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Cooperative Monitoring and Its Role in Regional Security

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Cooperative Monitoring and Its Role in Regional Security

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1. Abstract

Cooperative monitoring systems can play an important part in promoting the implementation of regional cooperative security agreements. These agreements advance the national security interests of the United States in a post Cold War environment. Regional issues as widely varying as nuclear nonproliferation, trade and environmental pollution can be the source of tensions which may escalate to armed conflict which could have global implications. The Office of National Security Policy Analysis at the U. S. Department of Energy (DOE) has an interest in seeking ways to promote regional cooperation that can reduce the threats posed by regional conflict. DOE technologies and technical expertise can contribute to developing solutions to a wide variety of these international problems. Much of this DOE expertise has been developed in support of the U.S. nuclear weapons and arms control missions. It is now being made available to other agencies and foreign governments in their search for regional security and cooperation.

This report presents two examples of interest to DOE in which monitoring technologies could be employed to promote cooperation through experimentation. The two scenarios include nuclear transparency in Northeast Asia and environmental restoration in the Black Sea. Both offer the potential for the use of technology to promote regional cooperation. The issues associated with both of these monitoring applications are presented along with examples of appropriate monitoring technologies, potential experiments and potential DOE contributions to the scenarios.

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3. Introduction

National security interests of the United States are affected by a complex mix of local, regional and global concerns. These concerns cover a wide range of topics that have undergone unprecedented changes in the past decade. The Office of National Security Policy Analysis at the U. S. Department of Energy (DOE) is tasked with providing analysis of this evolving national security picture. Areas of focus include: (1) the design, manufacture, dismantlement, safety and surety of the US nuclear stockpile and its associated industrial and research complex; (2) non-proliferation and counter proliferation activities including participation with the intelligence community; (3) conduct of research and development of advanced technologies needed to support national security requirements; (4) environmental security; and (5) non-conventional national security, i.e. economic and regional stability. Each of these issues can have direct impact on vital interests of the United States.

Many parallel paths are being pursued in support of these national security interests. These include military preparedness, diplomatic initiatives, research and development, economic and other forms of assistance, as well as sanctions and other punitive actions. One path to addressing growing regional concerns is to seek regional cooperation on topics as widely varying as nonproliferation and environmental concerns. This effort to reduce regional tension and build confidence can take many forms. These may include regional forums, cultural or technical exchanges, open travel and communication or establishment of regional agreements. Each of these measures is intended to promote trust, communication, and confidence. In addition, some of these measures open the door to establishing an infrastructure for future cooperation.

This report describes how technical collaborations and cooperative monitoring can contribute to stabilization of relations among countries in a region. The US has interest in promoting its own national security through that stabilization and can offer the use of DOE technologies and technical expertise, including technologies developed to support the nuclear weapon mission, for a wide range of cooperative applications. Through the use of US expertise, including that of the Cooperative Monitoring Center (CMC) at Sandia National Laboratories, efforts can be made to contribute to the analysis and implementation of regional cooperative agreements.

In support of the mission of the Office of National Security Policy Analysis, the CMC has prepared this report on two scenarios that 1) demonstrate how experiments with cooperative monitoring technology can help countries prepare for cooperative agreements; and 2) indicate how DOE technologies and expertise can contribute to the analysis of options for potential cooperative agreements and to the implementation of cooperative monitoring experiments.

Two scenarios have been developed which include: (1) nuclear transparency to promote nonproliferation in NE Asia (N. Korea, S. Korea, Japan, China, Russia); and (2) environmental restoration of the Black Sea. These two scenarios, consisting of different regions and different security issues, are representative of the broad range of topics in which monitoring technologies could contribute to regional confidence building. Potential contributions by the DOE in promoting regional confidence building and cooperation are also presented. An appendix describes the principles of cooperative monitoring on which these scenarios were based.

4. Cooperative Monitoring Scenarios

Two scenarios have been selected by DOE for evaluation of the potential role for DOE technology and expertise in contributing to solutions of a wide range of problems. The scenarios include (1) nuclear transparency in NE Asia and (2) environmental monitoring of the Black Sea. For each scenario, cooperative monitoring activities could be part of a regional confidence building process. Opportunities for DOE contributions through training, technology development and experimentation are presented.

4.1 Nuclear Transparency in NE Asia

4.1.1 Context for Nuclear Transparency in NE Asia

Transparency in nuclear activities is a good topic for discussions of cooperative monitoring in Northeast Asia for a number of reasons: All regional states have some degree of nuclear expertise, aspects of which have aroused expressions of concern from their neighbors. Moreover, all of these states are on the record as opposing or renouncing nuclear proliferation and endorsing safety and environmental protection in their nuclear operations.

We may summarize the nuclear status of the regional states as the following:

- Japan - Having renounced development of nuclear weapons, Japan has invested heavily in the nuclear power industry and generates one third of its electricity in about 50 reactors. Energy security is an important stated goal; consequently, Japan is operating a demonstration scale reprocessing plant and fast breeder reactor. Other states have expressed concern about present and future accumulations of plutonium, which Japan claims is earmarked for future reactor fuel.
- China - Although a nuclear weapons state, China has only 3 power reactors operating and 2 more under construction. However, in the last year China has announced plans for a ten-fold expansion over the next 15 years. China also is weighing the construction of a small fast breeder reactor.

- South Korea - With 9 reactors operational and 7 more under construction, South Korea is pursuing nuclear energy vigorously. As part of the 1991 agreement with North Korea they have renounced enrichment and reprocessing facilities, but they do manufacture fuel rods for some of their reactors. South Korea will be heavily involved in the supply of 2 reactors to North Korea, based on technology they have licensed from the US.
- North Korea - In exchange for a promise of two light water reactors, North Korea has suspended construction of a gas cooled graphite reactor and closed a reprocessing plant and an associated, small reactor. Safeguards against proliferation and unsafe operating practices are included in the agreement, but neighboring states will continue to be concerned on both accounts.
- Russia - Most of Russia's weapons and power reactor industry are in Europe and Central Asia; however, the Far East nuclear navy is based at Vladivostok. Dumping of low level nuclear waste into the Sea of Japan has been a concern for South Korea and Japan.
- United States - As part of the US removal of tactical nuclear weapons from foreign soil, the US denuclearized its forces in South Korea in 1991. The US will participate in the reactor deal with North Korea, but not as the principal supplier.

Given the proximity of states with nuclear technology and the historic regional tensions, it is not surprising that nuclear issues can be sensitive. China expresses concern about the accumulation of plutonium in Japan. South Korea may reserve the right to develop the full plutonium fuel cycle after the crisis of reunification has been overcome peacefully. Russia regrets dumping in the Sea of Japan, but will continue unless its neighbors pay for safe disposal. Japan appears to some observers to adjust projected needs for plutonium to match accumulations so that there will be no surplus stocks. Despite these problems the nuclear arena presents transparency opportunities, because some states (China and North Korea) are attempting to alleviate the concerns of the international community in order to facilitate economic growth and acquisition of modern technologies.

The US DOE is well-situated to facilitate the reduction of these nuclear tensions, both by reason of technical expertise and long term contact with the regional nuclear agencies. Particularly in the case of Japan, the DOE laboratories have a substantial history of collaboration on issues of safety, material accounting and waste disposal. A similar but more modest relationship with South Korea will deepen as the Framework Agreement with North Korea passes to construction and, finally, operation of light water reactors of US design. Furthermore, numerous visits between Chinese and DOE technical experts have set the stage for meaningful cooperation with China in the civil nuclear arena.

In this section we explore some options for nuclear transparency agreements that could include cooperative monitoring utilizing DOE expertise. The goal of these transparency measures could be to address concerns having to do with:

- Nuclear material control for nonproliferation
- Environmental monitoring of radioactivity
- Assurance of operational safety of reactors

We will present ideas for potential experiments that could prepare the technical infrastructure and political confidence that is required for meaningful transparency agreements.

