheads in view of increasing concerning over proliferation of nuclear weapons.

While some U.S. analysts have suggested that NTM and HUMINT are not adequate to the task of monitoring compliance with tactical/theater nuclear weapons destruction and storage requirements, the Bush Administration has argued that Russian cheating on the commitments would not be militarily significant, that on-site inspection would not significantly increase the probability that cheating would be detected, and that Russian inspections of U.S. compliance carry too costly and risky a burden to the U.S.

Nevertheless, the presence of some number of "legal" nuclear-armed missiles and dual-capable aircraft and rocket launchers will require methods for differentiating between nuclear and conventionally-armed delivery systems. To provide more effective verification, a regime could be negotiated which would require: detailed data exchanges; an agreement to keep nuclear-armed delivery systems separate from dual-capable conventionally-armed systems; short-notice challenge inspections of declared facilities and dual-capable delivery systems at these facilities; and possibly the use of functionally-related observable differences (FRODs) which would enhance the capabilities of NTM to monitor the location of "legal" delivery systems and the elimination of delivery systems scheduled for destruction.

U.S. Congressional legislation intended to assist Russia in the transport, safeguarding, and destruction of nuclear and chemical weapons has led to the bilateral Safety, Security, and Dismantlement (SSD) talks. The United States has agreed to provide Russia with soft armor blankets, emergency response equipment, fissile material containers, security enhancements for Russian railcars transporting nuclear weapons, options for the storage of fissionable material from dismantled Russian nuclear warheads, and assistance with the development of a system for the control and accountability of fissionable materials.

Monitoring the disposition of excess nuclear warheads will pose major challenges and obstacles for any agreement requiring their eventual elimination and the secure storage of the weapons-grade fissionable materials resulting from their elimination. Steps could be taken to **disable** nuclear warheads in the field prior to transporting them to storage and/or dismantling facilities. Monitoring such disablement would require inspection which could pose security problems. Maintaining accountability of excess nuclear warheads during the transportation, storage, and dismantlement process could be facilitated by the use of unique identifiers such as tags or serial numbers and tamper-proof seals.

Dismantlement of a nuclear weapon requires essentially the same expertise necessary to construct the weapon. In the United States, dismantlement is accomplished at the Pantex Plant in Amarillo, Texas; a similar facility is reported to exist in the Russian Federation. Monitoring the actual dismantling of nuclear weapons at such facilities without compromising sensitive nuclear weapons design information is the subject of separate, detailed studies beyond the scope of this paper. The fissionable materials from dismantled weapons could be stored at designated facilities monitored by the IAEA.

Future verification challenges may center around keeping retired nuclear missiles secure from terrorists and thieves, storing nuclear weapon parts and fissionable material safely and without environmental damage, and commercially cycling some nuclear materials without contributing to the spread of weapons. This last goal needs to be achieved in the near future because Russia will have more than 500 metric tons of highly enriched uranium (HEU) after dismantling its nuclear weapons. When blended with natural uranium, one pound of HEU would make about 27 pounds of so-called low-enriched nuclear power plant fuel, which could be used in some of the more than 330 nuclear power plants world-wide capable of using such fuel.

Cut-off in the Production of Fissionable Materials for Weapons Purposes

The United States has announced that it will not produce plutonium and highly enriched uranium, two key ingredients of nuclear weapons which have been in abundant supply for years. Tritium, which is used to boost nuclear yields and has a short half-life, is not a fissionable material, and is not included in this announcement. The announcement of an indefinite halt to U.S. production of these fissionable materials is largely a symbolic gesture since the United States has not produced uranium for nuclear weapons since 1964 and ceased plutonium production in 1988. The halt to production does not forestall creation of new nuclear arms, because the materials last for thousands of years and have routinely been recycled from old weapons into new ones. Since the U.S. arsenal of nuclear weapons has been shrinking since the mid-1980s, and will shrink further in the period ahead under the provisions of START and the follow-on to START, there will be a substantial surplus of fissionable materials.

The U.S. pledge is primarily intended to put pressure on Russia, Israel, North Korea, and India, countries which make either one or both of the materials now or have done so in the past. Russia has previously said that it would agree to a bilateral halt in production. Last year Pakistan promised that it would make no more highly enriched uranium. American-Russian agreement could be the first step in seeking an international halt to the production of weapons-grade fissionable material and, in turn, a step toward the goal of stemming nuclear proliferation.

The U.S. decision to cut-off production was a unilateral step, rather than an element in a binding arms treaty, and therefore it could be reversed without the political penalties of withdrawing from a treaty. Reversal is unlikely in the current period, however, with the Congress moving toward enactment of limitations on U.S. nuclear testing that would constrain development of new weapons and dampen interest in production of more fissionable materials.

Future agreements related to a cut-off in the production of fissionable materials for weapons purposes will have to provide for the existence of these materials by providing means to store and dispose of them. Storage of materials is straightforward, but requires proper inventory, then tight security to provide safe and secure storage. Since storage of plutonium and enriched uranium is a long-term proposition — Pu-239 has a half-life of 24,400 years and U-235 has a half life of 713 million years — conversion to peaceful purposes and disposal are better alternatives, but they are not easy technically.

A recent bilateral agreement calls for the United States to buy at least 500 metric tons of highly enriched uranium from the Russian government over 20 years. The uranium is to be diluted into commercial reactor fuel for civilian power plants.

Using the material in power reactor fuel would require an extensive conversion capacity as well as up-to-date technology. Russia's First Deputy Minister of Atomic Power has called for Western help with plans to recycle weapons-grade material, notably plutonium, as nuclear fuel for Russian power plants. Although Russia is said to be planning the construction of two temporary storage facilities, it wishes to avoid long-term storage of plutonium for reasons of economy, safety, security, and the environment. Objections to the use of plutonium in reactors have been voiced by German experts who fear unknown risks in the use of mixed-oxide fuel.

Enriched uranium can be mixed with natural or depleted uranium until its level of enrichment approaches that of natural uranium. Plutonium cannot be easily diluted isotopically; the only choice is to mix it chemically with highly radioactive, long-lived waste and store it. Consuming either material in a reactor is technically possible, but it is more feasible for uranium.

A verification regime for a formal agreement on a cut-off in the production of fissionable materials would need to take into account methods to demonstrate that the fissionable materials were put in safe and secure storage and/or burned. Cooperative measures such as data exchanges, notifications, and on-site inspections would be necessary to assure that these actions had taken place. Inspections might well be conducted under the auspices of the IAEA, given its mandate under Section A.XII.A.5 (international plutonium storage) once the nuclear material was transferred from military to peaceful use.

Limitations on Tests, Reducing the TTBT/PNET Thresholds, Testing for Safety Purposes, a CTB

American policy on nuclear weapons testing, as stated by the Secretary of Defense in July 1992, has been that testing is necessary for the purposes of keeping nuclear weapons safe, secure, reliable, and effective. Since Russia and France recently suspended underground tests, international pressure has been mounting on the United States to accept a one-year moratorium on nuclear weapon testing. A U.S. Senate plan calling for a nine month moratorium was approved on 3 August 1992 by a vote of 68 to 26, enough to override a Presidential veto; the plan also called for a permanent ban on all tests by September 1996, unless Russia were to resume testing.

Verification of a moratorium or a comprehensive test ban (CTB) requires the same general category of activities associated with the Threshold Test Ban Treaty (TTBT) and Peaceful Nuclear Explosions Treaty (PNET): the availability of seismic monitoring equipment capable of detecting and locating seismic events that could be caused by an underground nuclear explosion, determining whether the event was created by such an explosion, and — in the case of threshold limits — estimating the yield. NTM for monitoring nuclear testing treaties include seismic stations outside of the monitored country as well as technologies such as reconnaissance satellites and communications monitoring. Seismometers are the main monitoring tools for detecting underground tests. Verification of a CTB is a prime example of the benefits of verification synergies among various technical methods. For example, data exchanges can provide critical information for improving monitoring by technical methods; these methods in turn can highlight anomalous events which may require closer examination, for example, by OSI.

The official U.S. network of seismic, electromagnetic, and acoustic sensors, the Atomic Explosion Detection System (AEDS), has been operating 23 stations around the Soviet Union for over 30 years, and some observers believe it can detect explosions as low as 10 kilotons. The Conference on Disarmament's Group of Scientific Experts (GSE), created in 1976 to "consider and report on international cooperative measures to detect and identify seismic events," has carried out two major experiments to test methods for international collection, analysis, and exchange of detailed seismic data in an effort to determine the operational requirements for a global seismic network. There are over 10,000 seismic stations around the world at the present time, most of which are affiliated with mining companies and universities. In-country seismology, combined with data about the geology of the country — as called for in the TTBT — markedly improves the ability of signatories to testing treaties to monitor tests.

The yield of an underground nuclear explosion may also be estimated using hydrodynamic methods which make use of the fact that larger explosions create shock waves that expand faster than the shock waves created by smaller explosions. Several techniques have been used to measure the position of the shock front as a function of time, the most recent being the technique called CORRTEX (an acronym for Continuous Reflectometry for Radius versus Time Experiments).

Hydrodynamic yield estimation methods are more intrusive than remote seismic methods. Personnel from the monitoring country must be present at the test site of the testing country well before and during each test; the presence of these personnel observing test preparations poses some operational security problems. The exterior of the canister containing the nuclear charge and diagnostic equipment must be examined to verify that the restrictions necessary for the yield estimate to be valid are satisfied; for tests of nuclear directed energy weapons, this examination could reveal sensitive design information unless special procedures are followed. Sensing cables and electrical equipment tend to pick up the electromagnetic pulse (EMP) generated by the explosion; a detailed analysis of the EMP could reveal sensitive information about the design and performance of the nuclear device being tested.

Well-coupled nuclear explosions could be detected and identified with high confidence down to yields well below 1 kiloton using a high-quality seismic network. However, certain evasion schemes of countries attempting to conduct clandestine tests can be identified, for example, testing behind the sun or in deep space, simulating an earthquake, testing during an earthquake, testing in a large underground cavity (decoupling), testing in a nonspherical cavity, testing in low-coupling materials, or masking a test with a large chemical explosion. These scenarios need to be countered by a combination of seismic methods, treaty constraints, and other monitoring methods. Treaty constraints which have been proposed to improve the capability of various monitoring networks include the following: limitations on salvo-fired chemical explosions; limitations on ripple-fired chemical explosions; limitations to one inspected and calibrated test site; on-going test site inspections; joint on-site inspections of sites of possible violations which could be evident from chemical residues; and country-wide network calibration tests.

The Limited Test Ban Treaty (LTBT) of 1963 prohibits nuclear weapon tests in the atmosphere, outer space, and under water. It is verified by NTM which includes VELA satellites and air-sampling by aircraft outside the territory of the original parties. These verification capabilities would be applied to a moratorium and a CTB.

Strengthening the MTCR

The Missile Technology Control Regime (MTCR) is a voluntary arrangement among countries — it now has 22 members — sharing a common interest in arresting missile proliferation. The regime consists of guidelines for exports and an annex listing items subject to controls. It seeks to limit the spread of missiles and unmanned air vehicles/delivery systems capable of carrying at least a 500 kilogram payload at least 300 kilometers. Category I items, the export of which is subject to a presumption of denial, include complete rocket systems such as ballistic missile systems, space launch vehicles, and sounding rockets; unmanned air-vehicle systems such as cruise missiles, target and reconnaissance drones; specially-designed production facilities for these systems; and certain complete subsystems such as rocket engines or stages, re-entry vehicles, guidance sets, thrust-vector controls and warhead safing, arming, fuzing, and firing mechanisms.

Despite continuing efforts to delineate more carefully the items which contribute to proliferation, the MTCR's effectiveness could be reduced significantly over the coming decade because of disagreements over its interpretation among participants; questionable sales by China, even after the country has agreed to abide by the MTCR restraints; missile cooperation among Third World countries which are non-participants; and the proliferation spillovers of hardware and human resources resulting from the breakup of the former Soviet Union and the Warsaw Pact.

Economic and political sanctions imposed by the United Nations Security Council might support the MTCR by enhancing compliance, making it more costly to acquire controlled missile-related systems, and reinforcing the international norm against missile proliferation. "Rewards," in the form of security guarantees or transfer of anti-tactical ballistic missile and air defense systems could also reduce incentives to acquire nuclear weapons and advanced delivery systems in situations where a country's adversary was armed with such threatening weapons systems.

The MTCR is not a treaty. A major step toward strengthening the Regime would be to re-negotiate it as an arms control agreement and to develop a verification regime which would strengthen its purpose of prohibiting or delaying the acquisition of advanced delivery systems for nuclear weapons, thus reducing the risks of nuclear proliferation. Such a verification regime could formalize the confidence-building measures called for under the Regime — information exchanges and notifications — and provide for on-site inspections by an international agency in a manner similar to the IAEA.

The Chemical Weapons Convention (CWC)

The CWC verification regime, like that for START, was designed and negotiated during the Cold War period to assure full compliance by the Soviet Union. Neither Russia nor any other Republic of the former Soviet Union are likely to pose any significant chemical weapons threat, although the destruction of the thousands of tons of chemicals used for weapons purposes will present serious environmental and economic problems. (Indeed the Russians have asked U.S. assistance in an attempt to find a process to recycle at least some of their estimated 40,000 tons of poison gases to help pay their costs for the destruction.) However, the current regime will result in chemical weapons and related facilities of the U.S., Canada, and other developed nations being subjected to extremely intrusive and costly inspections. Proliferators in the Third World will either not sign the Convention or will sign it with the intention of cheating on its provisions.

Approaches to the CWC verification regime have ranged from demands made until recently by the United States for "anywhere/anytime" unimpeded access to any declared or undeclared location or facility to arguments made by the U.K., among other countries, for "managed access" in order to protect sensitive installations and data.

The resulting agreement calls for the parties to accept mandatory access within any challenged site, with the option of up to five days delay for preparation, and the right of the inspected state to determine how much and what kind of access will be granted. This restrictive managed access approach limits both the immediacy and the degree of access to suspect activities and facilities; however, it sets a precedent for mandatory access which could strengthen other agreements curbing proliferation.

Inherent in the debate over this treaty's verification regime was the classic dilemma which could be applied to a number of bilateral and multilateral agreements: how can a party have as much access to the other side's facilities as can be negotiated, while not compromising its own sensitive facilities? The compromise for the CWC verification regime attempts to ensure the protection of national security information and activities against intelligence-gathering challenge inspections; at the same time it strives for a challenge regime which has a reasonable chance of detecting noncompliance by other parties to the agreement.

While the CWC verification regime will not satisfy those who insist upon the criterion of political significance, the regime meets the standard of military significance if only military use of chemical weapons is considered. It meets this standard because of the synergies inherent in the combination of on-site inspections and the advanced means of gathering intelligence from multiple sources available to the U.S., Canada, Russia, and other developed countries which will be signatories to the Convention.

The CWC verification regime could be greatly simplified and still meet the criterion of military significance when only military uses are considered. No verification regime will be able to meet the political criterion and thus deny a Third World country the ability to acquire chemical weapons for terrorist or deterrent purposes. Nevertheless, the Convention will provide the infrastructure for improving international security by setting a standard of compliance for its signatories in the area of chemical weapons nonproliferation.

The CWC verification regime will be strengthened by initiatives taken in the 22-nation Australia Group. That supplier group has expanded its export controls to cover 50 chemical weapons precursors as well as CW-related dual-use equipment, and adopted a multilateral control list of biological organisms, toxins, and equipment.

The Biological and Toxin Weapons Convention (BTWC)

The BTWC has no verification regime; rather, it depends upon national intelligence means, declarations, and reporting without any provisions for intrusive challenge inspections of either declared or undeclared facilities. The recent statement made by President Yeltsin that the 1979 pulmonary anthrax "epidemic" near Sverdlovsk (now Ekaterinburg) was in fact the result of an accident at a biological weapons research facility raises serious questions about this approach. However, it should be remembered that analysis of data from NTM and other sources had earlier led to the conclusion that this was in fact a biological weapons program; this conclusion was reported in the annual reports entitled, "Soviet Noncompliance with Arms Control," issued by the United States.

Recently, the United States has argued that new verification measures "could even hinder effective verification by providing a false sense of confidence," since an inspection might not be able to uncover illegal biological research. For that reason, the U.S. BTWC negotiating team has not tabled any verification proposals, although it states that it will evaluate proposals and suggestions made by the other signatories from a technical and scientific standpoint.

It can be argued that there are lessons to be learned from the UNSCOM biological weapons inspections in Iraq which might apply to a BTWC verification regime. One lesson might be that despite the fact that OSIs cannot detect noncompliance with absolute certainty, the existence of an inspection program, complemented with aerial surveillance, may deter a clandestine biological weapons program or at least add to its costs. If such challenge inspections had been conducted at the biological weapons installation near Sverdlovsk, would they have detected the program? Would the Soviets have allowed such inspections which could have revealed a clear-cut violation to an arms control agreement? The answer to the first question is probably yes; the answer to the second is probably no. However, refusal of an OSI would have reenforced suspicions of illegal activities and led to focus of other collection resources on the facility.

In addition to the BTWC, there has been a recent agreement among the United States, Britain, and Russia which will provide British and American experts with access to Russian biological research sites. The provision for inspections is the most important element of the new trilateral agreement; the experts will be able to visit declared non-military biological sites in Russia to insure that germ warfare work is not being carried out at the sites at the time of the inspection.

Confidence-Building, Transparency, and Conventional Force Regimes

George Lindsey

Aerial Surveillance and "Open Skies"

The use of aerial reconnaissance for the monitoring of military facilities and equipment on the ground has been discussed for many years. For application in Europe it has been considered in two contexts. As a confidence-building measure, the Open Skies Treaty is intended as an instrument for openness and transparency, rather than as an integral instrument for inspection or verification. In contrast, the CFE Treaty negotiations saw aerial inspections as a means of verification. Complicating this picture, the Vienna Document of 1992, following the deliberations of the CSCE, allowed for the use of helicopters or fixed-wing aircraft during inspections, but as part of an extensive set of confidence building measures.