The experimental process allows regional states to become comfortable with the relevant technologies and establish working relationships at the technical level before being committed to an agreement. Moreover, the experiments will encounter and solve various problems that will be unique to the region, which will help define the most feasible agreements. DOE's CMC can help countries plan and conduct relevant monitoring experiments.

4.1.2 Two Possible Types of Agreements

Cooperative agreements may encompass similar facilities in participating states or, considering the different concerns from state to state, focus on a different type of potential problem in each state. In the former approach to nuclear transparency, participant states would agree to monitor the same type of facility, activity and technology in each state. Northeast Asia is well suited for this approach, in that highly similar "System 80" reactors will exist in South Korea, North Korea and the US. Generically similar, pressurized water reactors are also in Japan and China. Thus, five potential partners could host transparency measures whose implementation could be eased by the obvious equality in technology monitored.

Another transparency concept addresses the asymmetrical nature of concerns between the states. Reflecting a country-specific hierarchy of concerns, different sites and activities might be relevant in the various states. For example, Japan might be most concerned with operational safety at the North Korean reactor and disposal of radioactive waste in Russia. South Korea might be most interested in the plutonium fuel fabrication line in Japan and the shutdown reprocessing plant in North Korea. China might be interested in the isotope production reactor in South Korea and the material accounting at the Japanese reprocessing plant. Addressing asymmetrical concerns would involve different facilities, different monitoring technologies, and might be under the auspices of either a regional agreement or a series of bilateral agreements.

In the following, we consider example agreements of these two types and suggest some typical technologies that might be useful.

4.1.2.1 Example 1: A Light Water Reactor Agreement

A monitoring agreement at light water reactors would be equitable because all states have, or will have, reactors of this type. The two reactors to be supplied to North Korea by South Korea in the KEDO framework will be advanced models in the System 80 series of pressurized, light water reactors (LWRs). South Korea has two plants of this series themselves (Yonggwang Units 3 and 4), and the Palo Verde reactors near Phoenix are early System 80 models. Moreover, both Japan and China have pressurized water reactors. Thus, nearly identical nuclear technologies will exist in five of the regional states (counting the US).

Russia has four old, small, boiling-water reactors (BWR) at Bilibino above the Arctic Circle in the Far East. These are not of comparable technology and Russia would probably not be eager to participate with reactors that have seen 26 years of service under harsh conditions. However, they do have plans to build new power plants in Northeast Asia at Khabarovsk and should be consulted for possible future inclusion.

A study at Sandia has looked at options for transparency measures in the LWR context. Three topics were of interest:

- Material Diversion - Demonstration that materials are not diverted from peaceful uses. These measures may resemble some subset of IAEA Safeguards, but would be implemented independently for the purposes of sharing between states.
- Operational Safety - Demonstration that a facility is operated in a safe manner, or that operators are being trained as required.
- Environmental Protection - Demonstration that effluents are controlled and waste disposed of properly.

In a regional (or a bilateral) transparency measure, states can consider measures that either duplicate other treaty requirements, that is, IAEA Safeguards, or monitor some new parameter that most effectively addresses a concern.

States can also choose an appropriate degree of rigor for the cooperative monitoring. At a low level of transparency, states could exchange documentation, allow visits, and permit monitoring of some macroscopic parameter (a thermal record, for example). The purpose at this stage is to establish a cooperative tone, develop trust between operators and their neighboring peers, and show that the political benefits outweigh any operational inconvenience.

A more rigorous cooperative monitoring regime could address the deeper concerns between states. Fuel accounting data, normally only intended for IAEA eyes, could be subject to sharing. Regional inspectors could accompany IAEA inspectors, as in the Argentina-Brazil agreement. Monitoring could exceed that required for the IAEA in the areas of timeliness or event-triggered imaging.

The DOE has developed and utilized various technologies to perform monitoring at the appropriate level of transparency in support of domestic industry, national defense and international monitoring regimes. New agreements may be founded on technologies that incorporate periodic data recording, event-triggered recording, and automatic recognition of anomalous activities and materials. Conversely, states may be more comfortable duplicating and sharing the types of inspections that presently occur under the IAEA regime. In the following table we introduce a few ideas at low and high transparency for each of the three topic areas.

Table 1

<i>Topic</i>	<i>Goal</i>	<i>Method for Low transparency</i>	<i>Method for High Transparency</i>
Transparency in Material Inventory	Show that reactor was not producing low burnup fuel	Exchange fueling records and backup with remotely monitored thermal power	Event-triggered video of fueling area of reactor building plus authenticated thermal data
Transparency in Operational Safety	Show that plant was operating safely	Exchange training records and schedule reciprocal operator visits	Monitor outage indicators and operational status of backup safety systems
Transparency in Environmental Protection	Show that effluents are normal	Monitor off-site airborne and waterborne radionuclides	Monitor stack and coolant cycle radiation

The advantage to a transparency regime drawn from this equitable monitoring concept is that the methodologies are generally well known. Some can be duplicated from IAEA facility agreements and some are already in place for plant operations and need only to be adapted for use as shared data. The high similarity in both the monitored facility and the monitoring techniques for all parties should facilitate negotiating agreements along these lines. DOE expertise would play a key role in integrating monitoring devices to form a coherent, reliable system.

4.1.2.2 Example 2: Asymmetrical Concerns Agreements

Instead of providing transparency in nearly identical settings, states could agree to address country-specific areas of greatest concern. Because the concerns tend to be bilateral, as opposed to regional, an array of sub-regional compacts may be more likely. For some concerns, particularly those that have fallen outside of the bounds of conventional IAEA Safeguards, negotiations might identify needs for new monitoring technologies. These needs could open opportunities for technical collaboration under DOE leadership that would foster transparency.

Consider the range of concerns that we might address if we can be country-specific:

Table 2

Topic	Concern
Material inventory in a plutonium reprocessing and fuel fabrication system	Bulk quantities in the reprocessing stages can have large (1%) errors, amounting to significant quantities of plutonium
Plutonium isotopes in a reprocessing plant	Low burnup spent fuel can provide low ²⁴⁰ Pu plutonium, especially desirable for weapons
Isotope production in a research reactor	Medical and research isotope production could be masking plutonium production
Shutdown of reprocessing plant	Adherence to a fissile material ban
Shutdown of production reactor	Adherence to a fissile material ban
Radiation leaks at older or experimental reactors	Unproven and/or obsolete systems pose higher operational risks
Waste disposal from acknowledged weapons program	Convenient sea disposal may pollute the regional fisheries
Fast breeder programs	Outer blanket spent fuel will provide low ²⁴⁰ Pu content plutonium in large quantities
Transportation safety issues	Movement of fuel may threaten populations either through accidents or sabotage

Since each country has its unique security, economic and environmental concerns, the result of this approach could be a patchwork of sub-regional agreements:

For example, Russia might agree to nuclear waste monitoring in exchange for (current and continuing) technology assistance from South Korea and Japan to help it dispose of low level waste more safely.

North Korea has agreed to let the IAEA monitor the shut down of its reprocessing plant (with DOE-supplied technologies). In consideration of the 1991 agreement with South Korea to renounce enrichment and reprocessing technologies, perhaps the North would collaborate with the South to provide the South with the same information as the IAEA will receive.

China is concerned about the Japanese breeder reactor program as a proliferation mechanism, positioning the Japanese for a rapid weaponization in case their security alliance with the US should fail in the future. A one-way transparency from Japan to China, emphasizing fuel inventories perhaps, would help lower the rhetoric level even if it did not remove the plutonium fuel cycle from the scene. A cooperative implementation would increase the credibility of the transparency measures.