In March, 1992, an Open Skies Treaty was signed by 24 countries. All the territory of the United States, Canada, the European members of NATO, the former non-Soviet members of the Warsaw Pact, Russia, Ukraine, Belarus, Georgia, and other signatories who may join later, will be open for overflight by specially equipped aircraft. This includes large areas beyond the limits of the CFE Treaty, and no parts are to be exempt.

Under the Open Skies Treaty, each participating state is given a quota, specifying the number of overflights which it can make in a year, with the obligation to accept the same number over its own territory. The intention to conduct an overflight of another country must be communicated three days before arrival at a designated point of entry. On arrival, the detailed flight plan is delivered, with the overflight to follow within twenty-four hours.

The Treaty places severe restrictions on the sensors that can be used in the aircraft, and stipulates a minimum altitude for the overflight which is intended to limit the resolution that can be obtained in the imagery. During the first three years after the Treaty comes into force, the only sensors permitted are optical panoramic and framing cameras, to be flown at altitudes which will limit the resolution to 30 cm. After three years, video cameras, line-scan infrared sensors, and synthetic aperture radar will be allowed, with maximum resolution to be 50 cm for the IR devices and 3 m for the radar.

It is to be expected that aerial surveillance will be used for verification in coming years. The CFE Treaty provides for an aerial inspection regime upon completion of the residual validation phase (that is some 44 months after the Treaty enters into force). For multilateral arms control, it should be easier for many nations to take part in aerial inspection than in the more advanced forms of space surveillance. High-resolution surveillance satellites are possessed by only a very few states, and these are unwilling to distribute the imagery beyond their own carefully restricted control.

While the presence of aircraft in national airspace represents a degree of intrusion, the amount of detail which can be observed depends on the sensors which are carried, and on the altitudes flown. When the verification is part of a treaty the sensor packages and altitudes will be carefully controlled by its terms. Also, the inspected party will probably receive copies of the data, and will know what evidence has been collected.

For the type of unilateral arms control which might follow an operation of forcible peace restoration, involving disorganized and non-cooperative forces with a variety of weapons, some forbidden and some permitted, aerial reconnaissance could prove to be extremely important as a form of "coercive verification". Under these circumstances the monitoring states could probably mount any sensors they wished, but their aircraft might be subject to attack from the ground, especially if they flew at low altitude above sites occupied by armed and non-cooperative "inspectees". Such parties would probably resist or prevent any attempt at effective on-site inspections. If it were too dangerous to conduct the aerial inspection at low altitude, much could be observed from higher altitude if there were no restrictions on the types of sensors. An example was provided by the use of American high-altitude U-2 reconnaissance aircraft in Iraq.

When hostile action is not foreseen, there could be value in the use of large helicopters for a combination of aerial and on-site inspection, including unplanned visits to sites at which overhead observation had given cause for suspicion.

There are ample opportunities for synergy within a multilateral aerial surveillance operation, by coordination of overflights and exchange of information. There will be an Open Skies Consultative Commission, pooling of quotas within groups of countries will be allowed,* and all parties are entitled to purchase all of the raw data collected. And, between aerial inspection and other means of verification, synergy is possible in the selection of targets for OSIs and overflights, and in the comparison of imagery obtained by different sensors.

Another opportunity for synergy will be presented if the areas inside of which verification measures such as OSIs are agreed differ from the areas over which aerial surveillance can be conducted. This is already the case between CFE, authorizing verification within a designated area, and not (yet) allowing aerial inspections, as compared to "Open Skies", which permits aerial inspection (but not verification) over a considerably larger area.

Monitoring the Testing of Weapon Systems

Testing of weapons, whether of types already deployed or those under development, offers important opportunities for determining their characteristics. In addition, when an arms control agreement specifies limits to the type of testing to be allowed, it will be necessary to verify that the parties are complying with these limits.

Some testing of nearly all major weapon systems must be conducted outdoors, without overhead cover, and usually on a known test range. It is often accompanied by radio frequency transmissions, including telemetry of instrument readings, radio teleprinters, and voice, which can be intercepted by receivers in space vehicles, aircraft, or suitably located ground stations or ships. In the cases of space and missile launchings a great deal of information can be learned from these communications regarding the characteristics of the vehicle being launched. For tests of surface-to surface missiles one key item is the number of independently targeted warheads, a factor not discernable by examination of the exterior of the missile.

While some arms control treaties permit research, development, and modernization, they may forbid the introduction of new types of weapon. The dividing line between a "modernized" and a "new" weapon is often difficult to define, and verification is likely to be dependent on observation of the testing of systems in the

* For reception of overflights, Russia and Belarus have pooled their quotas of 42 and Belgium, Luxembourg and the Netherlands their 6.

later stages of development, before they have reached final design and long before they are produced and operationally deployed. For example, the ABM Treaty includes a statement that an ABM system based on physical principles other than those being employed in 1972 should be subject to discussion regarding specific limitations. In most cases such an innovation would require extensive testing before deployment could be considered.

Recent arms control agreements have included undertakings not to interfere with NTM, including a commitment to refrain from encrypting telemetry at test ranges. START provides for exchange of telemetry tapes, together with information useful for interpretation of the signals, and sets limits to the practice of returning data to earth in capsules, rather than by telemetry. It seems probable that further cooperation may be offered by invitations for observers to attend tests of various conventional weapons and of space launches. Precedents have been set by arrangements among the USA, Russia, and the UK for visitors to monitor nuclear tests, and to inspect ballistic missile reentry vehicles to determine the number of warheads. This latter activity will become more important with the "downloading" of multiple warheads, as encouraged by START and subsequent unilateral proposals. Such examples of transparency stand in sharp contrast to the former obsessive secrecy surrounding the technical characteristics of strategic missiles.

The systems whose tests reveal the most to monitoring by NTM are those such as space vehicles and long-range missiles which will follow a long trajectory at high altitude, some of it possibly in outer space or international airspace. Verification of an agreement not to put certain types of equipment into orbit, or to launch it for weapon tests, might demand inspection on the launch site. The testing of weapons such as short-range missiles and guns would be much more difficult to verify without the presence of inspectors at the test range.

Another aspect of verification which can involve testing arises when a treaty agrees to limitations on testing. The ABM Treaty allows testing of fixed ground-based ABM systems composed of interceptor missiles, launchers, and radars, but forbids testing of space-based ABM systems or testing "in an ABM mode" of systems originally designed for antiaircraft or antisatellite defence. If research and development is pursued into the design of a system intended for defence against tactical ballistic missiles, satellites, or aircraft, then live testing would be required, and difficulties could arise in verifying that its capabilities fall short of defence against strategic ballistic missiles. A fundamental difficulty lies with the definition of the categories "strategic" and "tactical" ballistic missiles.

It can be seen that testing of weapons can be both a valuable means of verification and also a subject for verification. Except for cooperative situations in which inspectors are permitted to visit test ranges or observe tests, the information will have to be gathered by NTM of a sophistication possessed by very few nations.

Personnel Limitations

Limitations on military personnel were discussed throughout the long and unsuccessful MBFR negotiations, but satisfactory arrangements for verification could not be agreed. The CFE Treaty — sometimes called CFE 1 — was signed* in November 1990, providing for reductions in several types of equipment (Treaty Limited Equipment or TLE), and includes provisions for intrusive verification. However, it left the vexed topics of aerial inspection and personnel limitations to be negotiated in follow-on CFE discussions, pending which the parties undertook not to increase the total peacetime authorized personnel strength of their armed forces. (In fact they made substantial unilateral reductions). A concluding act (often called CFE 1A) on personnel strength was signed in July 1992,

* The signatories were all 16 NATO nations (including the unified Federal Republic of Germany), the U.S.S.R. and the other states of the Warsaw Pact.

by all the members of NATO, all former non-Soviet members of the Warsaw Pact, and the eight states of the former USSR occupying territory already covered in CFE 1.

Difficulty was encountered over the definition of "military personnel", with the ultimate agreement being to include full-time personnel serving with land and air forces, but to exclude most personnel in naval formations and all in organizations employed for internal security. Numerical ceilings were established for each participating state, and it was agreed that information would be exchanged regarding authorized peacetime personnel strengths, command organization, and peacetime locations of formations down to the level of brigades, regiments, and wings, and also to include central headquarters, independent units, and rear services. Prior to an on-site inspection (as agreed in CFE 1), information on personnel will be added to that on TLE (the latter already specified in considerable detail in CFE 1), and the inspectors will have access to facilities such as barracks and messing facilities.

Doubts have been expressed regarding the practical feasibility of verifying troop limitations. Individual soldiers will not be recognizable in overhead imagery. While it would be possible to issue all military personnel with magnetically imprinted and electronically readable identity cards, carrying thumb prints, and to maintain a register listing each person's identifying features, military unit and location, there would be associated administrative costs and a requirement for continual updating. It would also be possible to have a permanently manned inspection post at the entrances to military bases, similar to the "perimeter portal monitoring" for missile production factories in the INF Treaty, and equipped with apparatus able to transmit thumb prints to a central registry, but considerable expense and intrusion would be involved, and deception would always be possible.

While the difficulties posed for direct counting of military personnel may seem formidable, and the provisions less than adequate, it may be that an acceptable level of verification can be attained by the application of synergy. The combined effects of the information exchanges agreed in CFE 1, CFE 1A, and the 1992 Vienna Document give the numbers of soldiers (or airmen) associated with the number of TLE for the units at the inspected site, and the verification provisions should allow a fairly accurate count of the TLE. Rough "orders of battle" and "tables of establishment" can be constructed in the basis of this information, and refined using data from NIM. Other information acquired during a CFE on-site inspection, such as the size of training, barrack, and messing facilities, and numbers of vehicles, would all add clues as to the number of personnel attached to the inspected site. As inspectors gain experience they should become better able to sense differences between the units of a particular army or air force, and to notice deviations from standard practices. It then becomes a judgement by the inspectors as to whether the evidence regarding the numbers of personnel associated with the units appears generally consistent with the stated numbers and the associated equipment.

Methods such as these would be applicable to large well-organized forces composed of standard units armed with standard equipment. They would be less effective for irregular forces armed with a wide variety of non-standard weapons.

The relationship of combat power to personnel strength depends on the type of formation. For naval and air forces, combat power depends primarily on the number and type of ships and aircraft. For an armoured or artillery regiment, it depends mainly on the number of tanks or guns. But for an infantry regiment the personnel becomes relatively more important. And for a force equipped with light, portable easily concealed weapons, but few or no large and more easily countable combat vehicles, aircraft or artillery pieces, verification of combat power will depend on personnel strength rather than weapon counts. Counting weapons will be difficult, and will not provide a reliable indication of the number of personnel.

It seems unlikely that personnel strength will ever be verifiable to a very high degree of accuracy. But as a measure of military strength, it does not need to be known with great precision. More significant than current numbers would be clear evidence of a substantial increase, possibly an indication of mobilization. Here again, synergy should be available by combining direct observation with information collected by a variety of other means.

Arms Transfers

An opportunity to control the proliferation of armaments is presented at the stage of international transfers. The transfer of nuclear weapons is explicitly forbidden by the NPT. At various times certain countries have placed embargoes on export of arms to particular nations (for example, US, Britain, and France against Egypt in 1950, US and Britain against India and Pakistan in 1965, US against Iran between 1984 and 1988). Many industrialized nations have statutory regulations regarding military exports. Negotiations to limit conventional arms transfers held between the USA and the Soviet Union in 1977 and 1978 proved abortive. However, there are examples of groups of industrialized nations attempting to control exports of conventional weapons and their related technology, and recent instances of efforts towards this goal by the United Nations.

The Co-ordinating Committee for Multilateral Export Controls (CoCom) was formed in 1949 by NATO countries together with Japan and Australia, to control the export of technology of strategic significance, directed primarily against the USSR, China, and their allies. Strongly influenced by the USA, a list of Militarily Critical Technologies is maintained, together with lists of munitions, items related to atomic weapons, and items capable of dual use for military and civilian purposes. Attention is paid to re-export to undesired destinations. Restrictions have been eased in recent years, and a CoCom Cooperation Forum has been formed in which most of the countries formerly proscribed have been invited to participate. There is no treaty, and the discussions and decisions are taken in secret. The group can wield sanctions through the power to withhold critical exports from countries or commercial organizations. A form of cooperative verification occurred when Czechoslovakia issued permanent visas in 1990 for American on-site inspectors to ensure that imported sensitive technologies were not being re-exported or diverted to military use.

The Missile Technology Control Regime (MTCR) has already been described in relation to verification regimes associated with weapons of mass destruction. The objects of control are ballistic missiles with payloads of over 500 kg, or ranges of more than 300 km, and of technologies needed for advanced missiles. If these performance characteristics were reduced, it might become possible for the MTCR to address the proliferation of tactical ballistic missiles armed with conventional payloads.

The five nations holding permanent membership on the UN Security Council contribute 88% of global armament exports. This group has begun meetings on restraining the proliferation of weapons of mass destruction and their delivery systems, as well as massive buildups of conventional weapons. They are to draft guidance on export of all conventional weapons, and exchange information on transfers to the Middle East.

In 1988 the United Nations General Assembly issued a call to increase openness in the buying and selling of weapons. A resolution passed in December 1991 established a global register of arms sales, to begin in 1993, and to include main battle tanks, armoured personnel carriers, combat aircraft and helicopters, large-calibre artillery, warships displacing over 850 tons, and missiles with ranges exceeding 25 km. Surface-to-Air missiles are not included. Initially, reports are to be filed on imports and exports. However, states are also invited to report on their own military holdings, national procurement, and relevant policies. The resolution established a Group of Governmental Experts to outline the details of the arms register.

The United Nations placed an arms embargo on South Africa in 1962, and on Yugoslavia in 1991. One of the main functions of the UN Coalition forces in the Persian Gulf has been to stop and search ships with cargoes bound for Iraq. The inspections of Iraqi installations carried out after the end of active hostilities have revealed the great quantity of armaments that had been imported, including both technology and finished weapons, over a period of years and in spite of export controls and arms control treaties such as the NPT. In 1992 an embargo on transfer of weapons to Yugoslavia is supported by monitoring of merchant ship traffic in the Adriatic by joint naval forces of NATO and the Western European Union.

A by-product of CFE will be to accelerate the form of arms transfer known as "cascading" or "trickle-down", in which equipment that has been in service for some years with a large modern force becomes surplus, perhaps because it is being replaced by more modern versions, or perhaps because compliance with an agreement requires reductions. Instead of destroying the surplus equipment it may be sold or given to another less well-equipped country, for whose forces it will represent an improvement.

As more nations acquire the industrial capability to manufacture advanced weapons, the power of groups such as the "permanent five", MTCR, or CoCom to influence non-members by threatening to withhold critical components will be weakened.

For the most part these various activities to establish some form of transparency and control over the international transfer of arms lack arrangements for verification, enforcement, or sanctions. However, the combination of information from the many other arms control activities, including confidence-building, transparency measures, and data exchanges, as well as monitoring by NTM (including commercial intelligence) and aerial and on-site inspection, offer the opportunity to exploit synergy, as long as the flow of data and the applications of analysis are fused together, rather than being compartmented by separate national and bureaucratic agencies. One problem will be to persuade governments to verify activities inside their own country, including the supply of armament by multinational corporations.

V. Adversarial and Coercive Verification

George Lindsey

Most arms control treaties have been negotiated among parties who had reasons to be suspicious of some of the other parties, but nevertheless were prepared to offer cooperation and to expect reciprocal cooperation sufficient to obtain and implement an agreement that would produce lasting mutual advantages. In the cases of the earlier multilateral treaties, the provisions for verification were comparatively weak, due in no small part to the unwillingness of the parties to extend effective cooperation or to permit intrusive measures. The only significant exception prior to CFE was the NPT, which did arrange for regular inspections by the IAEA to nuclear facilities declared by the owners. It should be noted that the terms of the IAEA safeguards permit challenge inspection of an undeclared site, but that up to 1992 no such inspection has ever been conducted.

The history of bilateral US/Soviet arms control began with a degree of cooperation so low as to prolong negotiations of major agreements over periods of many years, and to produce treaties in which verification was confined to NTMs. However, there was an increasing trend to protect NTMs against interference, and a remarkable breakthrough in the case of the INF Treaty, in which detailed data exchanges and highly intrusive on-site inspections were accepted. This trend has continued with START, and with the recent practices in the monitoring of nuclear tests.

The example set by INF was followed in the case of the multilateral CFE, which accepted data exchanges and intrusive inspections, and saw successful "mock inspections" in advance of ratification of the treaty. After its provisional coming into force, a large number of "baseline validation phase" on-site inspections have proceeded relatively well.

The conclusion of an Open Skies Treaty and the finalization of the Chemical Weapons Convention indicate willingness to provide cooperation and accept a considerable degree of intrusion, although it should be noted that Open Skies has been designed for confidence building rather than verification.

In conditions where there is compliance with the agreements, little reason for suspicion of violations, and good cooperation with the inspectors, verification should proceed in a satisfactory manner, and contribute to an ever-growing atmosphere of transparency and confidence. In such conditions, the verification could be described as "cooperative". But one of the main purposes of verification, and of arms control itself, is to contain apprehension and help maintain stability when relations have deteriorated and there is even a perceived prospect of armed conflict. An early sign of the approach of such a situation is likely to be a reduction or even outright refusal of cooperation with verification, although possibly short of blatant disregard of the legal requirements of the treaty.

Another possibility for the occurrence of adversarial conditions of verification could arise in a multilateral treaty involving pairs of states with long-standing bilateral disputes not related to the problems of the other states party to the treaty. Examples could be Hungary and Romania,* Turkey and Greece, or Armenia and Azerbaijan, in CFE. These states could use some of their inspection quotas against their rival, and would be unlikely to receive much cooperation. In circumstances such as these, verification could be described as "adversarial".

If the situation is not one of trust and cooperation, but one of suspicion and obstruction, verification will become much more dependent on NTM and on the synergy provided by combining the evidence from all forms of monitoring. The requirements for verification to be "militarily significant" may become more demanding, and more data may be desired. Obstruction may reveal clues as to what may be being concealed, and other changes in the behaviour of the adversary could be significant.

* The recent bilateral agreement between Hungary and Romania for Open Skies flights bodes well for better co-operation and transparency.