South Korea is considering a DOE-developed monitoring system for the Hanaro research reactor that could be useful as building blocks for regional transparency. The initial stage will probably be event-triggered video imaging that could allow observers to track isotope production operations. Addition of high resolution gamma ray spectroscopy would permit discrimination between medical isotope production and plutonium production, which South Korea has renounced.

The US would like to see progress toward a treaty banning the production of fissile material for weapons purposes. Ultimately, this means rigorous control of all plutonium production to exclusively peaceful uses. In industrial scale reprocessing plants this will pose a prodigious material accounting problem. There are some measures, however, that would be relatively easy to accomplish and make substantial progress in transparency. For example, in the weapons states, the US, China and Russia, this might mean monitoring shutdown production reactors and reprocessing plants. In the case that the production reactors in China and Russia are needed to generate power and heat, the refueling cycle could be monitored to ensure that it only produces high burnup spent fuel.

The non-nuclear weapon states could be involved too. Both of the Koreas have renounced plutonium reprocessing. Monitoring the continued shutdown of the North Korean reprocessing plant could be part of a regional fissile material cutoff agreement. South Korean participation would also be desirable; perhaps the large research reactor that is used for isotope production could be monitored for the signature of plutonium in its hot cell operations. Japan's existing and planned reprocessing activities pose the above-noted accountancy problem. An initial step that might be relatively simple would be to use high resolution gamma spectroscopy to assure that only high burnup fuels (i.e. high ^{240}Pu , less desirable for weapons) were being reprocessed. Although this would not rigorously control all plutonium, it would at least assure that the low- ^{240}Pu product was not present.

The Asian approach to these critical concerns has been to avoid confrontation, especially in the case of a China that is seeking technological assistance and investment from Japan, and to a lesser extent from South Korea. The DOE could facilitate the process of achieving regional transparency by offering technologies and technical expertise, building on collegial relations with the regional nuclear industries and authorities.

4.1.3 Experiments

Regional experiments with monitoring technologies can facilitate progress toward nuclear transparency agreements. While the DOE community feels comfortable with these technologies and accepts them as reliable tools, the regional parties may not have equal experience and confidence in the technologies. Experiments can provide a low-risk context in

which to transfer DOE expertise, establish the necessary working relationships, and solve fielding problems that may be unique to the region.

In this section experiments are suggested that might help set the stage for a light water reactor transparency agreement. The Material Control experiment builds upon an existing process that is gaining acceptance already in Japan and South Korea, where DOE monitoring technologies are being tested for use in IAEA safeguards applications. An alternative that could use many of the same monitoring elements is also discussed as an Operational Safety and Environmental Protection experiment.

A regional agreement banning the production of fissile material for weapon purposes might require technology development. Thus, experimental activities designed to develop or test new monitoring technologies might also be envisioned between regional institutions and DOE laboratories.

4.1.3.1 Experiments with Monitoring Technologies: Material Control

The DOE laboratories have developed specialized suites of monitoring technologies for measuring every characteristic of a nuclear site. Taking a building block approach, with the first steps using proven concepts, might be most acceptable to prospective agreement partners. Thus, we would suggest experimenting with a monitoring regime that is based on the existing International Remote Monitoring Project (IRMP), although the experimental process itself might be separate from IRMP.

The IRMP is a demonstration of remote monitoring of facilities around the world from one central location. As presented at the 1995 IAEA General Conference, remote monitoring with IRMP technologies may allow more timely and cost effective Safeguards in certain applications. Currently, facilities in Argentina, Australia, Japan, Sweden, and the US participate in this cooperative effort. Monitored sites emphasize spent fuel and nuclear material storage; however, the site in Sweden is an operational power reactor. At each site appropriate sensors monitor a selection of parameters: entry and movement of personnel, access to or movement of nuclear material, temperature and radiation. Each sensor reports by radio transmission to a central processor on-site and identifies itself with an authentication code. If required, the sensors can send state-of-health and tamper-indicating messages also. The processor may be programmed to acquire video images in response to sensor signals. Upon query by an operator, the processor communicates the accumulated sensor data and video images over commercial telephone or satellite links. The operator may be local or anywhere in the world, and merely needs the correct password for query authorization.

The sensor and Local Area Network (LAN) system was developed by the DOE with support of other agencies over a period of about four years. The components are now commercially available and are approved for export. Personnel movement detectors use infrared or microwave technologies. Magnetic switches monitor doors; fiber optic loops with LEDs can

monitor sealed objects. Motion of objects can be monitored either by mercury switches on the objects or change-sensitive video cameras in observation positions. The selection of other sensors will depend upon goals for the site; perhaps radiation, temperature, glass breakage, contact microswitches, or electrical use monitors will be useful. The processor and those detectors that use external power have battery backup in case of power loss. Finally, the processor can store up to 10,000 event records, which provides ample protection in case of communication loss.

As implemented at the Barsebaeck light water reactor in Sweden, the system provides video monitoring of spent fuel transfers. The video camera is located above the lift from the transportation dock to the reactor main floor, with a field of view that includes all expected locations for a fuel cask. Microwave motion sensors in the lift and above the reactor pool start the sequence of images, which continue as long as motion continues in the fuel cask area. Sweden's nuclear power regulatory agency and Sandia can access the data by telephone lines on a dial-up basis.

Adaptation of this system to a light water reactor transparency experiment in Northeast Asia would be straightforward, involving a collaboration of DOE technical experts with regional nuclear operators and regulators. As it is, the Barsebaeck example represents a very modest degree of transparency, primarily effective for confidence that large scale material diversion does not occur.

4.1.3.2 Experiments with Monitoring Technologies for Operational Safety and Environmental Protection

The DOE's IRMP system can be adapted to safety and environmental purposes, building on the nodal architecture and communications capabilities. If the Northeast Asia experimental exercise were aimed at operational safety, the monitors could emphasize thermal output recorders and sensors for the availability of the emergency cooling system. The former would warn of intermittent performance, indicative of maintenance problems. The latter would warn of an obviously dangerous mode of operation in the case where critical emergency backups were not ready for service.

If environmental concerns were foremost, monitors for airborne and waterborne radiation might be employed. As an example of a DOE-developed environmental transparency measure, Los Alamos National Laboratory has fielded a system, known as NEWNET¹, of monitors for airborne radiation in the communities surrounding their facilities. At each of five community locations, as well as 11 LANL sites, a solar-powered sensor array records gamma radiation levels and basic meteorological conditions and relays these by satellite to a central station. Community access is available on the Internet and currently records about

¹ NEWNET is described at <http://newnet.jdola.lanl.gov/newdcp.html>. SciSo, Inc., of Albuquerque produces the teller machines.

1000 queries per month. "Environmental Teller Machines" will be available soon for various community locations to provide additional access to the same data and also educational tutorials on radiation effects and sources. As a low intrusion example with use in the U. S. setting a precedent, these systems could provide valuable training to regional technologists in an experimental mode.

Further development of the NEWNET system may provide good topics for regional collaboration with DOE experts. In a first step, it might be desirable to add authentication and tamper-proofing to ensure the integrity of the data, a capability presently available in the DOE's Authenticated Item Monitoring System (AIMS). Additionally, upgrading the gamma detection system to include energy dispersion would add the capability to identify specific radioisotopes. The DOE's Environmental Measurements Laboratory (EML) has developed gamma ray spectrometers for remote applications in collaboration with Sandia and the University of Miami, Division of Marine and Atmospheric Chemistry. The RAMP² and AUTORAMP³ systems analyze gamma spectra on-site and report by satellite using commercial links. Cooperative deployment of such systems in Northeast Asia would require consideration of local communication and power conditions.

4.1.3.3 Technology Development for Advanced Experiments

Nuclear transparency agreements that would address more sensitive topics might require development to integrate specialized detectors into an IRMP-style system. We noted a range of possible topics that might be of high concern above, one of which is reprocessing of low burnup plutonium. While all grades of plutonium are judged to be useable in a weapon, low burnup-fuels with low ²⁴⁰Pu content are particularly significant indicators of a potential proliferation interest. The relative content of ²³⁹Pu and ²⁴⁰Pu manifests itself in the gamma radiation spectrum in a reprocessing plant product. A high resolution gamma spectrometer can continuously monitor this ratio with high accuracy. Combination of the gamma spectrum with tank level sensors and flow meters would contribute significant transparency to a reprocessing plant operation.

Modern reprocessing plants will include these instruments for normal operations, but such a system is not simple and would require experimental development to extend it to operation as a credible transparency tool. For example, communication systems are needed to share and protect the data. However, older reprocessing plants (particularly those built for weapons programs) would be more difficult to monitor, because little instrumentation was built into these systems and the radiation levels are high after years of use.

² Dean Mitchell, "the Remote Atmospheric Monitoring Project, RAMP", Sandia National Laboratories, CMC Factsheet, CMC95-0013f.

³ See 1995 EML Annual Report, Section 1.4 at <http://www.eml.doe.gov> and Colin G. Sanderson, Norman Latner and Richard Larsen, "Environmental gamma-ray spectroscopy at remote sites with satellite data transmission," Nuclear Instrumentation and Methods in Physics, A339, 271-277 (1994).

Some other potential agreements would require much less special development. For example, the monitoring of shut down facilities is well within the existing capabilities of DOE's IRMP technology. Entry, motion and electrical use sensors, perhaps allied with video images can be very effective. Experiments toward this purpose could be straightforward.

4.1.4 The Role of the DOE's Cooperative Monitoring Center

The DOE can facilitate regional security in Northeast Asia, while pursuing national nonproliferation objectives, by fostering experiments and collaborations in nuclear transparency. Contributing to that process, the Cooperative Monitoring Center at Sandia National Laboratories can help regional parties analyze regional nuclear concerns, understand technical options, and field experiments that would pave the way for actual agreements. In workshops at the CMC, DOE technology experts would demonstrate individual sensors and show how they are combined into functioning systems like the IRMP. Analysis exercises would help regional participants select appropriate system elements to monitor potential transparency agreements.

Follow-on activities would allow regional experts to collaborate with DOE technologists to design a prototype monitoring system, which could be tested first at Sandia, then in the region at selected sites. The CMC can accommodate regional visitors for extended stays in the case of collaborative development efforts of specialized sensors.

We have suggested the activities above as experiments to acquaint regional parties with technological options that have evolved from DOE programs in arms control, international safeguards, and the nuclear weapons program. The experiments might be performed in a bilateral mode, between the DOE and each state, with other regional parties joining when they were comfortable with the technology and the political climate was favorable. Under DOE auspices, the CMC role would be to bring the separate experiments to comparable stages of confidence, to facilitate the political process of coming to appropriate cooperative agreements.

4.2 Environmental Restoration of the Black Sea

In recent decades, the Black Sea has undergone severe environmental degradation, its entire ecosystem coming perilously close to collapse. In the last few years, however, the Black Sea has also been the focus of a major international effort at environmental cooperation, including an ambitious program for remediation. Application of procedures and technology for cooperative monitoring developed by DOE could greatly enhance this program's prospects for success.

4.2.1 The Environmental Context

The Black Sea is a unique and fragile marine ecosystem. It is effectively an inland sea, fed by rivers draining roughly one third of the land area of Europe and connected to the Mediterranean by the narrow Turkish straits. Its drainage basin encompasses nine countries and is inhabited by over 162 million people. Because of its constricted connection to the Mediterranean, the sea's water takes hundreds of years to replenish. As a result, the Black sea is the world's largest natural anoxic basin; bacteria quickly consume all the dissolved oxygen available in the deep water, and as a result the sea is incapable of supporting life below a depth of 150-200 meters. Nevertheless, the Black Sea's biological abundance supported major fishing industries for more than two thousand years, providing a vital source of income for the peoples living on its coast. In modern times, the tourist industry also thrived in the sea's littoral states (Russia, Ukraine, Georgia, Turkey, Bulgaria, and Romania), helped by a relatively moderate climate, scenic coastal areas and beaches, and the flourishing of marine life including dolphins and sturgeon.

In the past thirty years, however, the Black Sea has suffered catastrophic degradation of its natural resources. Increasing flows of sewage effluent and chemical wastes caused massive overproduction of phytoplankton (microscopic marine plants), seriously disrupting the food chain and threatening the commercial species upon which fishing industries depended. Pollution also contributed to toxic "red tides," killing fish and threatening water supplies in coastal areas. Poor or nonexistent pollution controls in the Soviet Union and Eastern Europe made matters worse, as untold tons of toxic chemicals and industrial and human wastes continued to pour into the Sea. Frequent oil spills, over fishing, and radioactive contamination from Soviet defense activities compounded the sea's environmental problems. By the 1980s, many key species of fish had become extinct and other important marine life including dolphins were seriously endangered. To make matters worse, a jellyfish-like invertebrate accidentally introduced from the eastern coast of the United States quickly consumed fish larvae and most of the native species' food supply.

At the start of the 1990s, the environmental picture of the Black Sea was bleak. River-borne contaminants and illegal dumping of toxic wastes made sea and estuary water unhealthy for human and animal life. Poor planning, industrial pollution, and sewage discharges ravaged the aesthetic resources of the coastline, and made the sea smell of decaying organic matter in many coastal areas, severely depressing the tourist industry. Biodiversity suffered severely as the invading invertebrate reached a total biomass of over 900 million tons (ten times greater than the world's annual fish harvest). Commercial species vanished or approached the brink of extinction, and fishing industries in some littoral countries were destroyed. (To give one example, Turkish Black Sea fisheries landed 338,000 tons of anchovy, mackerel, and other species in 1984; by 1989, the catch had collapsed to 15,000 tons, causing severe economic hardship among the coastal population). As pollution accelerated the rate at which bacteria consumed the available oxygen, some studies warned that the level of anoxic water was rising toward the surface, threatening to destroy all life in the sea.

The extent of the environmental problem was widely recognized, but efforts toward environmental cooperation were hampered by disagreements over other issues. Ethnic conflict and territorial disputes flared up throughout the region, particularly in Georgia (where the coastal region of Abkhazia threatened secession and still claims independence) and Turkey (where the ongoing "Kurdish problem" remains a sensitive and often violent issue). Russia and Ukraine disputed the distribution of the former Soviet fleet, and Turkey, Russia, and other former Soviet states disagreed over the construction of an oil pipeline from the Caspian Sea. Most crucially, a majority of the coastal states experienced wrenching political, economic, and social changes, and none could spare the resources necessary for a major program of environmental remediation. The only hope for the Black Sea's ecosystem lay in concerted international action.

4.2.2 The International Agreement

This hope of environmental remediation was realized as the littoral states, with the help of international agencies, agreed on a plan to save the Black Sea. In the 1992 Bucharest Convention, the coastal states agreed to set rules for limiting pollution, develop plans for managing fishing and coastal resources, and undertake a program for environmental monitoring and restoration. In 1993, with funding from the World Bank's Global Environmental Facility, the European Union, the governments of the Netherlands, France, and Japan, and other donors, a three-year Black Sea Environmental Programme (BSEP) began to coordinate the work of environmental agencies and scientific institutions in the six littoral states to characterize the sea's environmental status and begin planning for remediation and sustainable development. Under the BSEP's guidance, international working groups developed an action plan for environmental restoration, and, with the support of the IAEA and NATO's Science for Stability program, a network of scientific institutes received equipment and technical training for environmental research and monitoring. The BSEP cooperates with national environmental ministries, private industry, NGOs, and other international environmental programs, including the Danube Action Plan and the UN's Mediterranean Action Plan. Beginning in 1997, its work will be continued by a permanent secretariat, the Istanbul Commission. The Black Sea, which began the decade as an area of dangerous environmental neglect, may thus enter the next millennium as a sterling example of multinational environmental cooperation.