Like the normal arrangements for regular auditing of a reputable commercial enterprise, verification should be designed to be able to detect non-compliance, whether due to inefficiency, or intentional violation. A verification regime which is totally dependent on a high degree of cooperation could be dangerously vulnerable in times of deteriorating relations.

Most discussions of verification have been in terms of a particular agreement, negotiated among participants of equal status, and containing carefully worded provisions for verification. In view of the increase of violence in the post-Cold War world, the experience in Iraq, the serious troubles in the Balkans, the instability in other parts of Eurasia, and the rejuvenated willingness of the United Nations and possibly other multinational organizations to restore or establish peace by the presence or actual use of force, it is quite possible that a somewhat different type of arms control and disarmament (perhaps better described as "demilitarization") will become necessary. It would be imposed by a legally authorized international body on an unwilling party, but with clearly defined terms as to which armaments are permitted and which forbidden. Such a requirement would need to be verified, but it would be desirable to keep to a minimum the degree of intrusion, and to try to make it effective without depending on wholehearted cooperation by the inspected party.

Thus there is a spectrum of conditions under which verification may be needed. It extends from cooperative through adversarial to coercive verification. In circumstances of good trust and cooperation among willing participants there should be few problems.

With deteriorating to poor relations among parties, who have entered into agreements, but are prepared to carry them out only to the minimum legal extent required by the agreement, or perhaps somewhat less than this, and perhaps accompanied by deception and evasion, there is an adversarial situation, but it is between equals bound by an obligation.

The extreme case, is a one-sided situation between a powerful coalition with a high degree of international authority (eg the UN) and a rogue state (or states) which has been acting in a way to endanger international security, and had been ordered by the international authority to divest itself of some (or all) of its armaments. In these circumstances, instead of verification of adherence to a negotiated treaty, the problem will be to discover to what extent the rogue state is complying with the orders to disarm, whether or not it has agreed so to do, and whether or not it cooperates with the verification.

An example of verification in an adversarial situation has been provided by the experience of the UN Special Commission (UNSCOM) and the IAEA in Iraq . Since it arose from conditions imposed by the victors on the losers of a war, it differs from the circumstances of a treaty voluntarily agreed by all participants, in conditions of peaceful (though not necessarily friendly) negotiations. Nevertheless, it illustrates the difficulties encountered by inspectors when the inspected party employs concealment, evasion, and deception in order to prevent discovery of its armaments and the capabilities of its facilities. It also has demonstrated the importance of synergy in combining the results of observations from satellites, aircraft (including U-2 sorties), helicopters, on-site inspections, and information from defectors as well as from the Iraqi authorities.

The failure of the IAEA safeguards inspections to discover the extent of the Iraqi program to acquire nuclear weapons demonstrates the need for challenge inspections of undeclared sites. But lacking any intelligence capability of its own, the IAEA can only rely on synergy to select sites worthy of challenge. With the concern for nuclear proliferation growing, similar situations can be foreseen in other parts of the world, under conditions more likely to be adversarial or coercive than cooperative.

VI Synergistic Effects

Among Verification and Confidence-Building Methods

Patricia Bliss McFate and Sidney N. Graybeal

Monitoring arms control agreements is primarily a function of intelligence collection and analysis, using all information available concerning a particular activity or location. In certain developed countries — and most particularly the United States and Russia — this is mainly accomplished by **national technical means (NTM)** which includes: reconnaissance satellite systems using photographic, infrared, radar and electronic sensors; ground-, air-and sea-based radars and other sensors; seismographs; communications collection stations; and under-water acoustic systems. The terms, "PHOTINT," "RADINT," "ELINT," "COMINT," "SIGINT," and "MASINT," describe areas which would be included in NTM.*

In recent years, there have been proposals for international technical means (ITM) or multilateral technical means (MTM), ISMA and the Canadian PAXSAT, for example, or a satellite system shared by several European countries, such as HELIOS. Developing countries rely upon **national intelligence means (NIM)** which include the sum of the country's intelligence collection and analysis capabilities minus the technical systems described above which these countries do not possess. NIM is concentrated in the area of "HUMINT," collection by human sources, and the analyses of open-source information such as media or commercial satellite photography.

An example of capitalizing on the synergistic effects between NTM and NIM, the recently-formed Nonproliferation Center established by the U.S. Intelligence Community, will support international nonproliferation regimes. It will also seek to enlarge the pool of experienced, well-trained experts committed to the nonproliferation mission.

Whether NTM, ITM, MTM, or NIM, monitoring systems are complemented by **cooperative measures**. Cooperative measures are aptly named. While NTM is a unilateral activity, cooperative measures are negotiated or volunteered measures which require the cooperation of the other party or parties to the agreement. For example, the INF Treaty provides for the opening of the roofs of the launchers for ICBMs to assure by NTM that the launchers do not contain prohibited, intermediate range SS-20 ballistic missiles.

The START agreement's telemetry provisions greatly enhance the use of NTM to verify the throw-weight and "new type" provisions of the Treaty. These provisions require, with limited exceptions, unencrypted transmission of ballistic missile telemetry; and they mandate the exchange of detailed telemetry data tapes, interpretive data, and acceleration profiles after each ballistic missile flight test.

Included under the term "cooperative measures" are the following areas; examples are drawn from a variety of arms control verification regimes.

Data or **information exchanges** are comprehensive sets of information frequently covering the numbers and locations of treaty-limited equipment (TLEs) or treaty-limited items (TLIs), technical characteristics of specific weapons and their associated launchers, site diagrams, and information regarding force structure and movements.

Notifications often include advance information on planned flight test activities, movements of TLEs/TLIs, changes in the number of TLEs/TLIs, planned changes in personnel or existing units, conversion or elimination of TLEs/TLIs, and requested or planned on-site inspections.

* PHOTINT is photographic intelligence; RADINT is radar intelligence; ELINT is electronics intelligence; COMINT is communications intelligence; SIGINT is signals intelligence; and MASINT is measurements intelligence.

On-site inspections (OSIs) provide the verifying party with direct access to the facilities and TLEs/TLIs of the other side. There are four general types of on-the-ground OSIs: pre-agreement trial inspections; routine or short-notice inspections of declared facilities; challenge or suspect-site inspections of undeclared or suspect sites; and invitational inspections, offered by a country in order to remove ambiguities or reduce uncertainties.

Aerial Inspections include inspection of sites and TLEs/TLIs using a wide variety of sensors, many of which are similar to those described above for NTM/ITM/MTM, carried aboard fixed-wing aircraft or helicopters for overhead inspection purposes.

Although **Open Skies** is considered a transparency measure rather than a verification mode, because it is a cooperative form of aerial surveillance involving sensors and human observers, it offers the potential for synergies with the verification methods discussed above.

Confidence-Building Measures (CBMs), in the form of notifications, calendars of military events, information exchanges, and invitational observations of military exercises also hold potential for synergistic effects with NTM/ITM/MTM/NIM and certain cooperative measures. While various verification methods can be CBMs, not all CBMs will contribute to verification.

Synergistic Effects Among Methods

NTM/ITM/MTM and Data Exchanges. NTM/ITM/MTM provide limited, but useful information on the nature and scope of information expected to be included in data exchanges; on the other hand, data exchanges provide highly useful information for enhancing present and future monitoring capabilities. For example, information on technical characteristics, numbers, and locations of TLEs, and site diagrams provides "sanity checks" on data based on NTM/ITM/MTM and provides guidance for revising and upgrading the overall conclusions and capabilities of NTM/ITM/MTM. The CFE Treaty includes data exchanges on: types, nomenclature, and calibre of armaments; locations by geographic name and coordinates of TLEs, including numbers and types of armaments at each location; organizational structure and nomenclature of land and air forces; and photographs presenting a side, top, and front view of each TLE. The accuracy of much of these data can be confirmed by OSIs, as will be discussed later. Integrating such a comprehensive data base with that available from NTM/ITM/MTM provides a sound foundation for assuring effective verification of the Treaty. The synergies resulting from periodic updating of the information in the data exchanges and the continuing iteration between these data and those from NTM/ITM/MTM clearly enhance verification capabilities.

NTM/ITM/MTM and Notifications. As in the case of data exchanges, NTM/ITM/MTM has only a modest effect on notifications, but notifications have a substantial effect on NTM/ITM/MTM. NTM/ITM/MTM can provide insights regarding expected notifications, and in some cases confirm that the notified action has taken or is taking place. Prior notifications, on the other hand, can trigger a variety of NTM/ITM/MTM collection activities; in many cases, these activities will result in the acquisition of valuable information which might have been missed without such notifications. For example, the START agreement requires extensive and comprehensive notifications on a variety of activities associated with TLIs, including: movements; conversions and eliminations; a variety of flight tests; reduction in attributed warheads; operational dispersals; transfer of TLIs to/from another country; timing of open displays; and planned OSIs. The movement notifications alone involve most significant activities associated with the transit of TLIs. The START notifications will alert a variety of NTM monitoring systems which can be focused on specific activities, thus enhancing their effectiveness. In addition, the combination of the START notifications of flight tests and the provisions in the agreement calling for no denial of telemetric data contribute significantly to the effectiveness of NTM.

NTM/ITM/MTM and OSIs. The synergistic effects between NTM/ITM/MTM and OSIs are very high in both directions. Information from NTM/ITM/MTM can be used to trigger, focus, and evaluate OSIs. OSIs can provide "ground truth" for a variety of NTM/ITM/MTM systems which reinforces their credibility. In the implementation of UN Security Council Resolution 687 (1991), for example, while NTM/ITM/MTM could not see inside buildings where suspected illegal activities were taking place, OSIs provided access to the internal facilities and activities; combining these two sources of information clearly enhanced knowledge and thus overall verification of Iraqi activities. This example also applies to arms control verification regimes.

Verification regimes associated with the TTBT and PNET include OSIs utilizing complex technical equipment such as CORRTEX. These inspections and technical measurements provide valuable data for calibrating NTM's seismic measurements. NTM can provide the information necessary for directing the location and timing of the OSIs.

While NTM can provide information on the activities which will be covered by OSIs in the START agreement, confirming and/or correcting NTM data by OSIs gives the necessary precision to ensure effective verification and at the same time gives a basis for improving future NTM capabilities. Similarly, NTM data lends credence or raises questions about information obtained by OSI which cannot be otherwise verified, for example, the suspected presence of illegal activities within a facility. The net result of these very strong synergistic effects is enhanced verification and confidence in compliance with the agreement.

NTM/ITM/MTM and Aerial Surveillance. Information from NTM/ITM/MTM can be used to target aerial surveillance flights. Such flights can frequently cover sites which may not be accessible on a timely basis by NTM/ITM/MTM systems. They can fill in gaps in NTM/ITM/MTM coverage by operating at lower altitudes, often under the weather, at times when NTM/ITM/MTM will not be within the detection or observation range of the suspect activity. Aerial inspections also allow for real-time interaction between a sensing device and an inspector, and they permit release of data without compromising sensitive sources and methods. Open Skies' wide area coverage of a variety of locations on a timely basis complements NTM/ITM/MTM and aerial inspections, and it also avoids the concerns associated with sensitive sources and methods.

NTM/ITM/MTM and CBMs. CBMs are likely to become increasingly important to transparency and openness and, in turn, to arms control verification. There are some synergies among notifications, information exchanges, and observations which should be taken into account. In the side agreement to START regarding nuclear-armed SLCMs, for example, there is a requirement for unilateral declarations of the numbers of such weapons in order to affirm compliance with the overall nuclear-armed SLCM quota; these declarations, which are one form of CBMs, can be supported by NTM.

CBMs contained in the 1986 Stockholm Document include calendars of military events such as major exercises and invitational observations of such activities; the data drawn from these can be used to enhance the overall capabilities of NTM/ITM/MTM. In some cases, NTM/ITM/MTM could provide early indications of planned military activities requiring implementation of CBMs and could detect certain activities which should have been subject to CBMs.

Synergistic Effects among Cooperative Measures. The synergistic effects between OSIs, data exchanges, and notifications are of high value. They tend to be mutually reinforcing in many different ways. Data exchanges pinpoint locations which can be targeted for OSIs; OSIs can confirm data provided in the exchanges or detect inconsistencies. Notifications can trigger and direct both OSIs and aerial surveillance; in turn, they can confirm the accuracy of the notifications. Aerial surveillance can do preparatory work for OSIs by developing unclassified site maps and pinpointing promising search strategies; it can also monitor the perimeter around a facility prior to the arrival of an OSI team; verify certain baseline data; document elimination of TLEs; and monitor compliance with military exercise limitations. OSIs hold the potential to "flush out" illegal TLIs which can then be detected by aerial surveillance or other means.

NIM and Data Exchanges. NIM can provide a useful check on information provided in data exchanges. Information obtained from human sources and in open literature falls into a number of data categories, for example: sightings of weapons, weapon launching pads or bases, and submarine or naval sightings; construction of new roads, tunnels, emplacements, military camps, airfields, and radar stations; and military budgets and personnel levels. This information can be compared with that provided in data exchanges. In addition, since human sources may be unreliable, and open literature may include "planted" material, data exchanges are a means of checking on the reliability of the sources for NIM.

NIM and Notifications. NIM sources can also provide information associated with notifications, such as loading or unloading activities, evacuation of families from certain areas, movement of military convoys, activity at underground installations and caves, and military training activity. As in the case of data exchanges, the NIM sources may add to the knowledge base obtained through the notification process; and again, notifications may well serve as a check on the reliability of the NIM sources. In the Cuban Missile Crisis, for example, U-2 photography of Cuba was focussed on areas highlighted by human source information; the photographs provided a reliable, objective view to counter what was at times misleading and inaccurate information.

NIM and OSIs. The synergistic effects between NIM and OSIs are very high. Information from NIM can be used to trigger OSIs. In the UNSCOM inspections, for example, information from a "whistle blower" provided the inspectors with the information necessary to know that material was being moved clandestinely out of an area in advance of the inspection.

NIM and Aerial Surveillance. In addition to reports from human sources such as refugees, whistle blowers, defectors, and agents, NIM sources include blueprints of facilities, studies, media reports, photos, and commercial aerial surveillance. Information from NIM can provide clues about activities which merit closer examination by aerial surveillance. Such information, for example, can provide advance warning of activity in time to schedule flights over specific geographical areas. Conversely, aerial inspections may detect suspect activities which can become the focus of NIM.

NIM and Confidence-Building Measures. Information exchanges and notifications are two areas in which it is possible to compare material received from NIM sources with that received through CBMs. The CSBMs contained in "Vienna Document 1992" will provide comprehensive information on military forces, weapons, and budgets which will be invaluable data bases and which can be checked against NIM. Also, information gathered through the proposed scientific exchanges envisioned by the BTWC regime could be correlated with NIM source material.

Table 1 presents in tabular form the conclusions reached in this chapter. It is ordered beginning with NTM/ITM/MTM because these monitoring methods are the foundation for verification decisions in most developed countries today. The chart, however, recognizes the value received when a form of NTM/ITM/MTM is complemented by one or more cooperative or confidence-building measure.

Among Regimes, Agencies, Countries, and Regional Groups
George Lindsey

There are close similarities among verification, monitoring, and intelligence, but they are not the same. Both verification and intelligence rely on monitoring, and verification relies on intelligence. However, the sensitivities over preservation of national security have created major obstacles to acceptance of effective means of verification, and it has proved necessary to design regimes for verification in such a way as to minimize the opportunities which they present for collection of collateral intelligence. The problem is that while the signatories to an arms control agreement are, at least in part, partners

Table 1:
Synergies Among Verification Methods

	NTM/ ITM/MTM	NIM	Data Exchange	Notifi- cations	OSIs	Aerial Inspections	Open Skies	CBMs
NTM/ITM/MTM	—	M	L	L	H	M	M	L
NIM	M	—	L	L	H	M	M	L
Data Exchange	H	H	—	L	H	M	L	L
Notifications	H	M	L	—	H	H	H	M
OSIs	H	H	H	M	—	H	M	M
Aerial Inspections	M	M	L	L	H	—	M	L
Open Skies	M	M	L	L	M	M	—	M
CBMs	L	M	L	L	L	L	M	—

Helps or Impacts Items Listed Horizontally

Helps or Impacts Items Listed Vertically

H = High Value Synergies
M = Medium Value Synergies
L = Low Value Synergies

with a common interest, in matters of intelligence each nation is inclined to regard at least some of the others as potential (if not actual) opponents.

Despite such sensitivities, there are lessons to be derived from the experiences of intelligence organizations and agencies which can be applied to verification. It is the practice of many intelligence agencies to keep the groups involved in the various means of collection of information in carefully separated "watertight" compartments. Primary reasons for this are to preserve security regarding the means of collection, and the identities of informers and agents, and to minimize compromise in the event that secrecy is breached. Assembly and analysis of the information collected from the various sources is performed by a separate group, very much smaller than that concerned with collection.*

Synergy consists of combination and correlation of inputs from several sources producing a final result beyond what could be achieved by the separate inputs themselves. In the examination of major failures of intelligence to foresee serious disasters it has usually been found that evidence indicating the coming situation had been collected, but not taken into account by the all-source analysis.

A further problem is caused by the rivalry sometimes present among the intelligence agencies within a major country, which vie for power and influence and refuse to share their source material.

Within a large nation, some of the organizations and agencies likely to conduct collection and analysis of intelligence that could aid in verification of arms control agreements could include: army, navy, air force, department of defence, foreign office, other ministries such as commerce, energy, or science & technology, civilian law enforcement agencies, and non-government organizations concerned with defence and arms control.

There may be a better opportunity to apply synergy to verification than to intelligence. Because of the reduced pressure for secrecy there will be less reason to keep the various sources of information separated from one another and from the group responsible for synthesis and analysis. Useful feedback from analysts to sources should be easier to maintain. When facts emerge which are difficult to explain, it should be possible to obtain the advice of well-informed persons or groups not integral to the intelligence or verification communities. On the other hand, considerations of commercial secrecy are likely to be more evident in the verification of some types of multilateral arms control.

The comparison of the voluminous information required by data exchanges with the observation of actual deployments offers a form of synergy dependent on careful selection and analysis. If aerial inspection is permitted, this should offer great opportunities for synergy with on-site inspections, for example in scheduling of visits, providing cues for the inspectors to pursue, and for the interpretation of results. Timing of overflights could be synchronized to observe locations between the request for an on-site inspection and the arrival of the inspection team, to monitor possible removal of equipment. If permanently sited unmanned sensors are deployed, their signals could provide useful cues as to locations deserving inspection or overflight, or evidence of hurried removal prior to inspection.

It may be more difficult to obtain synergy with the inputs from NTM sources, since they retain the need to protect secrecy regarding the means and success of collection. However it

* It has been estimated that in the 1970s the United States expended 91% of its intelligence costs on collection, and only 9% on all-source analysis. See "Intelligence and Arms Control Verification", by Michael Herman. Chapter 19 in Verification Report 1991: Yearbook on Arms Control and Environmental Agreements. J.B. Poole (ed), VERTIC, London, 1991. p. 191.

should be possible to provide overhead imagery collected from military satellites with its resolution degraded to the level being achieved by contemporary commercial satellites and aerial photography, and to make available much of the intelligence assembled from study of open sources.

The most difficult problem in achieving effective synergy may come from bureaucratic resistance to the establishment of an adequate agency for synthesis and analysis. It could be regarded as unwanted competition by the already established intelligence agencies, lest it draw off some of their funding, talented personnel, secrets, and power. But without a competent analysis agency the opportunities for effective verification, let alone synergy, will never be exploited.

Verification of multilateral arms control agreements provides an international dimension to the exploitation of synergy at an organizational level. In the case of intelligence, the formation of military alliances has offered the opportunity for synergy, both for collection and for analysis. Geographic location gives some countries a particularly advantageous opportunity for collection of information, both strategic and tactical, regarding the activities of a powerful neighbour. The thorough understanding of a particular country needed for accurate analysis is most likely to be possessed by a neighbour familiar with the language and maintaining an active cross-border intercommunication. Therefore a pooling of both sources and analysis should produce an improved product. In practice, the cooperation in exchange of intelligence among countries has been graduated according to the closeness of the alliance, and has produced most benefits for the smaller members. However, reticence to share the products of NTM is still present.

The case should be somewhat different for multilateral verification, and quite possibly complicated by local bilateral antagonisms. The quotas for on-site inspections and aerial overflights are likely to be based on the number of declared sites, without regard for the relative locations of inspecting and inspected parties. Synergy should be achieved by a systematic allocation of inspections among allied partners, arranging for them to be carried out by the countries most knowledgeable of the equipment, forces, and customary behaviour of the country being visited. If all inspections are to be restricted to using the same sensors, there should be no reluctance to full sharing of the data obtained by them.

So far, verification has been organized in terms of the relevant treaties for arms control, with no interaction affording opportunities for synergy among regimes. However, the number of regional groups and international regimes and agencies now involved to a greater or lesser extent in multilateral arms control is considerable. Regional groups include the North Atlantic Treaty Organization (NATO), the North Atlantic Cooperation Council (NACC),* the Conference on Security and Cooperation in Europe (CSCE), the Western European Union (WEU), the European Community, and the Organization for the Prevention of Nuclear Weapons in Latin America (OPANAL). International Organizations include the United Nations and agencies created by it, the Coordinating Committee for Multilateral Export Controls (CoCom), the Nuclear Suppliers' Group, the Australia Group. the Zangger Committee, and the Missile Technology Control Regime. As described in the following section, some of the treaties have created bodies to implement the agreements.

* The membership of the North Atlantic Cooperation Council consists of members of NATO, the former Warsaw Pact and successor states of the former U.S.S.R.

For synthesis and analysis of the data obtained in the course of multilateral verification, much depends on the organization of the regime. If decisions concerning charges of non-compliance are left to individual parties there could still be synergy in the sharing of data and in cooperation in analysis, especially among allies. Collecting, correlating, and storing the data in readily accessible form will require competent staff with modern data processing equipment, and it would be extremely inefficient to have this task repeated by all of the parties to a multilateral treaty. Nevertheless the desire to retain an expert national intelligence operation is likely to limit the extent to which countries will be prepared to pool their resources.

If a central multinational agency were to be formed for the collection and analysis of data, there would be a maximum opportunity for synergy, albeit accompanied by some danger of internal conflict and obstruction. In the case of the Non-Proliferation Treaty, the IAEA has functioned without serious contention, but there is some doubt as to its ability to detect steps towards nuclear proliferation on the part of nations wishing to conceal such activity.

In the case of verification in a starkly adversarial situation (such as the post-war Persian Gulf) between a multinational coalition and an uncooperative opponent, it would be desirable to have a central organization for collection and analysis, and legitimate to expect considerable synergy, but it could be necessary to exclude the adversary from the central organization.

For the verification of an agreement among willing participants, each prepared to fulfil his undertakings, synergy should aid in the establishment and maintenance of confidence. But the arrangements should be designed to continue to function effectively when one or more of the signatories comes under justifiable suspicion, and to be able to discover violations (if they really occur) as well as to confirm compliance (if it is in fact being observed). The ship should be built to survive storms as well as to sail handsomely in the best of weather.

Among Implementing Bodies and in the United Nations
Sidney N. Graybeal

Most arms control agreements call for the establishment of an implementing body whose purpose is to assure implementation of all provisions of the agreement. These functions usually include: establishing agreed procedures called for by the agreements; handling ambiguities and clear cases of non-compliance; assuring that called-for data exchanges and notifications are performed in a timely manner; and monitoring or conducting permitted on-site inspections (OSIs).

In addition to implementing bodies established by the agreements, separate national agencies are created to conduct specific activities, for example, the U.S. On-Site Inspection Agency, which was created to conduct the OSIs which that country is allowed by the INF, START, and CFE agreements. The United States also established a Nuclear Risk Reduction Center (NRRC) which has become the mechanism for transmitting data exchanges, notifications, and requests for OSIs. The former Soviet Union established one body, Nuclear Risk Reduction Center, which performs the functions of both the OSIA and the U.S. NRRC. The IAEA is the implementing body for the NPT, although its functions are restricted to assuring that nuclear materials are used only for peaceful purposes. In the case of the BTWC, the UN Security Council itself performs the functions of an implementing body.

Table 2 summarizes some arms control agreements and regimes associated with non-proliferation, their implementing bodies, and the verification methods employed. It should be noted that there are formal implementing bodies designated in some agreements, less formal arrangements involving use of the UN Security Council and its bodies in other agreements, and some agreements with no formal implementing mechanisms.

The potential synergistic effects among these formal and informal implementing bodies should be recognized and utilized by assuring closer cooperation and exchanges of data between them. A few specific examples follow:

- In the bilateral area, the ABM Treaty Standing Consultative Commission (SCC), the INF Treaty Special Verification Commission (SVC), and the START Joint Compliance and Inspection Commission (JCIC) have similar responsibilities and charters. All rely on NTM, and the SVC and JCIC both are responsible for cooperative measures including data exchanges, notifications, and OSIs. In addition to benefitting from lessons learned in these separate bodies, there should be opportunities to coordinate OSIs in a manner which improves their effectiveness. These opportunities are recognized and being implemented by OSIA in its operations.
- In the multilateral area, the data acquired by flights permitted under the Open Skies agreement will be valuable to the IAEA, the CWC Conference of State Parties, and the CFE Joint Consultative Group. Conversely, data from these bodies and their requirements will make the Open Skies flights more effective in acquiring useful information.
- Future regional arms control implementing bodies will have to rely on the individual parties' NIM, data provided by respected international bodies such as the IAEA and Open Skies Consultative Committee, and shared information from nations with advanced NTM/MTM. NIM can focus requests for data from outside sources; conversely, data from these outside sources can focus NIM resources.

Within the United Nations, there are beneficial synergies from the activities of UNSCOM and IAEA in the case of inspections of Iraq. Similar situations may occur in the future in which UN resolutions and sanctions are directed at assuring compliance with multilateral agreements, for example, the CWC, and regional agreements, such as the Joint Declaration for Denuclearization of the Korean Peninsula.

The United Nations should give serious consideration to establishing a new body which would perform expanded functions of the IAEA and UNSCOM for current and future agreements constraining the proliferation of weapons of mass destruction and their delivery systems.

The United Nations should establish a body for acquiring, integrating, and analyzing information from a variety of sources to assist in verifying compliance with multilateral and regional agreements. Determination of its scope and function and assessments of its effectiveness should take into account the synergistic effects among its sources of information and the countries involved. Such a body could provide information to all states which are parties to current and future non-proliferation agreements and to those UN bodies charged with implementing these agreements.

Table 2:
Synergies Among Agreements and Regimes

Treaty / Regime / Agreememt	Implementing Body	Signatories* (October 1992)	Verification Method
Rush-Bagot Agreement - 1817	None	2	NIM
Geneva Protocol - 1925	UN Security Council	129	NIM
Antarctic Treaty - 1959	None	40	NTM/NIM/OSI (Antarctic only)
Limited Test Ban Treaty - 1963	None	3** 117	NTM/NIM
Latin America Nuclear-Free Zone Treaty (Tlateloco) - 1967	Agency for the Prohibition of Nuclear Weapons in Latin America (OPANAL)	25	IAEA safeguards (auditing, sampling, seals, reports, OSI) NIM
Outer Space Treaty - 1967	None	92	NTM/NIM/OSI (moon, celestial bodies)
Non-Proliferation Treaty (NPT) - 1968	International Atomic Energy Agency (IAEA)	143	IAEA safeguards, NIM
Seabed Arms Control Treaty - 1971	UN Security Council	86	NTM/NIM/OSI (seabed)
Anti-Ballistic Missile Treaty (ABM) - 1974	Standing Consultative Commission (SCC)	2	NTM
Threshold Test Ban Treaty (TTBT) - 1974***	Bilateral Consultative Commission (BCC)	2	NTM, information exchanges, hydrodynamic yield measurements, OSI, seismic monitoring on territory
Nuclear Suppliers Group - 1974	None	27	NTM/NIM
Biological Weapons Convention (BTWC) - 1975	UN Security Council	108	NTM/NIM
Underground Nuclear Explosions for Peaceful Purposes (PNET) - 1976***	Joint Consultative Commission (JCC)	2	(See Verification for TTBT)
Environmental Modification Convention (ENMOD) - 1977	Consultative Committee of Experts (CCE)	56	NTM/NIM
Intermediate-Range Nuclear Forces (INF) - 1987	Special Verification Commission (SVC)	2	NTM, data exchanges, notifications, OSI
Missile Technology Control Regime (MTCR) - 1987	None	22	NTM/NIM
Australia Group - 1988	None	22	NTM/NIM
Conventional Armed Forces in Europe (CFE) - 1990	Joint Consultative Group) (JCG)	29	NTM, data exchanges, notifications, OSI
Strategic Arms Limitation and Reduction Treaty (START) - 1991	Joint Compliance and Inspection Commission (JCIC)	2**** 5	NTM, data exchanges, notifications, OSI
Vienna Document - 1992	Conflict Prevention Centre (CPC)	52	NTM, OSI (visits), data exchanges, notifications
Open Skies Treaty - 1992	Open Skies Consultative Committee (OSCC)	25	NTM/NIM
Chemical Weapons Convention (CWC) - 1993	Organization for the Prohibition of Chemical Weapons (OPCC)	130*****	NTM, NIM, OSI (visits), data exchanges, notifications

* Numbers provided by External Affairs and International Trade Canada.

** Original Signatories (U.S., U.S.S.R., U.K.).

*** Verification Protocols ratified in 1990.

**** Original Signatories (U.S. and U.S.S.R.).

***** As of 19 January 1993.

VII The Impact of Verification Synergies on the Nature and Scope of Various Treaty Regimes Which Curb Proliferation

Patricia Bliss McFate and Sidney N. Graybeal

Numerous agreements and collateral approaches are being pursued to curb the proliferation of weapons of mass destruction and their advanced delivery means. Proliferation of conventional weapons are contributing to regional instabilities and need to be constrained. In each of these agreements or approaches there is the need to assure that all parties are complying with the limitations whether contained in formal treaties,in reciprocal actions or in unilateral initiatives. Any evaluation of the effectiveness of an existing or proposed verification regime, whether formal or informal, must take into account the number of beneficial synergies associated with the regime.

Many questions are being posed concerning planned and likely future multilateral agreements, their verification regimes, and the potential verification synergies associated with these regimes. The following are examples of these questions and multilateral agreements.

- What verification measures will be needed to support agreements regarding a global cut-off in the production of plutonium and highly-enriched uranium for nuclear explosive purposes?
- What verification measures will be required for further reducing the testing thresholds for TTBT/PNET, for testing limited to safety purposes, and for a moratorium and a CTB?
- What lessons from the UNSCOM inspections can be applied to future regional initiatives to constrain proliferation, and what verification measures will be necessary to strengthen these initiatives?
- What verification regimes, however informal, can address regional instabilities resulting from the infusion of advanced conventional weapons and exacerbated by proliferation of weapons of mass destruction and their delivery systems?
- Are there verification actions, such as strengthening IAEA capabilities, which could enhance the viability and effectiveness of the NPT?
- What verification technologies and modes make sense for a BTWC verification regime? For enhancing the CWC regime?
- How can verification contribute to further nuclear rollback?

Verifying a global cut-off in the production of nuclear materials will depend on the number of parties involved, the specific countries participating in a cut-off agreement, and each country's willingness to accept cooperative measures, including OSI and aerial inspection/Open Skies. From a U.S. perspective, NTM will be the foundation for verification of any such agreement, but NTM will need to be complemented by cooperative measures. Those countries with less advanced NTM, or less access to such NTM data, will have to place greater reliance on NIM and cooperative measures, and they will need to rely on IAEA safeguards.

While a cut-off in the production of fissionable materials will curb proliferation of future nuclear weapons, it will not address weapons already in existence, for example, the thousands of "Soviet" tactical nuclear weapons which need to be safely stored, dismantled, and destroyed. Lessons learned in this process could well be applied to the destruction of other countries' nuclear weapons. The first step is the determination of the exact number of these weapons. NTM can provide a reasonable estimate, but it cannot provide precise numbers and locations; therefore, cooperative measures will be required. Such measures should include data exchanges on the numbers and types of nuclear weapons stored at specific, designated storage sites, notifications of their movements, and invitational OSIs to confirm these data and to help monitor weapons storage and dismantling or destruction.

The dismantlement and destruction of such large numbers of nuclear weapons will require considerable time and effort by nuclear weapons experts. As soon as possible, all the weapons need to be disabled and placed into secure and monitored storage sites. Their subsequent dismantlement and destruction should take place in designated facilities under observation by international experts consistent with national security. Verifying the actual dismantlement and "destruction" of all of the tactical nuclear weapons which belonged to the former Soviet Union will be very difficult if not impossible. However, the totality of information being provided by CIS and Republic officials and acquired through OSI by U.S. experts, combined with data from NTM and NIM, should provide high confidence in the eventual destruction of the preponderance of these weapons.

Determining the synergistic effects between the various monitoring techniques associated with the elimination of the delivery systems of tactical/theater nuclear weapons and the nuclear warheads per se must await a decision on whether there will be a formal agreement on verifying these reductions and the specifics of the resulting verification regime. If NTM and NIM were combined with cooperative measures such as the development of specific timetables and procedures, the requirement of data exchanges and notifications, and the use of simple verification technologies to aid on-site inspections, clearly there would be significant synergistic effects.

Verification of the nuclear testing treaties TTBT and PNET is supported by the right to use in-country sensing of seismic disturbances caused by either earthquakes or nuclear explosions and on-site hydrodynamic sensors placed in emplacement holes at the U.S. and Russian nuclear test sites. Determining the yield of "non-standard" tests — those tests generally used for evaluation of weapons effects and the operation of military systems in a nuclear environment — is complex, and the protocol provides for the use of additional hydrodynamic measurement devices such as the U.S. method, HYDROPLUS. This technology uses the measurements of the peak stress, peak particle velocity, and ground shock velocity at ranges beyond the range of the "standard test" yield methodology, CORRTEX. The synergies associated with using the suite of HYDROPLUS data with new data processing techniques produces more accurate determinations of the yield and the degree and limit of any uncertainties. Knowledge gained by the use of this new method will contribute to future bilateral and multilateral agreements in which the testing thresholds for TTBT/PNET are reduced, testing is limited to safety purposes, and a CTB is negotiated. Sharing this knowledge will be beneficial for verifying multilateral agreements.

What lessons have been learned from the UNSCOM experiences in Iraq which might apply to future regional verification regimes constraining proliferation? These are a few:

- Some countries may be prepared to cheat on their international non-proliferation obligations; stronger verification measures are needed to deter, detect, and provide a basis for penalizing those involved in such activities. Those measures should be analyzed in terms of their effectiveness individually and their synergistic effects in total.
- The traditional emphasis of safeguards on the detection of the availability or diversion of a significant quantity of nuclear materials is not sufficient. Exchanges of open-source information and, in some cases, national intelligence could provide information on suspect sites in the areas of imports of nuclear and dual-use items and fuel cycle activities. This information could then be used to target aerial surveillance of suspected sites or activities.
- Regional zones should be promoted in which reprocessing plants, enrichment plants, and the use of weapons-grade materials would be banned. Such zones would need to be supported by verification methods including NIM and aerial surveillance.
- Non-nuclear weapon states should sign no-transfer, no assistance pledges similar to those required of NWS parties by Article I of the NPT. These pledges should be backed up by effective means of verification.

The Iraqi situation has underlined a principle which appeared in the study, *Verification to the Year 2000*, namely, verification of treaty compliance based on a system of on-site inspection of declared facilities may make cheating considerably more difficult, but it does very little to deter covert facilities and activities from development of weapons. Individually and collectively, compliant countries need to consider the intelligence requirements needed to meet future nuclear proliferation threats. The IAEA would benefit by having its own intelligence/information assessment unit based on some form of international technical means (ITM). A future ITM, and/or a willingness on the part of countries having NTM to share more of their data, combined with strengthened inspection rights and an improved data information system bank would certainly strengthen the IAEA and any other agency associated with the UN whose function is verification of international arms control accords. ITM data could provide synergies with future IAEA "suspect site" inspections at undeclared facilities.