The success of this ambitious program to save the Black Sea is far from assured, however. Although much has been achieved by the creation of an institutional framework, the real work of practical action remains to be done. As with any international agreement, the establishment of goals and steps to be taken does not guarantee that they will be carried out. Most significantly, while the establishment of the Istanbul Commission has put the Black Sea Action Plan on a firm organizational basis, and key donors and international agencies remain committed to support the project, it is not certain that funding will continue at levels sufficient for a comprehensive program of remediation. Political problems continue to pose difficulties as well. To give one example, the exclusion of Abkhazia (which is not

recognized by any of the participating states) from the environmental accord has effectively left a substantial section of coastline south of the Caucasus Mountains outside of the program.

In general, through a successful negotiating process, the contracting parties have already realized what is politically possible in the area of environmental cooperation, but they may not fully appreciate what is economically and technically feasible. In particular, while the Action Plan includes provisions for cooperative monitoring, the technical capabilities of the institutes charged with monitoring the Action Plan are underdeveloped, particularly in their ability to employ deployed sensors and real-time monitoring. Most of these institutes will also face shortages of funds for operating the equipment purchased in the initial stages of the program even if international funding is renewed.

Additionally, under the existing Action Plan, responsibility for monitoring various sources of pollution is dispersed among the littoral states, primarily for political reasons. While being careful not to criticize these existing arrangements, DOE specialists could acquaint the parties with the political, economic, and scientific advantages of collecting and fusing remotely sensed data in a monitoring center staffed by experts from the participating countries. With these considerations in mind, there is considerable scope for DOE-sponsored experiments in cooperative monitoring to support existing regional environmental agreements.

4.2.3 Cooperative Monitoring Experiments

In the following pages we briefly outline a selection of technical contributions and experimental support that the DOE could offer to existing cooperative agencies such as the BSEP that would utilize existing DOE resources or emerging monitoring technologies. The proposed experiments are intended to be complementary to existing experimental programs and could be instituted through close working arrangements with universities and other scientific institutions affiliated with the Black Sea Environmental Programme. The complexity of the proposed activities ranges from relatively simple experiments that could be implemented quickly to more complex activities that would require significant advance planning and interaction with local scientific organizations prior to implementation. The intent of these experiments would be to improve an understanding of the complex interactions of various Black Sea environmental stressors by concerted data collection, analysis, and dissemination. Another focus of the proposed work involves the use of scientific data to more fully understand the economic implications that may result from various courses of action or inaction with regard to Black Sea environmental remediation activities. A description of four possible experimental programs follows.

4.2.3.1 Continuous Monitoring of the Black Sea Chemocline

The capability of the Black Sea to remain a viable ecosystem has significant economic and social impacts on the region. A number of researchers have hypothesized that a reduction in freshwater inflow into the Black Sea, as a result of upriver water impoundment, may be responsible for observed depth perturbations in the Black Sea chemocline, the interface between oxygenated, fish-bearing surface waters and underlying oxygen depleted waters incapable of supporting marine life. Further concerns include a complete infiltration of the anoxic layer into the upper layer with resulting dire consequences for all marine life in the Black Sea. Others have countered that the chemocline layer is exhibiting natural depth fluctuations not associated with external influences such as freshwater input. The opportunity to objectively address these concerns could provide a basis for regional cooperation.

An experiment could be conducted using a tethered buoy equipped with a number of multi-sensor probes deployed at fixed depths to monitor the position and variability of the chemocline over time. The automated buoy/sensor system could be placed in locations previously monitored via earlier manned cruises to provide a credibility link to existing data. The multi-sensor probe would measure water temperature, pH, dissolved oxygen, salinity and other water quality parameters of interest. The commercially available probe would routinely transmit data via telemetry or satellite link to a receiving station and require minimal maintenance. Reliable data interface and telemetry functions would be adapted from systems currently in use in other DOE cooperative monitoring programs.

Data from these sensor systems would be available to interested parties and would add to the data already gathered by research organizations. The data could be obtained at a fraction of the cost of periodic manned sampling efforts often used for these types of investigations. The data set would be quasi-continuous in nature would allow trend and statistical analyses to be carried out on chemocline depth variability and trends. Possession of such data may enable a definitive answer to be put forth with regard to chemocline stability in the Black Sea.

4.2.3.2 Continuous Monitoring of a Major River

Present regional data on Black Sea environmental quality suggests that the sizable influx of sewage and industrial pollutants from the major rivers such as the Danube, Dnieper and Don is a major contributing factor to Black Sea water quality degradation, particularly for the severe eutrophication (rapid, excessive growth or "blooms" of phytoplankton and algae) observed in the sea's northwest sector. Undesirable phytoplankton growth occurs primarily as a result of high concentrations of inorganic nutrients, such as nitrate and phosphate, in untreated or inadequately treated sewage. Further stress to the marine ecosystem occurs when the plant material dies, sinks to the bottom and decays. Freshwater source pollutant concentrations and accompanying time trends are incomplete however. Standardized, routine, real-time data collection of a priority list of pollutants would assist in gaining a

comprehensive understanding of the scope of the nutrient input load and would lead to improved understanding how limited remediation funds could be best invested for maximum environmental and economic benefit to the Black Sea region.

A pilot program would be instituted to develop and implement real-time monitoring capabilities of river flow and pollutant content at the mouth of the Danube or other major river flowing into the Sea. This effort would be complementary to efforts currently underway with the BSEP Special Monitoring Programme headquartered in Odessa, Ukraine, and also in conjunction with the EROS-2000 Danube river water quality monitoring project currently sponsored by the European Union. A priority pollutant list would be gleaned from ongoing monitoring activities being carried out by the BSEP. Monitored water quality parameters might include pH, total phosphate, total nitrate, ammonia, chromium (VI), chemical oxygen demand, total carbon and other heavy metals such as cadmium, copper and lead. This automated system would utilize commercially available sensor units and would be coupled with data acquisition, processing and telemetry systems currently in use in other DOE cooperative monitoring programs. The system would provide a real-time measure of water quality data for transmittal to a central data repository in Odessa. The data would then be accessible to member nations of the BSEP for further processing and analysis.

Continuous monitoring stations could form the basis of a standardized water quality monitoring systems that could be installed at all major fresh water inlets to the Black Sea. Continuous water quality data would also form the empirical basis for nutrient input models used to forecast and monitor trends in eutrophication commonly encountered in the relatively shallow northwest shelf region of the Black Sea. The data would also provide an objective measure of the extent to which formerly negotiated pollution reduction goals were being met by countries adjacent to the major rivers of the region. The data would also assist in arriving at a quantitative determination of the severity of heavy metal pollution as compared to phosphate and nitrate pollution in terms of overall adverse effect on the ecologically-threatened, northwest shelf of the Black Sea.

4.2.3.3 Remote Monitoring of Black Sea Temperature, Algae, and Circulation Patterns

Over the past several decades, remote monitoring of Black Sea surface color and other features has been conducted by satellites with on-board spectrometers that measure reflected light from the sea surface. For example, the Coastal Zone Color Scanner on board the NIMBUS-7 satellite was used to collect such data from 1978 through 1986 as a part of the Ocean Colour European Archive Network (OCEAN) Project. These data are useful for measuring such environmental indicators as the spatial extent of phytoplankton blooms, sea surface temperature, sea circulation patterns and others. Phytoplankton or algae blooms can be directly related to the influx of various pollutants such as phosphates and nitrates into the Black Sea. The presentation of these remote sensing data in geophysical parameters of interest requires considerable data processing however, through various models that take into account in-water optical properties as well as significant atmospheric effects in the

intervening layers between the sea surface and the top of the earth's atmosphere. Such models require verification and refinement in order to yield credible data on which environmental assessments and trend analysis can be based.