While the concept of nuclear rollback has not seemed feasible in the past, the examples set by seven countries have renewed interest in this concept as a solution to regional instabilities in the Middle East and Southeast Asia.* After years of research aimed at advancing a nuclear weapons option and national debate about the acquisition of such weapons for defensive purposes, Sweden formally renounced nuclear arms and signed the NPT in 1968. Prior to this decision, research had been conducted on the technical details of nuclear weapons design, a laboratory to separate small amounts of plutonium from spent nuclear fuel was constructed, and possible delivery systems for nuclear weapons were studied.

South Korea and Taiwan succumbed to U.S. diplomatic pressure and experienced nuclear rollback. Following four years of talks with the United States, the former Soviet Union, and the United Kingdom, South Africa joined the NPT in July 1991 and gave up its right to acquire nuclear weapons. President DeKlerk attributed this decision to an dramatic change in the world order with the end of the Cold War.

Canada was the first country to renounce nuclear weapons after participating in the U.S. World War II Manhattan Project. Subsequently, Canada renounced dual-ownership of nuclear weapons, namely, the Genie missiles.

Argentina and Brazil's commitment in November 1990 in the second Foz do Iguazu Declaration to renounce the nuclear weapons option demonstrates that confidence-building measures and the existence of the Treaty of Tlatelolco have had the effect of excluding nuclear weapons from the territories of these two rival countries. In December 1991, Argentina, Brazil, and an Argentine-Brazilian Agency for Accounting and Control of Nuclear Materials (ABACC), and IAEA signed an agreement which put all of the two countries' nuclear facilities under IAEA safeguards.

According to the negotiating history of the NPT, nuclear-weapons-related research, development, fabrication, or testing activities by a non-nuclear-weapon-state party would violate the Treaty's prohibition in Article II against the "manufacture" of nuclear explosives. This suggests that the possession of non-nuclear components for nuclear weapons would constitute a violation of the NPT. This prohibition could be applied to South Africa, North Korea, Argentina, and Brazil, and the non-Russian Soviet successor states once they join the NPT.

While a full rollback of the weapons-related nuclear programs of India and Pakistan appears to be unlikely in the period between 1992 and 2002, prospects for a nuclear standstill are much better. This would require the negotiation, perhaps facilitated through the five-power conference, of a standstill agreement which would commit India and Pakistan not to assemble, test, or deploy nuclear weapons. A verification regime for the agreement, involving data exchange and on-site inspections would clearly

* Nuclear rollback is defined as the voluntary and credible renunciation of efforts to move closer to a nuclear weapons capability. Giving up a weapons-related program because of domestic revolution or defeat in war is not regarded as rollback.

have synergies with those countries' NIM and with the NTM/MTM/ITM of other interested countries. Southeast Asia would also constitute an excellent region to utilize Open Skies as a confidence-building measures. Assistance in development of inspection regimes to verify regional agreements might be offered by interested countries, similar to the many in which the U.S. government worked closely with the government in Seoul to help the Republic of Korea conclude an inspection regime to verify its bilateral agreement with North Korea when it enters into force. Although India might refuse to sign the NPT in this period, the inspections associated with the NPT would yield certain synergies in respect to Pakistan. Indeed, such a standstill agreement might bring India to the point of agreement to join the NPT.

Nuclear rollback in the Middle East focuses on Israel. Capping its nuclear weapons capabilities might cause other countries in the region to defer the acquisition of such weapons. Israel's concerns about its security would be enhanced by the verified adherence to the CWC by its neighbors. This may require a strengthened CWC verification regime, as discussed below. In addition, potential nuclear proliferators in the region would need to be denied the technology, equipment, and material needed to build reprocessing or enrichment plants. This denial would need to be backed up by strengthened export controls and by the synergies associated with combining targeted aerial and on-the-ground surveillance.

A number of actions should be taken in order to enhance the verification synergies associated with a CWC. A sophisticated international data base management system should be developed that not only collects information, but identifies those pieces of information which signal the need for additional verification activities. The development, testing, and evaluation of signature exploitation systems suitable for on-site inspection verification purposes will assist in the resolution of technical issues concerning sampling during the conduct of challenge inspections. Evaluation of the effectiveness of various types of sensors, intrusion and/or tamper detectors, inventory control devices, closed circuit television, and other pertinent equipment will enhance site monitoring by the International Inspectorate.

Recent efforts made by verification experts from Canada, the United States, and a number of other countries to begin identifying measures that could determine whether a signatory to the BTWC is in compliance with its obligations should be continued. The experts are compiling lists of potential measures in three areas: development; acquisition or production; and stockpiling or retention.

Under its Enhanced Proliferation Control Initiatives (EPCI), the United States has expanded its export controls to cover all 50 identified chemical weapon precursors, dual-use equipment relevant to chemical and biological weapons production, whole chemical plants, and knowing assistance to chemical or biological or missile programs. The Australia Group has followed the U.S. lead in EPCI by expanding its export controls to cover the 50 chemical weapon precursors as well as CW-related dual-use equipment. The EPCI could well serve as a model for countries who are not members of the Australia Group.

For those parties who believe that a rigorous CWC verification is required, the current regime could be strengthened considerably by the addition of aerial monitoring using several sensor technologies including multi-spectral imagery. Air sampling of production facilities could also be incorporated into the verification regime, along with sampling of water, foliage, and earth at or near production facilities.

Non-proliferation treaties must provide for challenge inspections of suspected activities on a timely basis, while still meeting concerns about frivolous challenges, security risks, and economic espionage. A more effective verification regime might include the following three elements: a right of any state party to challenge the activities of another party if it suspects activity in violation of treaty obligations; submission of a formal complaint and request to the UN Security Council for a challenge inspection by the appropriate international inspectorate, to include evidence supporting the validity of the accusation; and detailed procedures for challenge inspection of suspected facilities and activities, without a right of refusal and without a right to deny reasonable access.

Options for an international inspectorate include a new and expanded role for UNSCOM or a new, comparable UN body. In the United States, it has been demonstrated in the case of OSIA that expanded responsibilities for that inspection agency have increased its expertise and knowledge base. A similar case could be made that the experience which UNSCOM has gained in inspecting Iraqi installations and activities would be of great value in future adversarial or coercive verification activities.

Non-proliferation strategy, in general, needs to address both the "demand" and "supply" side of the problem. Regional confidence-building measures may be the best way to alleviate mutual suspicions in the near term; these measures can be developed in settings such as the five-nation conference in South Asia and the Middle East Initiative. International security guarantees will strengthen the CBMs. The United States has already stated that it will "take into account other countries' performance on key international non-proliferation norms in developing its cooperation and technology transfer relationships, and will consult with friends and allies on similar approaches."

On the supply side, additional strengthening of the guidelines and additional membership in the Nuclear Suppliers Group, the MTCR, and the Australia Group will reduce the number of countries which will have to undergo the challenge or special inspections called for in the non-proliferation arms control agreements. Other actions to enforce international non-proliferation norms include: United Nations Security Council embargoes, inspections, and sanctions; assistance to victims of attacks with such weapons; extradition agreements; immigration or trade restrictions against individuals or companies which have knowingly contributed to proliferation; and various political pressures.

Appendix A: Formal Models of Verification Synergy

D. Marc Kilgour

Introduction

Arms-control verification, the process of collecting information and using it to make policy judgements about whether a country is complying with an arms-control regime, can be conceived as an array of decisions about specific observed behaviour, events, facilities, or equipment. Are the observations consistent with, or contrary to, the rules governing types and locations of equipment, strengths and locations of forces, etc., laid down under the arms-control regime in question? Although these specific decisions are of great importance to national security, available relevant information is often quite limited. It is therefore desirable to expand the information base insofar as possible, and to use available information as much, and as efficiently, as possible.

Verification synergies make valuable contributions to both gathering and processing information. Synergy can occur

- **across decisions,** when a single piece of information provides useful input to many specific verification decisions;
- **across data,** when information from several sources is combined effectively to reach a specific verification decision.

In this Appendix, a formal model is developed for the process of using information effectively and efficiently in arriving at a specific decision. No attempt will be made to model how an individual item of information, originating, for example, in an information exchange and/or a declaration, can improve many subsequent verification decisions. Rather, the purpose of this model is to explore the underlying logic of across-data synergy and to explain which aspects of inputs are most important in shaping outputs.

Like most formal models, the one presented here is quite abstract, including general or stylized representations, and excluding details that distinguish particular real-world instances of across-data synergy. The objective of such simplification is to provide insight into the costs and benefits of additional relevant information and its integration into the decision-making process — to offer general guidance to those who must face these problems.

Thus, attention is here focused on questions of when, why, and how many sources of information can synergistically contribute to verification goals, in the context of a specific decision problem. To model a specific verification decision, it is assumed that a "suspect event," an abnormal occurrence or observation, has been identified. The analysis addresses the question of which, if any, sources of information should be tapped prior to assessing whether this event constitutes compliance or violation. The formulation takes account of the costs of information, including not only the direct costs of collecting and interpreting it, but also the possible costs of delay during collection and interpretation.

The analysis applies to sources of information relevant to the suspect event. In general, these sources are monitoring and inspection activities, typically including NTM/ITM/MTM, intelligence sources, overflights and on-site inspections. General information, such as from preliminary data exchanges, would not normally be counted as an information source in this sense, for it usually does not bear directly on a specific verification decision. Instead, general information ordinarily serves to expand specific information and to make it more precise and accurate.

The aim of the analysis below is to develop a means of identifying which new source of information should be accessed and to explore how the information should be integrated into the decision-making process. Nonetheless, the methodology is quite general and can be used to address questions related to additional independent information in many enforcement processes.

Problem Description

The operation of information synergy in verification is best understood in the context of decision problems under uncertainty. In the most fundamental model of a specific verification decision, a decision-maker must use whatever information is available to decide either to

- **Accept:** to conclude that the suspect event in question is actually consistent with applicable arms control regime(s); or
- **Alarm:** to single it out for special attention and action.

The true "state" (i.e. condition or status) of the situation is generally unknown to the decision-maker and outside his/her control. We distinguish two cases only, according to the decision-maker's interests. The situation is

- **Red** if, knowing the true state, the decision-maker would prefer to Alarm; and
- **Green** if, knowing the true state, the decision-maker would prefer to Accept.

This Basic Verification Decision Problem is shown in matrix form in Figure 1, where

- **rows** represent the decision-maker's possible choices;
- **columns** represent possible true states of the world;
- **cells** represent possible outcomes.

Note that this model applies to a verification decision about a specific suspect event; any connections to other decisions or events are not modeled explicitly. Neither are "shades of grey" allowed; intermediate action choices for the decision-maker, and intermediate levels of gravity of the true situation, are not included.

In the context of arms-control verification, to Alarm means to accuse publicly, to make military preparations, to threaten or impose sanctions, etc., and to Accept means to take no special action as a consequence of the suspect event. A situation is Red if some or all of the aforementioned actions are indeed warranted; it is Green otherwise.

Of course, the essential difficulty of the Basic Verification Decision Problem is that a decision-maker may be required to decide on an action without certain knowledge of the true situation. It can be presumed that the decision-maker combines whatever knowledge he/she does have, along with judgment and experience, to come to a decision. But, nonetheless, a verification decision is often a decision taken under uncertainty, and the action selected may, in hindsight, prove to be wrong.

An **information source** is any activity or procedure that may be used to give the decision-maker additional data with which to make an inference about the true state of the situation. Commonly employed information sources include aerial monitoring, in which photographic or other images are obtained by an overflying aircraft or a reconnaissance satellite, and on-site inspection, in which a specially trained and equipped inspection team makes a direct, hands-on examination of equipment and facilities. Other information sources include intelligence assessments, the detailed re-examination of existing images, etc.

Different information sources can have very disparate properties, including some that can

Figure 1:
Basic Verification Decision Problem

DECIDE	True Status: *Green*	True Status: *Red*
Accept	Accepted Compliance	Successful Violation
Alarm	False Alarm	Detected Violation

discourage their use. The most important problems with data are

- **Inaccuracy:** Many inspection procedures typically either miss large quantities of useful information (e.g. satellites with limited swath-width and/or making relatively few passes), or provide data that can be very difficult to interpret (e.g. aerial photographs).
- **Cost:** Some inspection procedures either require large direct and indirect expenses (e.g. training, equipping and operating on-site inspection teams) or impose high time costs (e.g. waiting for satellite passes).

Were it not for these and related problems, every verification decision would benefit from a large amount of information. Ideally, decision-makers interested in making the best possible decision would supplement prior information with accurate data from free inspections. In other words, decision-makers face the problem of deciding what information to seek out and how to use it effectively precisely because data rarely lead to certainty and are almost never free.

When is it to a decision-maker's advantage to access additional information — to pay the cost, and accept the possible inaccuracies, in hopes of making synergistic use of the new information and thereby arriving at a better decision? The formal model that follows determines criteria for when and how a decision-maker faced with the Basic Enforcement Problem of Figure 1 should supplement existing information. As well, the model provides a means of assessing the level of costs the decision-maker should be willing to bear to obtain this extra information, and a method for incorporating the new information into the decision process.

Methodology

A convenient and natural tool for representing and analyzing the Basic Verification Decision Problem of Figure 1, and others like it, is Bayesian Decision Analysis. The purpose of Bayesian Decision Analysis has been defined as the logical analysis of choice among courses of action when

- the consequence of any course of action will depend upon the "state of the world," and
- the true state is as yet unknown, but
- it is possible at a cost to obtain additional information about the state.*

Bayesian Decision Analysis has previously been used to explore how, and to what advantage, information from different sources ("tests") can be combined in a verification context.**

Bayesian Decision Analysis is founded on Bayesian Statistics. The latter is essentially a model of how a "rational" individual, who holds a personal ("subjective") probability distribution over the states of the world, should update this prior distribution after evidence about the state of the world has been received. For example, in the Basic Enforcement Problem, the decision-maker is assumed to have a **prior** belief about the likelihood of state Red. When new information becomes available, the decision-maker should rationally revise this probability belief. Bayesian Statistics defines a **posterior** distribution, which in this case represents the decision-maker's revised belief that the state is Red. Appendix B presents an illustration of how Bayesian Statistics can be applied in arms control.

To Bayesian Statistics, Bayesian Decision Analysis adds a simple decision analysis procedure, which begins with a value for each possible outcome, i.e., each possible combination of action and state of the world. The decision-maker can then evaluate each action according to its expected ("average") value under the decision-maker's current beliefs about the true state. The rational decision-maker then selects the action with the greatest expected value according to his/her own beliefs.

* Howard Raiffa and Robert Schlaifer, Applied Statistical Decision Theory, MIT Press, Cambridge, MA, USA, 1961, p. 3.

** "New Research in Arms Control Verification using Decision Theory: Site Selection for On-Site Inspection under CFE I and Interactions among Verification Methodologies," External Affairs and International Trade Canada, March 1991.

The emphasis on values gives Bayesian Decision Theory another dimension that is especially valuable in an assessment of the synergy of information. Not only can new information be included in the decision-maker's updated probabilities, but also the costs of the information can be included in the values. Thus it is possible to represent a rational decision about whether to seek the information in the first place. Taking into account the cost and the expected value of the data to be received, can the decision-maker expect to be better or worse off by accessing it?

Thus, application of Bayesian Decision Theory to the Basic Verification Decision Problem provides, first of all, a model for integrating information from new sources into the decision process. But, more important, it also determines the level of costs the decision-maker should be prepared to accept in return for the information. Consequently, information which is so imprecise as to be not worth accessing even if free can be identified, and optimal rules about when to stop looking for additional information can be generated.

The Model

The Basic Verification Decision Problem described in Figure 1 will be analyzed using the cost parameters shown in Figure 2. Below the Bayesian rational decision-maker will be called "Decision-maker." Note that Decision-maker's costs, rather than values, are used for convenience. Decision-maker's value for any particular outcome should be taken to be the negative of the cost. Technically, these values should be measured in units of von Neumann-Morgenstern utility.

In Figure 2, the Accepted Compliance outcome is shown as having cost zero. This is not intended to suggest that Accepted Compliance has neither cost nor value; it indicates only that the other cost parameters, F, L, and M, measure the costs associated with the other outcomes relative to that of Accepted Compliance. Formally, the cost parameters are

F = RELATIVE COST OF { FALSE ALARM }
L = RELATIVE COST OF { SUCCESSFUL VIOLATION }
M = RELATIVE COST OF { DETECTED VIOLATION).

The only assumptions made on these cost parameters are

$$F > 0; \quad L > 0; \quad L > M.$$

These assumptions reflect only Decision-maker's preference for Accepted Compliance over False Alarm when the true state is Green, and for Detected Violation over Successful Violation when the true state is Red. Note, in particular, that no assumption is made about the value of Detected Violation relative to Accepted Compliance; Decision-maker may prefer either Accepted Compliance ($M > 0$) or Detected Violation ($M < 0$).

Later, some assumptions concerning the cost of additional information will be introduced. For now, however, it is important to analyse how well Decision-maker can do without it.

Figure 2:

Basic Verification Decision Problem – Cost Parameters

	True Status: *Green*	True Status: *Red*
Accept	0	L
Alarm	F	M

Verification with No Additional Information

Assume that Decision-maker, on the basis of past experience and knowledge (including all data already received), assigns a prior probability p to the statement that the true state is Red. Thus the prior probability of state Green is $1 - p$. We assume throughout that $0 < p < 1$.

A crucial quantity for Decision-maker is the threshold probability value

$$p_0 = \frac{F}{L - M + F}.$$

The value of p relative to p_0 determines Decision-maker's best course of action, which is

- Accept if $p < p_0$;
- Alarm if $p > p_0$.

(To avoid complicating the presentation with transitional cases, possible "chance" equalities of parameters, such as $p = p_0$, will be ignored.)

Thus, p_0 is the threshold separating the zone where Green is very likely (so Decision-maker should choose Accept) from the zone where Red is sufficiently likely that Decision-maker should choose Alarm. These two zones, and some expected cost lines to be discussed below, are shown in Figure 3 for the example

$F = 20 \quad L = 100 \quad M = 40$

In this example, the cost of failing to detect an actual violation is very high (100), but is reduced considerably (to 40) if the violation is detected. Also, the cost of a false alarm (20) is small, but not negligible. As long as there is no information source, the threshold separating the Accept zone from the Alarm zone is $p_0 = 0.25$.

In Figure 3, the heavy line labelled "0CM" represents Decision-maker's expected (or average) cost if the optimal decision policy given above is followed. Note that Decision-maker's expected cost increases as p increases, for as Decision-maker finds it more likely that the true state is Red, then it becomes more likely that the best that Decision-maker will be able to do (in this example) is to hold the cost to 40 units.

The straight line labelled "0M" in Figure 3 is important also. It is called Decision-maker's Expected Cost of Perfect Information and represents the expected cost in the event that Decision-maker knows for certain that he/she will learn the true state prior to taking his/her decision. Thus the vertical distance between the 0CM and 0M lines measures the extra expected cost that Decision-maker faces as a result of his/her uncertainty about the true state, when the subjective probability of Red is p. This height is therefore the maximum that Decision-maker would rationally pay to learn the true state.

Necessarily, therefore, Decision-maker will avoid any information source that provides only uncertain information about the true state and costs more than this maximum. As Figure 3 makes clear, a larger value of $L - M$ corresponds to a more pronounced kink in the 0CM line, which increases Decision-maker's willingness to pay for information — perfect or imperfect.

In summary, for any level of prior belief about the likelihood of a violation, there is a calculable ceiling on the cost of any worthwhile information. This ceiling rises as the amount lost by missing a violation increases.

Verification with Fixed Cost Information

Now, assume that Decision-maker has available a process yielding binary information. Binary information is information that has only two possible values, which will be called here

* *Clear*, recommending that Decision-maker choose **Accept**, and
* *Flag*, recommending that Decision-maker choose **Alarm**.

The most important characteristics of a process yielding binary information are its error probabilities and its cost. The error probabilities are the probabilities that the wrong recommendation results. Specifically, they are

Pr{ Flag | Green } = α

Pr{ Clear | Red } = β.

We assume that the probabilities (numbers) α and β are known in advance. We also assume that $\alpha + \beta < 1$, for otherwise the procedure would be no better than random. The third characteristic of a binary (or any other) information source is its cost, c. For now, we assume that the information is cost-free, i.e. $c = 0$.

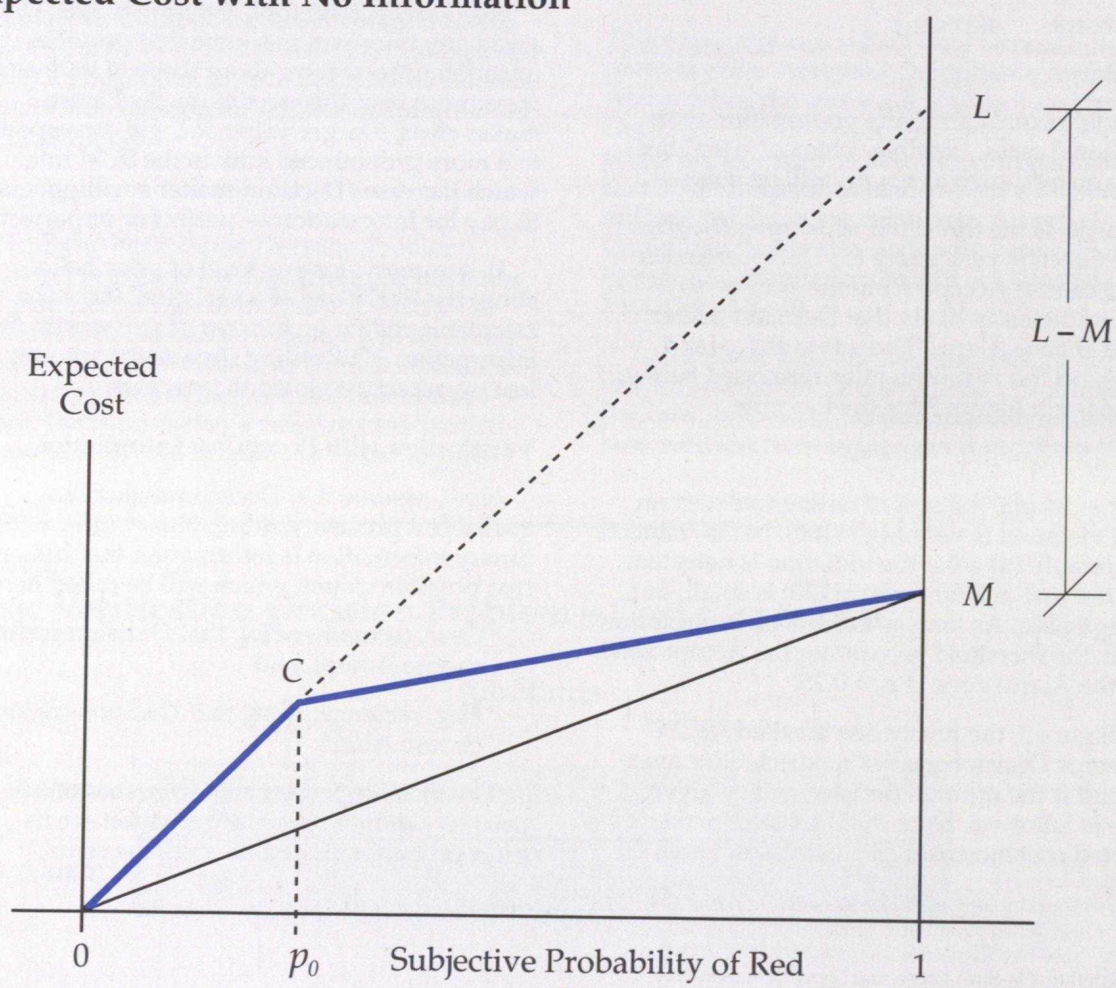
Should Decision-maker access this binary information? It can be shown that Decision-maker's optimal policy is determined by two thresholds,

$$p_G^{\,0} = \frac{\alpha F}{\alpha F + (1 - \beta)(L - M)} \;;$$

$$p_R^{\,0} = \frac{(1 - \alpha) F}{(1 - \alpha)F + \beta(L - M)} \;;$$

Figure 3:

Expected Cost with No Information



with the properties that

$$0 < p_G^0 < p_0 < p_R^0 < 1 ;$$

$$p_G^0 \to 0 \text{ as } \alpha \to 0 ; \; p_R^0 \to 1 \text{ as } \beta \to 0 .$$

Decision-maker's optimal policy is

- Accept immediately, if $p < p_G^0$;
- Obtain Further Information [then Accept if Clear and Alarm if Flag] if $p_G^0 < p < p_R^0$;
- Alarm immediately if $p_R^0 < p$.

Thus, if Decision-maker is sufficiently confident that the state is Green ($p < p_G^0$) or Red ($p > p_R^0$), then the additional information is of no value, even though it is free. The information is so uncertain that the results could not change Decision-maker's mind (at least, not enough to alter Decision-maker's optimal course of action). Thus, information should be sought only when Decision-maker is relatively uncertain about the state, for only in that case can the information have a bearing on the action selected.

The three zones defined by Decision-maker's optimal policy for free information are shown along the "cost 0" line in Figure 4. Figure 4 also shows how the optimal policy is altered if the information costs Decision-maker an additional c units. (Note that information cost is assumed **fixed**, i.e. independent of the true state. A different assumption is made in the next section.)

Figure 4 shows geometrically the definitions of two new thresholds, p_G^c and p_R^c, that determine Decision-maker's optimal policy when the information has a direct cost of c units. This policy is

- Accept immediately if $p < p_G^c$;
- Obtain Further Information [then Accept if Clear and Alarm if Flag] if $p_G^c < p < p_R^c$;
- Alarm immediately if $p_R^c < p$.

This is shown along the "cost c" line in Figure 4. Note that as c increases, the zone in which information is sought becomes narrower and narrower, finally shrinking to a point at $p = p_0$, before disappearing altogether.

The same methodology, based on the principle of minimum expected cost, can be applied in more complex situations. Following is an illustration, based on the $L = 100$, $M = 40$, $F = 20$ example. Assume that satellite reconnaissance of a declared facility has these characteristics

Satellite: $\alpha_S = 0.4$, $\beta_S = 0.25$, $c_S = 0$;

(error-prone, but costless); while on-site inspection has these characteristics

On-Site: $\alpha_O = 0$, $\beta_O = 0$, $c_O = 8.0$;

(infallible, but costly). These two techniques can also be used in sequence; the On-Site Inspection may or may not take place, depending on the information from the Satellite Inspection. The two possibilities are Satellite-OSI if Clear and Satellite-OSI if Flag.* Their characteristics are

Satellite-OSI if Clear:

$\alpha_C = 0$, $\beta_C = 0.25$, $c_C = 3.2 + 2.8p$.

Satellite-OSI if Flag:

$\alpha_F = 0.4$, $\beta_F = 0$, $c_F = 4.8 - 2.8p$.

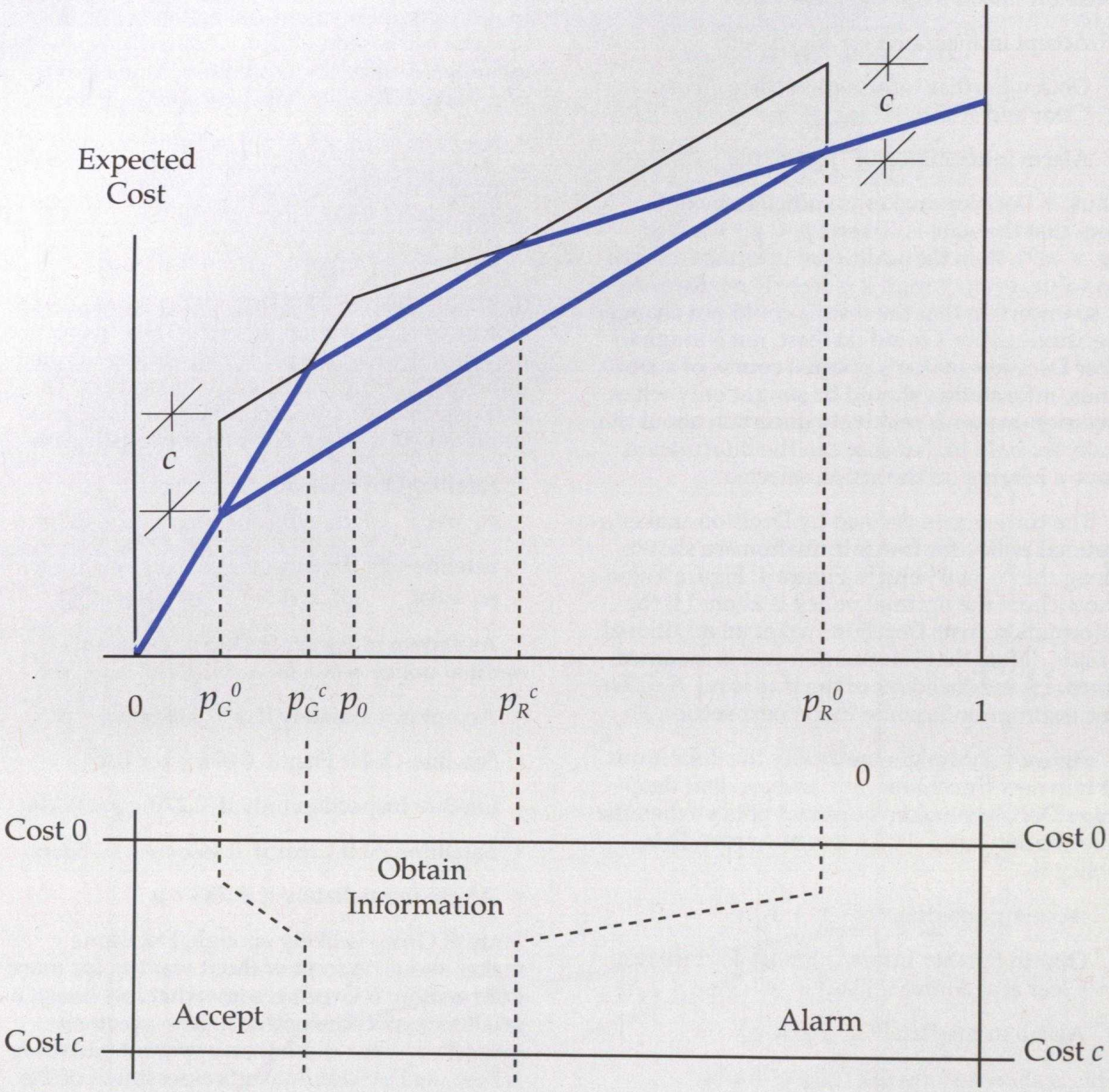
As shown in Figure 5, Decision-maker's optimal policy when faced with this choice is

- Accept immediately if $p < 0.076$;
- Satellite-OSI if Flag if $0.076 < p < 0.270$;
- On-Site Inspection only if $0.270 < p < 0.444$;
- Satellite-OSI if Clear if $0.444 < p < 0.783$; or
- Alarm immediately if $0.783 < p$.

Thus, if Green is likely enough, Decision-maker should Accept without waiting for more information. If Green is somewhat less likely, a satellite inspection, with a follow-up on-site inspection when there is an apparent violation, is best. As Decision-maker's assessment of the likelihood of Red increases, On-Site Inspection

* In the terminology of "New Research in Arms Control Verification Using Decision Theory," op. cit., these two inspection plans are called Sequential (Satellite, On-Site) Loose and Sequential (Satellite, On-Site) Tight, respectively (p. 14). There are no other useful ways of combining two binary tests sequentially.

Figure 4:
How Cost of Information Changes Optimal Policy



alone becomes the optimal policy. As Red becomes more likely (but still far from certain) Decision-maker should use a satellite inspection and follow up with an on-site inspection when no evidence of violation is turned up. And if Red is likely enough, Decision-maker should Alarm without delay. As Figure 5 shows, a sequential scheme can indeed produce synergy; the resulting inspection protocols are optimal across a fairly broad range of circumstances.

As the characteristic values above indicate, the cost of gathering information sequentially depends on the true state. This is because the use of the expensive process (OSI) is contingent on the result of the free process (Satellite Inspection). Thus, the probability that OSI is used (and paid for) depends on the true state. In general, variable cost is easy to handle when it is a consequence of a contingent information-gathering procedure, as above. A somewhat different problem is presented by time cost, which is typically variable because delay in acting is a problem only when there is a genuine violation (i.e. when the true state is Red). Costs of this type will be considered next.

Verification with Delay Costs

Suppose that a suspect event occurs at time zero, and that Decision-maker must decide whether to act immediately or to seek out further information one or more times before acting. We assume that the information is essentially cost-free, except that in state Red (the event really was a violation) Decision-maker's costs increase the longer Decision-maker takes to act. This is a simplified model of a satellite inspection problem, in which the time between satellite passes may be substantial, resulting in extra risks.*

To build the Delay Verification Decision Model, modify the cost parameters of the Basic Verification Decision Model (Figure 2) as shown in Figure 6. The relative cost parameters, F, L, and M, retain their meanings, and satisfy the same inequalities

$$F > 0\,; \qquad L > 0\,; \qquad L > M\,.$$

The quantity k represents the delay time, i.e. the number of satellite passes ("looks") between the occurrence of the event and the choice of an action by Decision-maker; the parameter d represents an extra cost for each pass, provided the state is Red. Thus, delay is costly if, and only if, there is a violation. In the following, the example

$$L = 110\,; M = 20\,; F = 10\,; d = 10$$

will be discussed in detail. (Note that the numerical values of L, F, and M are not the same as in Figure 5. The new values, which make failure to detect an actual violation extremely costly, and a one-pass delay in detecting as costly as a false alarm, have been chosen to make Figure 8 clearer.) For this example, $p_0 = 0.10$, so if no satellite passes were available, Decision-maker would choose Accept if $p < 0.10$, and Alarm if $p > 0.10$.

The information source in the model represents satellite reconnaissance of a region in which one mobile weapon is permitted, but two (or more) are suspected. It is assumed that the satellite can view a randomly chosen 40 per cent of the area of the region on each pass, and that the interval between consecutive passes is long in comparison to the speed of movement of the weapon. Then, taking Green to represent the presence of one weapon, and Red the presence of two, the probability table of Figure 7 results.

As Figure 7 makes clear, satellite surveillance does not provide binary information in this case; there are three (or more) possible observations ("results"). Of these, 'Observe 2' convinces Decision-maker that the true state is Red, whereas the other two observations merely

* For a general introduction to satellite surveillance, see "Surveillance from Space: A Strategic Opportunity for Canada," by George Lindsey, Working Paper 44, Canadian Institute for International Peace and Security, June 1992. More details concerning the timing problems resulting from satellite kinetics can be found in the Annex to "Some Quantitative Aspects of Verification," presentation by George Lindsey to the International Amaldi Conference of Academies of Sciences and National Scientific Societies, Heidelberg, Germany, July, 1992.