The DOE has several airborne spectrometer systems that could be used in a radiometric bench-marking experiment in the Black Sea region to provide important spectral radiance data near the Black Sea surface. These data could be directly compared with similar data being collected by satellites. The DOE airborne system would allow measurements to be taken at various altitudes above the sea surface such that atmospheric effects could be quantitatively evaluated and used to refine satellite data processing models such as OCEAN code developed by the European consortium noted above. The DOE Airborne Multi-sensor Pod System (AMPS) is one such airborne system that could be used in such an experiment. The Multi-sensor Imaging Pod operated by the DOE Remote Sensing Laboratory flies on a US Navy P-3 aircraft and consists of a number of optical cameras, thermal imagers, and spectral scanners for the measurement of discrete wavelength bands of reflected light from the sea surface. The wavelength bands in these spectral scanners could be matched to wavelength bands currently being monitored by a number of satellites used for sea surface color measurements, providing bench-mark data useful for improvement of satellite data processing algorithms. Such an experiment might be coordinated with other airborne remote sensing assessments that are anticipated for the DOE AMPS system in Kazakhstan in 1997.

As noted above, the possession of Black Sea surface-reflected radiometric data without significant atmospheric effects would be useful in the refinement of satellite data processing models. An experiment such as this would improve the quality and reliability of remote sensing data from satellite systems, resulting in increased credibility and use of a powerful, truly comprehensive Black Sea water quality monitoring system. While point measurements of water quality are useful, an overall picture of the entire region, via satellite imagery, is essential in coming to a more complete understanding of the overall status and trends of the Black Sea ecosystem. The information gained through such an experiment would also prove useful for the earth resources remote sensing community at large since similar sea surface color measurements are being conducted around the globe via a number of satellite sensor systems and all require the use of data processing algorithms that require similar validation and refinement.

4.2.3.4 Development of a Decision Support System for Environmental Restoration

Experts concerned with the environmental quality of the Black Sea generally agree that the Black Sea ecosystem is on the verge of collapse and is threatened by a number of significant pollutant impacts. An important need exists to quantitatively link the observed ecological decline of the Black Sea with regional economic impacts. For example, the fisheries and tourism industries are both significantly influenced by Black Sea water quality. Empirically-based, credible models are needed to establish a quantitative link between Black Sea ecological decline and regional economic impact. The DOE has developed such models for

addressing other regional environmental and resource issues. The ability to carry out remedial action simulations and to observe their expected effect on ecological and economic vitality is an important step in developing an understanding of economic impacts from Black Sea ecological decline. In this context, we suggest the development and use of a Decision Support System (DSS) for participant countries in the Black Sea Environmental Programme.

A Decision Support System would be a software product based on integration of:

- The results of a vital issues process;
- Simulations of the behavior of the contamination in the Black Sea (source, transport, impact on the ecology of the region);
- Data defining natural biological systems, engineered remedial action systems, and socioeconomic impacts associated with ecological improvements or decline; and;
- Explicit treatment of uncertainty in data, assumptions, and simulation model results.

The vital issues process would call together representatives from governments, universities, industry, and the public to identify and rank key issues of concern to all parties. Simulations of natural and engineered remedial action systems are a core element of the DSS because they relate management decisions to consequences using scientific and engineering understanding of the system as embodied in computer models. A properly designed simulation distills technical understanding by connecting decisions to consequences. Data uncertainties and expert assumptions would be integrated into the system. The simulation would also be a teaching tool, allowing decision makers to gain insight into system behavior by observing the consequences of alternative decisions.

The implementation of a functional Black Sea environmental quality decision support system would offer a number of benefits to participants in the Black Sea Environmental Programme:

- Establishment of a neutral forum for the exploration, discussion and quantification of adverse economic impacts associated with declining Black Sea environmental quality;
- Support for the regional peace by encouraging regional cooperation and regional economic development;
- Establishment of transparency of information and international confidence building through data exchange, on-site data collection and the development of empirically based models linking causes and effects;
- A focus on data optimization--collecting those data that are crucial in linking environmental quality to economic impact;
- The identification of scientific investigations necessary to reduce observed uncertainties in the decision-making process; and;
- The development of effective communication channels among neighboring scientists and policy makers through regular model development conferences and published reports.

Using DOE developed procedures and expertise, the proposed DSS would integrate much of the current data and activities associated with the Black Sea Environment Programme, particularly in its Black Sea Information System, a growing database of Black Sea

environmental data. The DSS could also serve as a training tool for the Integrated Coastal Zone Management (ICZM): Phare and Tacis Black Sea regional training program. The European Union's Phare and Tacis projects have initiated a training program in five of the Black Sea countries. Participants from Bulgaria, Georgia, Romania, Russia and Ukraine are receiving training in integrated coastal zone management, environmental impact assessment and environmental audit. Using the DSS in the training program, the trainers and facilitators could help participants develop an understanding of ICZM as a process. Coastal land management and development decisions and their resulting environmental and economic impacts could be explored using the DSS.

4.2.4 Potential DOE and CMC Contributions

By undertaking one or more of the experiments proposed above in cooperation with the BSEP and regional scientific institutions, DOE researchers can make a significant contribution to the restoration of the ecologically unique and economically important Black Sea. Experiments with remote and deployed sensors, and technical training in their use, will help monitoring organizations make maximum use of their limited resources, which is an especially important consideration for the region's developing economies. Additionally, a decision support system could help environmental scientists and officials to ascertain the effectiveness of the remediation plan and determine the best options for continued progress. Overall, the Black Sea case offers an excellent opportunity for DOE to contribute to the success of an important international environmental agreement by developing and facilitating measures for cooperative environmental monitoring. The scientific, technical, and regional expertise concentrated at the Center for Environmental Security at Pacific Northwest Laboratories, the Cooperative Monitoring Center at Sandia National Laboratories, and other DOE research facilities is an important resource which can be applied to advance both environmental and political cooperation in the Black Sea region.

5. Conclusions

Cooperative monitoring offers an opportunity for countries to engage in meaningful collection and exchange of information that can increase transparency and reduce tensions. The nuclear and environmental scenarios presented in this report represent examples of the use of monitoring to further regional cooperation. As indicated, work is already underway in the regions described to engage in cooperative efforts.

The Department of Energy and its National Laboratories have a long history of developing and deploying monitoring systems. Programs such as the Cooperative Monitoring Center at Sandia and PNL's Center for Environmental Security are examples of efforts by the DOE to make some of the technology and expertise of the national laboratories available to address a broad range of national and international security concerns. DOE contributions to these regional and global efforts can include training and educational efforts to familiarize others

with technological systems and their use in implemented agreements. The range of DOE expertise include the design, development, implementation and evaluation of monitoring systems based on laboratory personnel experience in nuclear monitoring, environmental monitoring, arms control, and numerous other topics. The DOE labs also have the necessary training facilities in which to share much of this information with regional political and technical experts. Joint research efforts to address or analyze specific regional concerns are also possible. Efforts to carry out field experiments or assist in implementing monitoring regimes for specific agreements offer an additional mission for DOE and the potential to establish or enhance the monitoring infrastructure. Finally, DOE laboratory analysis efforts, including the use of decision support system tools, offer the promise of quantifying the benefits of regional cooperative agreements and their associated monitoring regimes. In all of these ways, DOE is able to leverage the technologies and experience of its laboratories to numerous new areas of national security concern.