Figure 5:
Satellite – On-Site Example

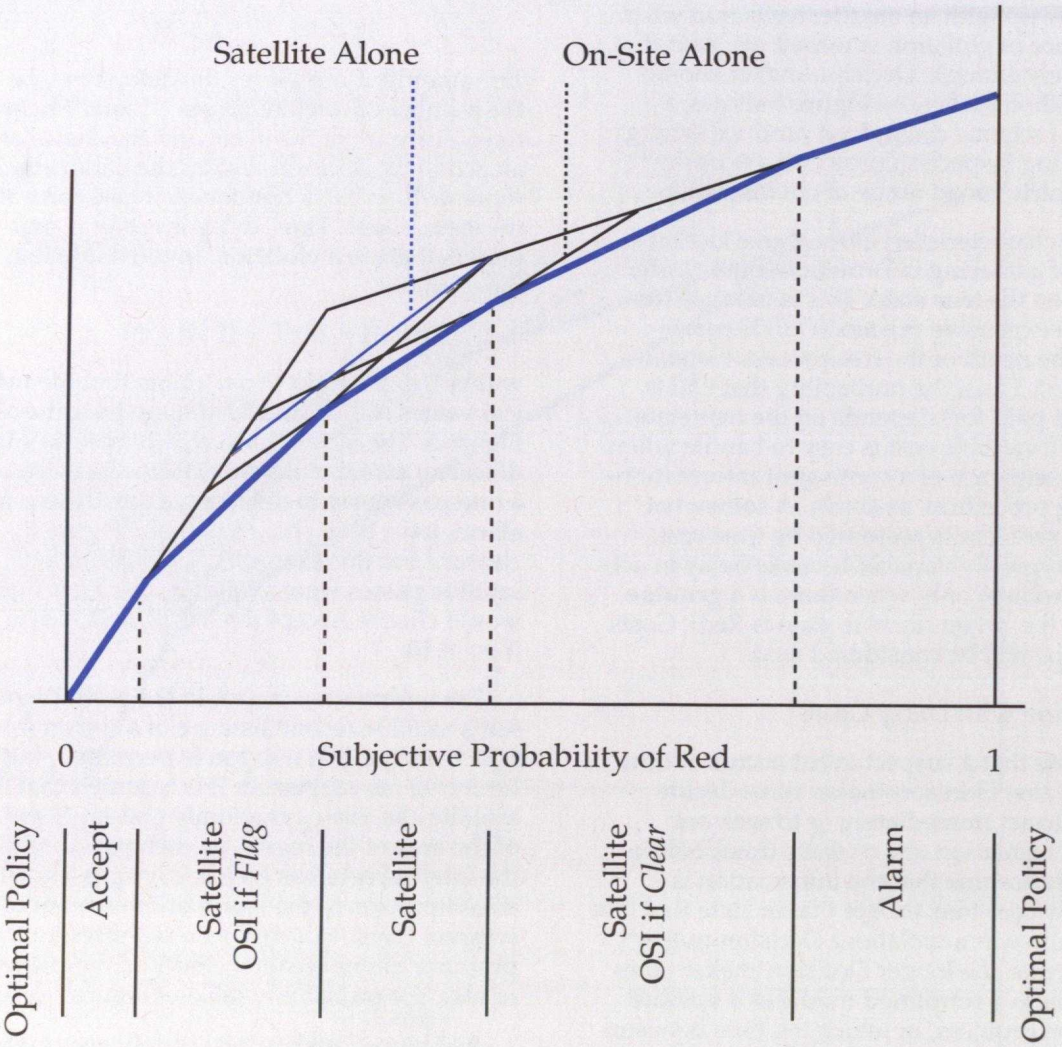


Figure 6:
Delay Model – Cost Parameters

	Green	*Red*
Accept	*0*	*L + kd*
Alarm	*F*	*M + kd*

cause Decision-maker to revise his/her beliefs. If p is Decision-maker's prior probability of Red, and p' is the posterior probability (i.e. p' is the updated probability of Red after the observation), then it can be shown that

$$p'|_{x=0} = \frac{.36\,p}{.6 - .24\,p};$$

$$p'|_{x=1} = \frac{.48\,p}{.4 - .08\,p};$$

$$p'|_{x=2} = 1.$$

Note that Decision-maker now has the possibility of multiple looks. Bayesian Decision Theory provides a clear prescription for carrying out a multi-look policy. First, Decision-maker must decide whether to wait for a satellite pass or to act immediately (and, if so, how). After the satellite information has been received, Decision-maker must use it to update his/her probability of Red, and then decide whether to act immediately or await another satellite pass, etc. When evaluating the option of waiting for satellite information, Decision-maker must always take into account the likely value of the information, as well as the cost increase if the true state is Red. The decision to await satellite information is therefore recursive; in the optimal policy, no action is taken as long as the expected gain from the information that is about to be received exceeds the expected cost increment.

The illustrative case presented above is fairly easy to analyse, because it can be shown that information from a satellite pass will be used at most twice. In fact, Decision-maker's complete optimal policy is as follows:

- If $p > .1284$, Alarm.
- If $p < .1284$, Await Next Pass; then Update p to p'.
    - If $p' > .1240$, Alarm.
    - If $p' < .1240$, Await Next Pass; then Update p' to p''.
        - If $p'' > .10$, Alarm.
        - If $p'' < .10$, Accept.

The expected cost for this optimal policy is shown as a function of p in Figure 8. Also shown in Figure 8 is the expected cost of optimal immediate action and the expected cost of the optimal policy if Decision-maker must act after at most one satellite pass.

The tendency of Decision-maker to seek out more information when almost sure of Green should not be surprising, for if the true state is Green, then the information is free. It is only the small risk of Red, and the substantial costs Red would imply that limit the use of satellite information in this model. If satellite use had a fixed cost irrespective of the true state, then no matter how small that cost, Decision-maker would Accept immediately, as soon as p or p' became small enough (i.e. as soon as Green became sufficiently likely). On the other hand, if delay costs were lower, Decision-maker would use more satellite passes, continuing up to a new, higher maximum, or until the accumulated evidence made a violation sufficiently likely.

Figure 7:

Probability Table for One Pass

	Observe 0	Observe 1	Observe 2
Green	0.60	0.40	0
Red	0.36	0.48	0.16

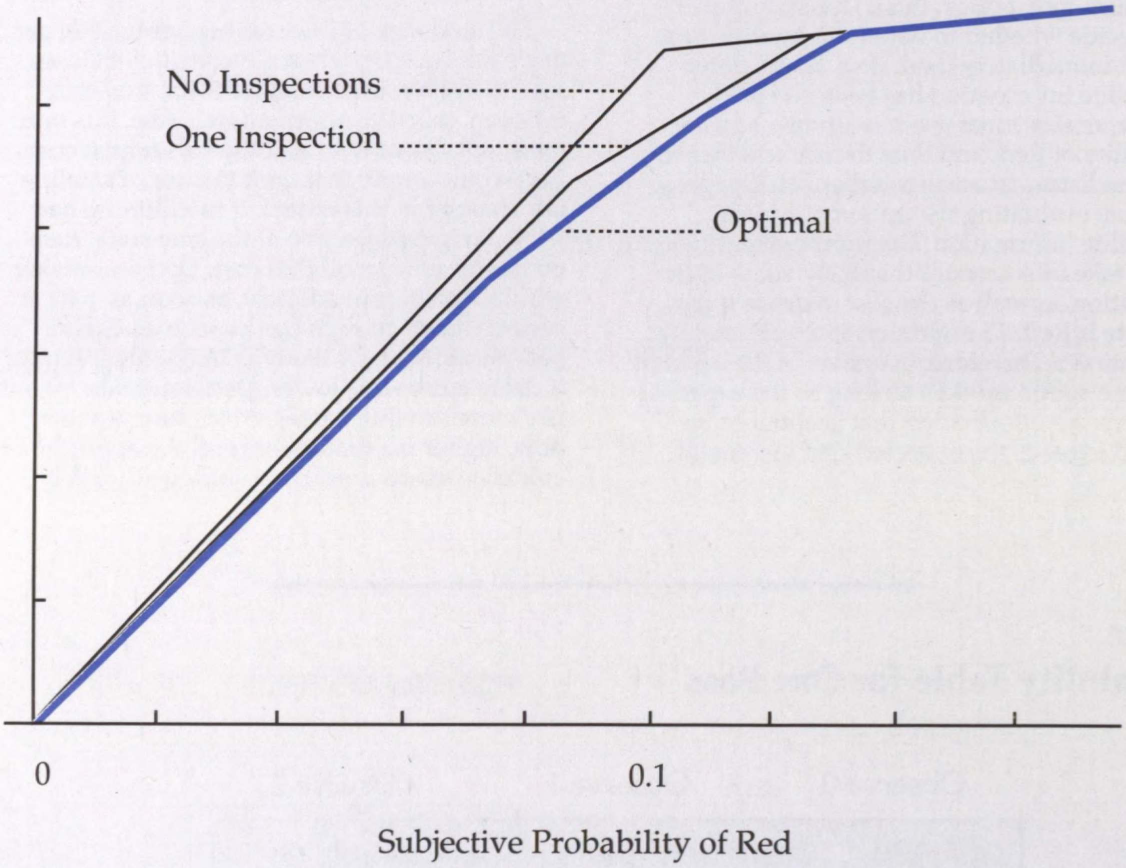
Conclusions

Within a formal context, this Appendix has examined the application of verification synergy across sources of information. Bayesian Decision Theory, a natural tool for this purpose, has been the primary methodological tool. It has been shown that

- The value of information is limited by the value of the most accurate information a decision-maker can receive. The potential benefits of information are greatest not when uncertainty is a maximum, but when the best available courses of action appear to be about equally costly.
- If an information source provides imprecise information, then there is a limited range of circumstances in which it should be used, approximately centred on the situation when information is most valuable. The more the information costs, the narrower this range, and a source that costs too much should

Figure 8:

Optimal Policy – Delay Model



never be accessed. Applicability ranges can be determined for information sources with known characteristics, facilitating comparison of different sources and different schemes for combining sources.

- When the costs of delay in acting against a violation are most important, additional information tends to be most useful when the likelihood of a violation is low, but not zero. It is important to update beliefs as soon as possible, so that there will be an immediate response should the data indicate that a violation is likely.
- Synergy across different information sources, or across independent information from the same source, seems to be possible over a wide range of circumstances. However, different data-handling schemes need to be constructed to capitalize on synergy in different circumstances. For instance, information from a low-cost source, even if too inaccurate to be used alone, can be extremely valuable if used sequentially and contingently with information from other sources. Schemes involving follow-ups on prior data from low-cost sources may be especially useful for adversarial or coercive verification, when there is a likelihood of a violation somewhere, but when precise data can come only from on-site inspections that are costly, difficult and/or subject to quotas.

The following are some potential policy implications of these findings, which should aid in achieving synergy across information sources.

Value of Independent Information

Independent information, even if incomplete or difficult to interpret, should never be discounted entirely. It may be possible to combine synergistically a source of cheap, but "noisy," information with other sources possessing different characteristics. For instance, in the Satellite/On-Site example presented above, the Satellite information was never useful by itself but, in various circumstances, appropriate combination procedures were optimal.

Design of Information-Acquisition Procedures

If several sources of information are available, combination acquisition procedures — which source to access first, which source to access next or whether to act immediately, etc. — should be designed carefully. Note that the procedure may be designed so that the information obtained can affect subsequent choices. For example, in the Delay Model, the decision is always to Alarm immediately if 'Observe 2' is obtained in the first pass, but to Await Satellite following 'Observe 0.' The Satellite/On-Site example shows that different combination of information-acquisition procedures can be optimal, synergistically achieving the greatest effectiveness and cost-effectiveness, in different circumstances.

Readiness

It is not a good idea to commit to a long sequence of information-gathering steps. It is much better to maintain readiness to act as soon as the evidence is sufficiently clear, continuing to seek information only so long as the situation remains uncertain. Thus, in the Delay Model, the response to 'Observe 1,' is to Alarm immediately, without awaiting any further information, whenever this finding makes the updated probability of a violation high enough.

Appendix B: Combining Different Types of Information Using Bayesian Statistics

George Lindsey

Nearly all of the published material concerning the technology and operational procedures employed for verifying and monitoring arms control agreements has described methods of obtaining information from a single means of collection. The subject of this report is to investigate the use of synergy to exploit two or more **different** sources of information. This Appendix introduces an example of the problem of synthesizing information of different types in a mathematically logical manner, obtained by different methods.

The essence of synergy, as applied to monitoring for verification, is the synthesis of different sets of knowledge (data, opinions, assessments, etc., all of which are subject to error or imprecision), in order to arrive at the best available inference as to the true situation.

Classical statistics allows us to obtain estimates of numbers, based entirely on measurements, together with an indication of the accuracy of the estimates. Usually these measurements are all of the same type, although statistical techniques allow for cases in which some measurements differ from others in their accuracy.

However, while conducting a verification of an arms control agreement, a situation may arise in which auxiliary information, possibly not based on measurements, perhaps not even quantitative at all, is available. It may be desirable to make use of this information, probably incorporating it into the eventual conclusion as to what the real numbers are.

There is a theory involving subjective probabilities and Bayesian statistics (which is not universally accepted by statisticians) that can be applied to problems of the type described above.

This can be illustrated using the example of repeated sampling, by some sensor, of a large area in which an arms control agreement allows the deployment of $N_0 = 200$ mobile weapons. We suppose that the sensor can only observe a small fraction (S = 2%) of the area each day, under conditions in which it will detect the presence of every weapon actually deployed within its limited field of view. Statistical theory indicates that after 100 days of observation of a deployment of 200 weapons, the number N_E estimated to be there will have a normal probability distribution with a standard deviation σ of 10. This permits calculation of the probability that the estimated number will be N_E. For example, the probability that the estimate N_E will be exactly 200 is only 4%; but the probability that N_E will fall somewhere between 177 and 223 is 98%.

If the actual number of weapons is larger than N = 200, the standard deviation of N_E will be larger, i.e., the accuracy of the estimate will be lower.

Classical ("frequentist") statistics makes no prior assumptions as to the actual number N of weapons deployed. It is assumed that the actual number can be 0, 1, 2, ..., with no upper limit.

Suppose that, as well as the observations, there is evidence from completely different sources suggesting that, after a long period during which the deployment was at the permitted level of $N_0 = 200$, additional weapons were being deployed. To offer an example, suppose that a factory has been observed shipping 100 crates of a size and type which could each contain one new weapon of the type limited by the treaty. Call this hypothesis C, i.e., now N = 300. Suppose, further, that a new military unit of the type operating the weapons and of a size appropriate for 50 additional weapons is known to have been formed, yielding hypothesis B, that the actual number deployed is now N = 250. However, earlier experience has given little indication of any breakout, and many analysts continue to believe that only the permitted 200 weapons are deployed. Call this hypothesis A.

There is no objective method of comparing the prior probabilities as to which of these three hypotheses (A, B, or C) is correct. The assumption is that one of the three is correct, which makes the formulation of the problem different from the classical one (which allows the possibility of N being any number at all). Instead, it can now be assumed that the true number of weapons N must be 200, 250, or 300, with no other possibilities. The problem is to use statistical analysis of recent observations to indicate which of these is most likely to be true.

To apply Bayes' method, it is necessary to attach "prior probabilities" to the three hypotheses. One could make them equal (i.e. each 1/3), but this is equivalent to making a judgment.

For example, suppose that the "expert opinion" favours hypothesis A (i.e. that there has been no violation, and that N = 200), and is very skeptical regarding hypothesis B (that N = 250). Prior probabilities are assigned, established before any of the recent observations have been taken into account, as follows:

Hypothesis A, that N = 200, has a prior probability of 0.6. For the other hypotheses (B : N=250 and C : N=300) the prior probabilities are 0.1 and 0.3, respectively.

After an estimate of N based on new observations collected during the past 100 days has been made, the statistician is asked to infer which of the three hypotheses is most probably correct.

To take a specific example, suppose that the observations produce the estimate that the true number of missiles is $N_E = 230$. Then the calculations will be as indicated in Table 3.

The first two columns indicate the hypotheses established prior to the observations. The third column, labelled "Conditional Probability", or "Likelihood", represents the probability that the observations would result in an estimate N_E of 230, if the estimates follow the normal distribution associated with the indicated hypothesis.

If hypothesis A is true (and N = 200), the probability of the observation producing the estimate $N_E = 230$ would be 0.000443. The usual notation for this (conditional) probability is $\Pr(N_E = 230 \mid A)$. But what we want is the reverse of this:

$\Pr(A \mid N_E = 230)$, the probability that A is true, given that the estimate is $N_E = 230$.

The fourth column is the product of the second and third column, and represents the joint probability that the hypothesis is true and that

Table 3

Prior Intelligence		Subsequent Observation	Combinations	
Hyp.	Prior Prob.	Conditional Probability (Likelihood)	Prior Prob. x Likelihood	Posterior Prob.
A	0.6	$\Pr(N_E = 230 \mid A) = 0.000443$	0.000266	0.27
B	0.1	$\Pr(N_E = 230 \mid B) = 0.00720$	0.000720	0.73
C	0.3	$\Pr(N_E = 230 \mid C) = 0.00000$	0.000000	0.00

the measurement would produce the estimate that $N_E = 230$. For hypothesis A, Prior Probability x Likelihood =

0.6 x 0.000443 = 0.000266.

When the calculations are repeated for hypotheses B and C, it is seen that the probability of estimating $N_E = 230$ is nearly three times higher under hypothesis B than A, and is negligible under hypothesis C. Since measurement has resulted in the estimate 230, the probability that N_E is 230 is now 1. This is "normalized" by multiplying the separate probabilities that A is true, that B is true, and that C is true by a common factor, raising the total probability to 1. The "posterior probability" $Pr(B \mid N_E = 230)$ that hypothesis B is true is therefore estimated to be 0.73, with the probabilities for A being:

$Pr(A \mid N_E = 230) = 0.27$,
and for C, $Pr(C \mid N_E = 230) = 0.00$.

The calculated example above was for the particular case in which the observations produced the estimate $N_E = 230$. Figure 9 plots these probabilities for values of N_E, ranging from below 180 to beyond 320.

The three distribution curves at the top of Figure 9 show the probabilities of estimating the indicated value of N_E, assuming the prior probabilities for the three hypotheses A, B, and C. They are bell-shaped curves (of the normal distribution) centred on the estimated numbers 200, 250 and 300, and with areas proportional to the prior probabilities 0.6, 0.1, and 0.3. It can be seen that only hypothesis A is at all likely to produce an estimate N_E less than 220, only B an estimate between 235 and 260, and only C one above 280. But either hypothesis A or B could produce a value of N_E between 220 and 235, and either B or C for $260 < N_E < 280$.

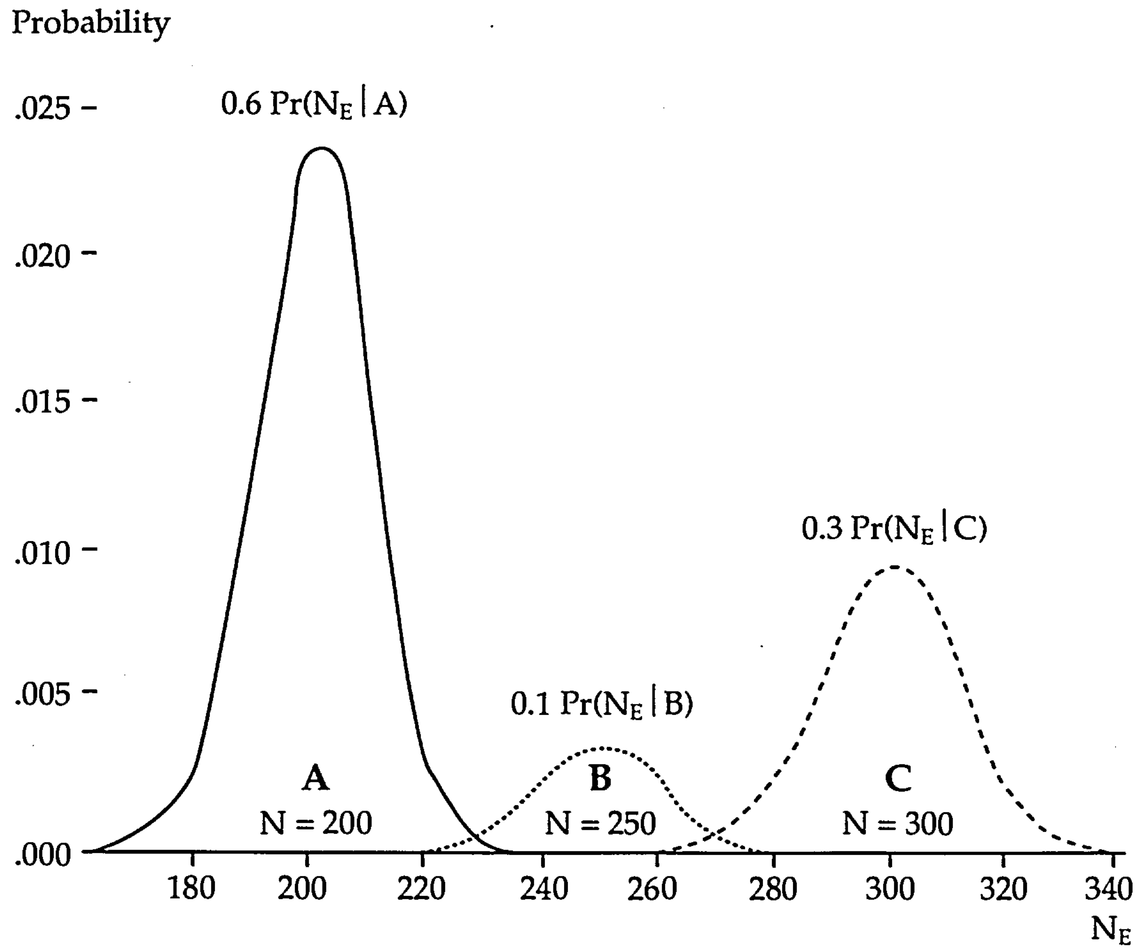
The three distribution curves at the bottom of Figure 9 show the posterior probabilities that hypothesis A, B or C is true, after using the information that the measurement has produced its estimate N_E. For example, the curve labelled $Pr(A \mid N_E)$ indicates that for $N_E < 215$, the probability that hypothesis A is true is virtually a certainty; but in the range $215 < N_E < 240$, it drops to nearly 0. At $N_E = 228$, the posterior probability that hypothesis B is true has exceeded that for A. But when $N_E = 272$, it is more probable that C, rather than B, is true.

It can be seen that if $0 < N_E < 225$, one can infer that N = 200; if $230 < N_E < 265$, N is probably 250 (almost certainly 250 if $240 < N_E < 260$); while if $N_E > 275$, then N can be inferred to be 300. If N_E is in the range 225-230, it is not possible to choose decisively between hypotheses A and B, while if $265 < N_E < 275$, B or C may be true.

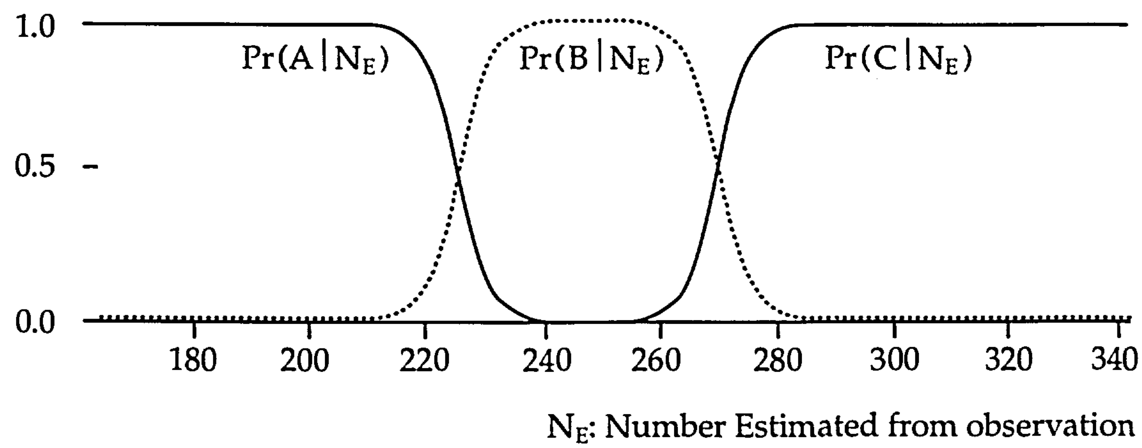
This provides a simple example of synergy between observed (objective) and other (possibly subjective) factors.

Figure 9:

Probability that Observations Will Make Estimate N_E if True Number N is 200, 250 or 300 (Hypothesis A, B and C)



Posterior Probabilities for Hypothesis A, B and C



Appendix C
Synergies Related to Environmental and Other Non-Military issues*

George Lindsey

Military and commercial intelligence organizations make synergistic use of many sources of information beyond those that they have established themselves. Examples are newspapers, periodicals, books, commercial and scientific journals, and statistics and other records published by governments.

Verification agencies may not have the support of any intelligence agency. They may need to exploit the synergy available from open sources by studies and analyses of their own. But, though generally obtainable, a large mass of public information is costly to assemble and scan, and the analysis requires experienced personnel.

Another opportunity to exploit synergy for arms control verification may exist in the rapidly expanding volume of information being collected for environmental monitoring, resource development and basic scientific research. Satellites and aircraft are being equipped with a growing variety of sensors able to detect features of the earth's surface, the surface of oceans, lakes, and rivers, and the atmosphere.

Many of the electro-optical sensors used for non-military spaceborne and airborne Earth surveillance are able to collect imagery at infrared wavelengths, detecting objects by reflections of sunlight not distinguishable at visual wave lengths. Sensors operating in the infrared range can detect very small temperature differences between objects and their surroundings, by night and by day. In fact, multispectral scanners provide an excellent example of synergy in technical methods: when the information obtained at the different wave lengths is combined, it yields knowledge not evident in panchromatic images in black and white, even though the latter are likely to have superior resolution.

While the resolution of these images will not match that available to the most advanced military-reconnaissance satellites and aircraft, it may well suffice to indicate the presence of installations or activity not previously noticed by a verifying agency. In fact, with all its resources fully engaged in the Gulf War, the U.S. Department of Defense rented the services of the commercial French SPOT surveillance satellite to produce imagery over the relevant regions of the Middle East. The information was, of course, required for operations, rather than verification, but it proved to yield invaluable information regarding the deployment of military formations.

Before long there will be several commercial observation satellites in orbit equipped with synthetic aperture radar, surveying all of the Earth's surface. Again, their resolution will not match that of the most advanced military-reconnaissance satellites, but it will offer an ability to collect images of any part of the Earth in conditions of cloud cover, at all hours, and without the need for obtaining permission from the observed party.

Both electro-optical and radar sensors can be mounted on aircraft as well as (in fact, often more easily than) on satellites, and can obtain much better resolution because of the smaller distance between sensor and target. Other advantages of airborne surveillance include cost and, in contrast to satellite surveillance, the ability to direct the overflights to the area of greatest interest, and remain there for some hours. But access to the airspace may be denied,

* Useful material for this Appendix was supplied by Mr. Jeffrey Tracey of the Non-Proliferation, Arms Control and Disarmament Division of External Affairs & International Trade Canada, and from an address by Mr. E. N. Golovko of the Russian Federation, in an address to the Open Skies Consultative Commission on 25 June 1992. Much of the background regarding the multiple uses of space surveillance is available in Surveillance from Space: A Strategic Opportunity for Canada, by George Lindsey. Working Paper 44, Canadian Institute for International Peace and Security, Ottawa, June 1992.

or, in a case of adversarial verification may encounter the risk of destruction of the aircraft. The recent agreement to permit Open Skies overflights has restricted their use to confidence-building, and has so far not extended to verification, although this is expected to occur in the future of the CFE.*

The concern over the deteriorating global environment is motivating an energetic program for atmospheric pollution monitoring, including the ozone layer, on land and on water. Objectives include arrival at an understanding of the magnitude of the problems and of the best means of alleviating them, and may also extend to the precise identification of pollution sources. Monitoring instruments can be placed on the ground and on ships, sounding rockets, balloons, aircraft and satellites. Much has been learned about the structure of the atmosphere from radiometers and sounding instruments operating at radio and optical wave lengths, but it is probable that the detection and identification of atmospheric pollutants will best be achieved by "lidar." This type of instrument resembles radar, but uses short pulses of laser radiation, which interact with small concentrations of aerosol chemicals and return echoes revealing both the location and composition of the material. Lidar can also locate and identify small concentrations of pollutants on water surfaces. Satellites provide the best platforms for global monitoring by remote-sensing techniques, and do not require permission from investigated parties. Aircraft offer the important advantage of being able to fly right through identified concentrations of pollutants in the lower atmosphere, and to collect physical samples for subsequent analysis. They may also be able to fly low enough to detect unusual radioactivity on the ground.

If the U.S., other countries or a group of nations pursues plans to control air pollution, they will have to establish some form of monitoring agency able to detect, locate and measure the quantities of controlled material released into the atmosphere. It seems possible that such surveillance might be able to provide information useful to those attempting to verify the development or manufacture of chemical weapons, or the testing of NBC weapons.

In conclusion, it should be noted that synergy also works in the opposite direction. Systems designed and operated primarily to verify arms control agreements could also have useful non-military functions. These include environmental monitoring, resource development, cartography, plotting ice cover, search and rescue, and alleviating the consequences of natural disasters, such as forest fires and floods. Some systems could also be used for security-related operations, such as peacekeeping, or enforcement functions, such as fishing control. It would be a waste of resources to confine the use of an expensive system to one application if it is also capable of other sensing with a small additional marginal cost. Further, such secondary applications could offset the cost of an Open Skies program.

* The Preamble to the Open Skies Treaty notes that signatories intend to develop the Open Skies regime to deal with such areas as the environment.

Appendix D
Suggestions for Future Research

Sidney N. Graybeal and George Lindsey

The following suggestions, made here in the form of a few questions which attempt to sketch the topic, are not necessarily in order of priority. They represent areas for further research which might be pursued.

- What are the "spin-offs" from overhead surveillance and aerial inspection for verification and for environmental monitoring?
  - What effect will declassification of certain U.S. and Former Soviet Union intelligence satellite photos have?
  - What contribution do these spin-offs make to transparency, and what impact will the resulting transparency have on arms control verification?
- Would field trials designed to assess the synergistic effects among space surveillance, aerial inspection, and ground observations be a desirable way to evaluate a verification regime associated with limitations on military forces, including personnel strength?
  - To what degree does the Cloud Gap experience contribute to designing such a field test?
- What are the interrelationships among arms control verification, the confidence-building process, and peace-keeping?
  - What verification synergies are possible?
  - Given the growing trend toward regional and local disarmament and toward peace-keeping, how could these interrelationships contribute to international security?
  - How can the roles of certain international bodies be expanded, coordinated, and optimized to contribute to arms control verification, transparency, and security?
- How could adversarial and coercive multilateral verification regimes and peacekeeping activities be "red-teamed" in order to determine what lessons potential violators learn from these activities?
  - How could these lessons be utilized to modify these verification regimes and peacekeeping activities to minimize their potential benefit to such violators?
- Table 1 in this study summarizes the synergistic effects between verification and confidence-building methods. How could the lessons learned from Table 1 be expanded to include analyses of the optimum use and cost effectiveness of various combinations of these methods for specific agreements?
- Are there verification regimes which could be effective in controlling the application of dual use technologies to weapons programs in the face of political, economic, and technological realities of the post-Cold War period?
- How could the recognition of verification synergies be incorporated into training programs for international inspectors?
  - How could these verification synergies affect the decision to form an international inspectorate and to assist in determining its nature and scope?
- What are the possible, unique contributions which monitoring methods and verification regimes can make to curtailing the proliferation of conventional arms such as surface-to-air missiles, short-range ballistic missiles, light artillery, mortars, automatic infantry weapons, land mines, and associated ammunition?

Appendix E
Additional Reading

Verification to the Year 2000
Sidney Graybeal, George Lindsey,
James Macintosh, Patricia McFate
Arms Control and Disarmament Division
External Affairs and International Trade Canada
Ottawa, 1991, Arms Control Verification
Studies No. 4

"Where Do We Go from Here? Verifying
Future Arms Control Agreements"
Patricia Bliss McFate
The Washington Quarterly
Sept. 1992, 75-85

Verification: Monitoring Disarmament
Francesco Calogero, Marvin Goldberger,
Sergei Kapitza
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The graphic on the back cover is based on an ancient Egyptian hieroglyph representing the all-seeing eye of the powerful sky god, Horus. Segments of this "eye in the sky" became hieroglyphic signs for measuring fractions in ancient Egypt. Intriguingly, however, the sum of the physical segments adds up to only 63/64 and, thus, never reaches the equivalent of the whole or perfection. Similarly, verification is unlikely to be perfect.

Today, a core element in the multilateral arms control verification process is likely to be the unintrusive "eye in the sky," or space-based remote-sensing system. These space-based techniques will have to be supplemented by a package of other methods of verification, such as airborne and ground-based sensors, as well as some from of on-site inspection and observations. All these physical techniques add together, just like the fractions of the eye of Horus, to form the "eye" of verification. Physical verification, however, will not necessarily be conclusive and there is likely to remain a degree of uncertainty in the process. Adequate and effective verification, therefore, will still require the additional, non-physical element of judgment, represented by the unseen fraction of the eye of Horus.

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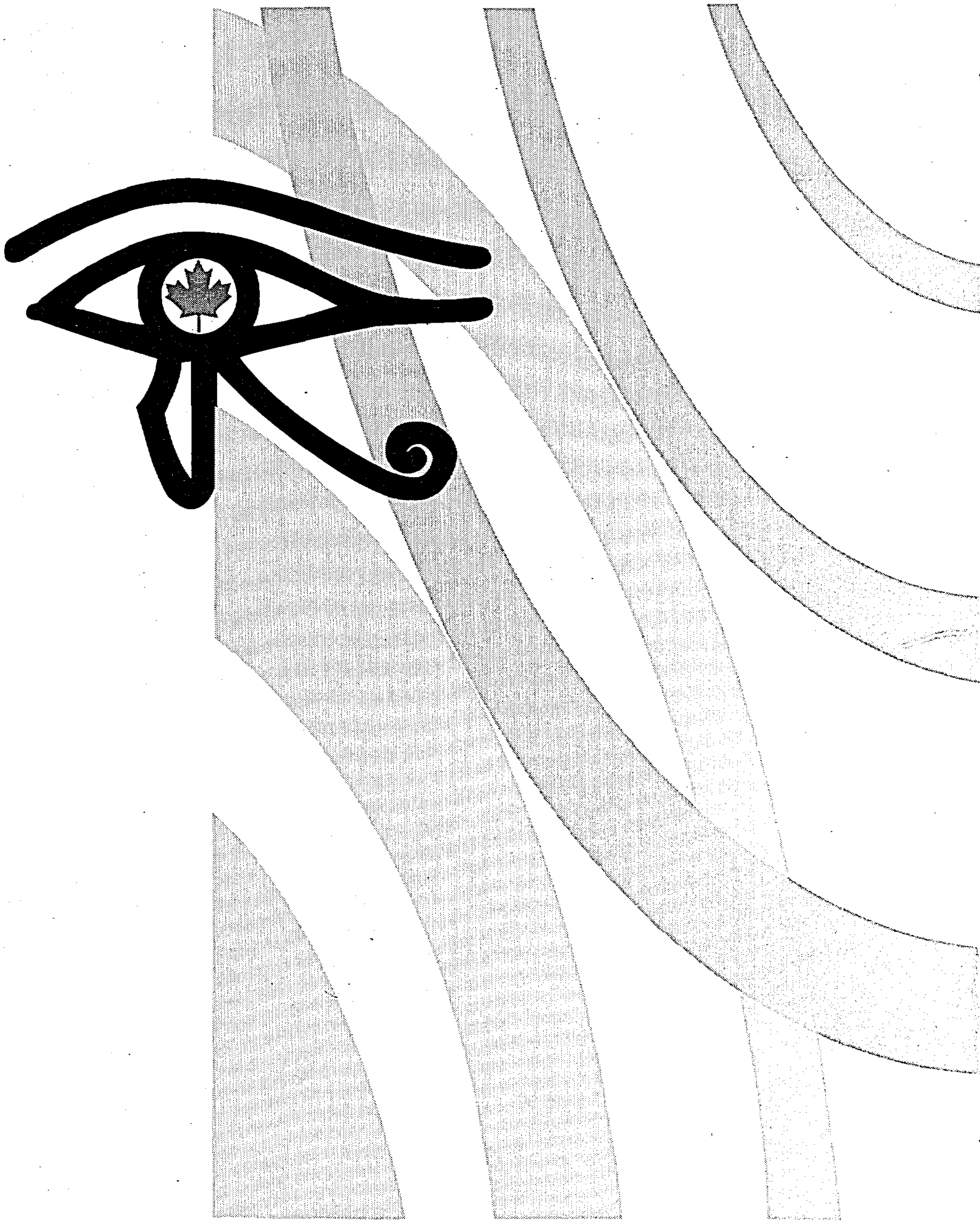

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