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Appendix A- Principles of Cooperative Monitoring

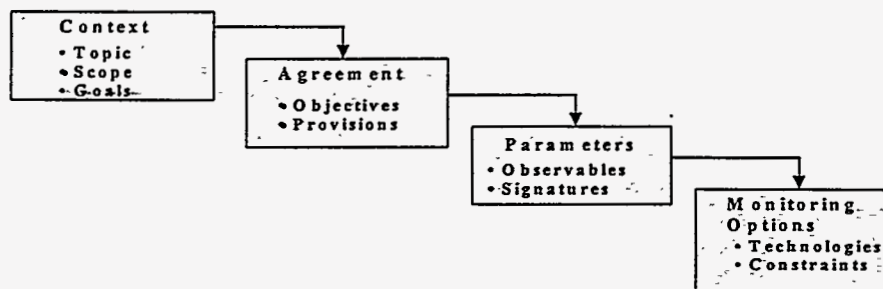
Cooperative monitoring is the obtaining and sharing of agreed information among the parties to an agreement. It makes use of technologies that are shareable among all of the parties to the agreement. This means that the technologies that collect, display, or analyze the data are not classified and are exportable to interested countries. The data collected as part of a cooperative monitoring agreement are equally accessible to all of the parties to the agreement. In addition, procedures should exist for addressing anomalies in the monitoring information. In that way, questions can be resolved to avoid escalation of concern that could lead to armed conflict.

There are many examples of cooperative monitoring systems, including formal treaty verification systems as well as less rigorous confidence-building measures. The systems may consist of inspections or sophisticated sensor and data processing equipment accessed remotely. These systems are not limited to arms control or military applications, but also may monitor a wide range of other regional concerns including natural resources, commerce and trade, the environment, or emergency response issues.

In each case, establishment of a cooperative monitoring regime is a process. There is no single monitoring solution. To evaluate monitoring options it is first necessary to establish a framework. The diagram and discussion which follow present a model for evaluating the role of monitoring systems in addressing a variety of applications.

Figure A-1

Framework for Cooperative Monitoring



Context

The framework begins with a context for undertaking security or confidence-building measures (CBMs). The context has several elements that include:

Topic--This is the subject of interest.

Scope—The scope of the agreement addresses the region, the number of parties involved, the time frame, and the extent to which the agreement will apply.

Goals—These are the high-level purposes for which an agreement is being considered. These high level goals will become more specific when incorporated in the agreements that are to be implemented.

Agreement

A desire for improved relations will eventually lead to specific agreements. The agreements, whether formal treaties or less formal CBMs, have certain objectives and provisions intended to achieve the goals established in the context. In addition to specifying the contextual elements described above, the agreements contain:

Objectives—All agreements, treaties, and CBMs have a stated purpose or objective. These objectives may:

- set limits or restrictions on objects or activities.
- provide mechanisms for transfer of information, thereby reducing uncertainties or perceived threats.
- promote or enhance relationships among the parties to the agreement.

Provisions—The objectives of the agreement are expanded in the detailed provisions. The provisions describe, for example:

- the types of control proposed,
- the objects controlled by the agreement, and
- the phase in the life cycle of the objects at which they become subject to the agreement.

Agreements may specify provisions for format and frequency of communications. Other provisions may include quantity, performance characteristics, physical dimensions, location, or operational doctrine.

Parameters

The next step in defining a monitoring system identifies specific parameters of the agreement that are measurable.

Observables—Observables are those items in the agreement that lend themselves to being monitored and observed. These may include objects, activities, processes, or movements.

Signatures—Signatures are the specific characteristics of the item, object, or process being observed. They may include optical characteristics, thermal profile, chemical composition, acoustic patterns, isotopic composition, or other measurable parameters associated with the observation. These signatures allow sensor systems to detect and classify differences between the items observed.

Monitoring Options

Once the objectives and provisions of an agreement have been determined and the monitoring parameters defined, a wide range of monitoring system options are possible using different types of technology. Other factors such as cost, manpower, redundancy, timeliness, data and hardware security, power requirements, sensor function and display, environmental conditions and vulnerability need to be assessed. In addition, the level of access or intrusiveness permitted under the terms of the agreement will affect the possible monitoring systems.

Although the chart shows the framework as a single flow path, there are many feedback loops as well. Understanding monitoring options and limitations may result in a need to modify the original agreement to establish provisions that can be monitored.

Generally, increasing the extent of monitoring will lead to increased confidence that the agreement is being followed. All systems are subject to some level of uncertainty. However, by including redundancy, utilizing different sensor phenomenologies, performing vulnerability analyses, and having extensive coverage, high levels of confidence can be achieved. It should be noted that confidence is as much a political issue as a technical one. The political tone set by national leaders, along with their willingness to provide needed openness, is critical to the success of cooperative technical monitoring systems and procedures.

Cooperative monitoring systems supplement rather than replace other national means of data collection, including intelligence means. Ultimately, each nation will use the entire set of shared and private data to determine treaty compliance.

A wide range of monitoring options can be incorporated into the terms of an agreement, ranging from no monitoring provisions to extensive technical monitoring options. Human inspectors are a key element of many agreements. Baseline inspections may be included as a formal part of an agreement to establish and confirm initial agreement declarations. Agreements may also require regularly scheduled inspections or less frequent challenge inspections. Other inspections, known as elimination inspections, may be required to ensure that items to be eliminated under the terms of the agreement have been destroyed or otherwise eliminated.

Finally, permanently manned or unmanned monitoring may be possible under terms of an agreement. This monitoring may take place within a facility or outside from the ground, air, or space. These different monitoring options represent different levels of intrusiveness.

In addition to intrusiveness, many other constraints affect the design of the monitoring regime as shown in the following figure.

Figure A-2

Considerations in Designing a Monitoring Regime

- **Cost and manpower constraints**
 - installation and training
- **Confidence level**
 - redundancy, different sensor phenomenologies
 - timeliness
 - security: tamper indication, data authentication
- **Intrusiveness**
 - inspections (announced or challenge), on-site sensors, remote sensing
- **Sensors**
 - Functions- Detection, screening, assessment
 - Parameters- false alarms, reliability, maintenance, exportability, operating conditions, site and power requirements
- **System Integration**
 - Communications, hardware and software compatibility
 - Vulnerability Assessment

Monitoring system costs consider not only the financial costs of hardware associated with design, deployment, and operation, but also the manpower requirements or limits associated with the system. The level of confidence required for the system will depend on the specific concerns addressed by the agreement. The more critical the information, the higher the requirement for redundancy in numbers of sensors and use of multiple sensor phenomenologies. Timeliness and security of the data are other variables affecting the system design.

Similarly, the functions expected of the technical monitoring system will affect the level of system complexity and choice of sensors. For example, sometimes it is sufficient for sensors to detect activity and to sound an alarm. People can then respond to the detection alarms. In other cases, it may be desirable for the monitoring system to screen the sensor data. This could allow sensors to distinguish between vehicles and animals as they were detected. Screening not only detects the presence of an object but measures other parameters such as weight or magnetic characteristics. The final level of system

sophistication is item identification. In this case, a camera or other sensor system specifically identifies the detected item.

Many other parameters affect sensor operations and performance. These include the false alarm rates of the sensors and systems as well as non-detection probabilities. Reliability measures, maintenance efforts and expense, and environmental operating conditions also help establish criteria for appropriate monitoring system design and choice of components.

Individual components need to be integrated into an operational system. This introduces an additional set of design and cost considerations, including the need to communicate between sensors, to transmit data to a central control point on-site or away from the site, and to provide power for the system. Software to manage the sensors and data collection system is another important element in system integration. Data security can also be essential. Data authentication provides a means for ensuring that data have not been altered. Data encryption provides codes that scramble the information and require decoding to read the data. A complete system design and evaluation also must include an assessment of system vulnerabilities. Many analysis tools can assist in analyzing the weaknesses of monitoring system designs.

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Appendix B- Annotated Briefing

This appendix contains an annotated briefing of this study as prepared for the Office of National Security Policy Analysis at DOE.



Cooperative Monitoring and Its Role in Regional Security

Prepared by:

**Cooperative Monitoring Center (CMC)
Sandia National Laboratories**

Prepared for:

**U.S. Department of Energy
Office of National Security Policy Analysis**

November 1996

2

- This presentation documents efforts by the Cooperative Monitoring Center at Sandia National Laboratories to describe and provide examples of the role played by cooperative monitoring techniques and technologies in furthering regional security. This work was sponsored by the Department of Energy Office of National Security Policy Analysis and is intended for use by the Office of the Secretary of Energy for evaluating technology options for selected regional security issues.
- Cooperative Monitoring Center personnel who contributed to this study include: Kent Biringer, John Olsen, Richard Lincoln, Fred Wehling, Wayne Einfeld, and David Betsill. In addition, Pauline Spaulding and Ahmed Hasan of the University of New Mexico provided contributions.



Outline



- **Project Background**
- **Scenario Development Examples**
 - **Nuclear transparency in Northeast Asia**
 - **Environmental monitoring of the Black Sea**
- **Conclusions**

3

- The briefing is divided into several sections. The background section describes the organizations involved, the history of the project, and the statement of work.
- The main body of the briefing addresses two specific applications of interest to the DOE sponsors. The first is an evaluation of monitoring options for increasing the transparency of nuclear activities in Northeast Asia. The second is an example of environmental monitoring options for the Black Sea.
- Finally, a conclusion section discusses the next steps that are possible in evaluating and implementing monitoring options for regional security and cooperation.



Project Background

4

- The background section describes the organizations involved, the history of the project, and the statement of work.



Project Summary



- **Sponsor**
 - The DOE Office of National Security Policy Analysis, PO-51
- **Study Team**
 - Cooperative Monitoring Center, Sandia National Laboratories
 - Builds on earlier interactions with PO-51
- **Statement of Work**
 - Evaluate two scenarios for Cooperative Monitoring
 - Nuclear transparency in Northeast Asia
 - Environmental monitoring in the Black Sea
 - Identify potential monitoring experiments
 - Prepare report and briefing on role of Cooperative Monitoring in regional security

5

- The sponsoring office for this work within the Department of Energy is the Office of National Security Policy Analysis under Ken Schafer. The action officers in charge of this study are Ms. Carolyn Teclaw and Mr. Fred Abel.
- The project was carried out at the Cooperative Monitoring Center (CMC) at Sandia National Laboratories in Albuquerque, New Mexico. The CMC is involved in the dissemination of information on the use of monitoring technologies to support cooperative security agreements. Late in 1995, the CMC provided information to the Office of National Security Policy Analysis on CMC activities and technologies. As a result, the CMC was provided with funding and asked to undertake the study described in this report.
- The statement of work for this study calls for development of two monitoring scenarios. One deals with nuclear transparency in Northeast Asia, while the other addresses environmental monitoring and restoration in the Black Sea. These particular topics were selected at the request of the DOE. As part of the investigation of these topics, suggested monitoring experiments to promote transparency and cooperation were developed. The results of this effort are included, along with a general description of the cooperative monitoring concepts, in a report and briefing.

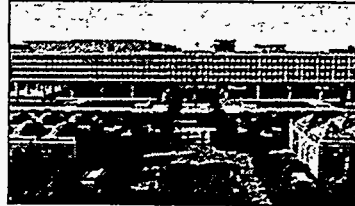


Project Organizations and Their Responsibilities



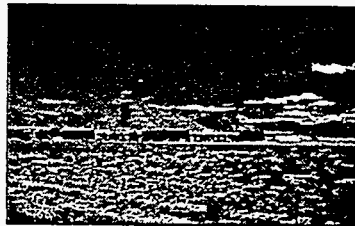
- Department of Energy, Office of National Security Policy Analysis (PO-51)

- U.S. nuclear stockpile
- Nonproliferation
- National Security technologies
- Environmental security
- Economic security and regional stability



- Sandia National Laboratories, Cooperative Monitoring Center (CMC)

- Monitoring technologies and procedures
- Monitoring applications
- Education and training

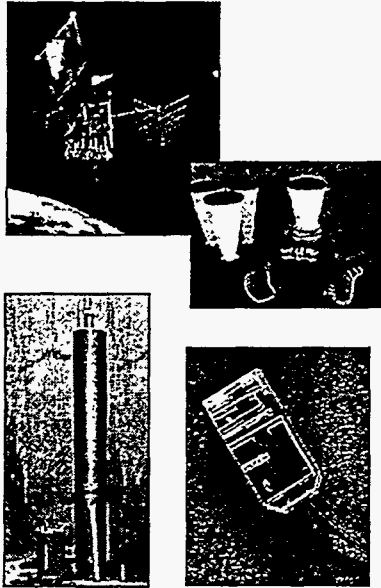


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- The national security interests of the United States are affected by a complex mix of local, regional, and global concerns. These concerns cover a wide range of topics that have undergone unprecedented changes in the past decade. The Office of National Security Policy Analysis at the U. S. Department of Energy (DOE) is tasked with providing analysis of this evolving national security picture. Areas of focus include: (1) the design, manufacture, dismantlement, safety, and surety of the U.S. nuclear stockpile and its associated industrial and research complex; (2) non-proliferation and counter-proliferation activities; (3) conduct of research and development for advanced technologies needed to support national security requirements; (4) environmental security; and (5) non-conventional national security, i.e., economic and regional stability. Each of these issues can have a direct impact on interests vital to the United States.
- Because of the need for openness in agreements between countries, the need exists to provide information that can be used to establish compliance with the agreements. Technology and procedures for cooperatively monitoring such agreements can be vital to success in providing needed transparency. The Cooperative Monitoring Center (CMC) at Sandia National Laboratories was established to assist political and technical experts around the world to acquire the technology-based tools they need to assess, design, analyze, and implement non-proliferation, arms control, and other security measures. The technologies at the CMC have been assembled from several DOE national laboratories, as well as other government agencies and industry. The CMC serves a role in providing education and training on concepts and use of monitoring to establish viable agreements and cooperation. As a part of its mission, the CMC also conducts analysis on the use of monitoring technologies for different applications.
- *Top Photo:* Department of Energy, Forrester Building, Washington, D.C.
- *Bottom Photo:* Cooperative Monitoring Center, Albuquerque, New Mexico.



DOE Laboratories' Monitoring Capabilities and Experience



- Developed satellites to detect atmospheric nuclear detonations in the early 1960s
- Continue to supply space sensor packages
- Designed monitoring system for Intermediate Range Nuclear Forces (INF) Treaty monitoring
- Developed containment and surveillance equipment for the IAEA
- Monitored underground nuclear testing
- Working with Russia on program for nuclear material protection, control and accounting
- Conducting program of international remote monitoring of nuclear facilities
- Performing environmental research and monitoring

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- The Cooperative Monitoring Center at Sandia was created in 1994 to address growing interest in applying the technologies and expertise of the DOE laboratories to new cooperative security issues including regional conflicts and motivation of countries to acquire weapons of mass destruction. Like many of the DOE labs, Sandia has a long history in the development, deployment, and operation of monitoring technologies. These include: space-based sensor systems; treaty monitoring systems such as the system deployed in Russia at the Votkinsk missile assembly plant; development of tags, seals, and video systems for use in international nuclear materials management by agencies such as the International Atomic Energy Agency; on-going projects to improve nuclear material protection and control in Russia and to enhance global nuclear material monitoring capabilities; and development and operation of numerous environmental monitoring systems for air, soil, and water.
- *Top Left Photo:* Global Positioning System (GPS) satellite.
- *Top Right Photo:* Advanced radiation-detection payload.
- *Bottom Left Photo:* Seismic sensors (note decreasing size).
- *Bottom Right Photo:* Cobra seal.



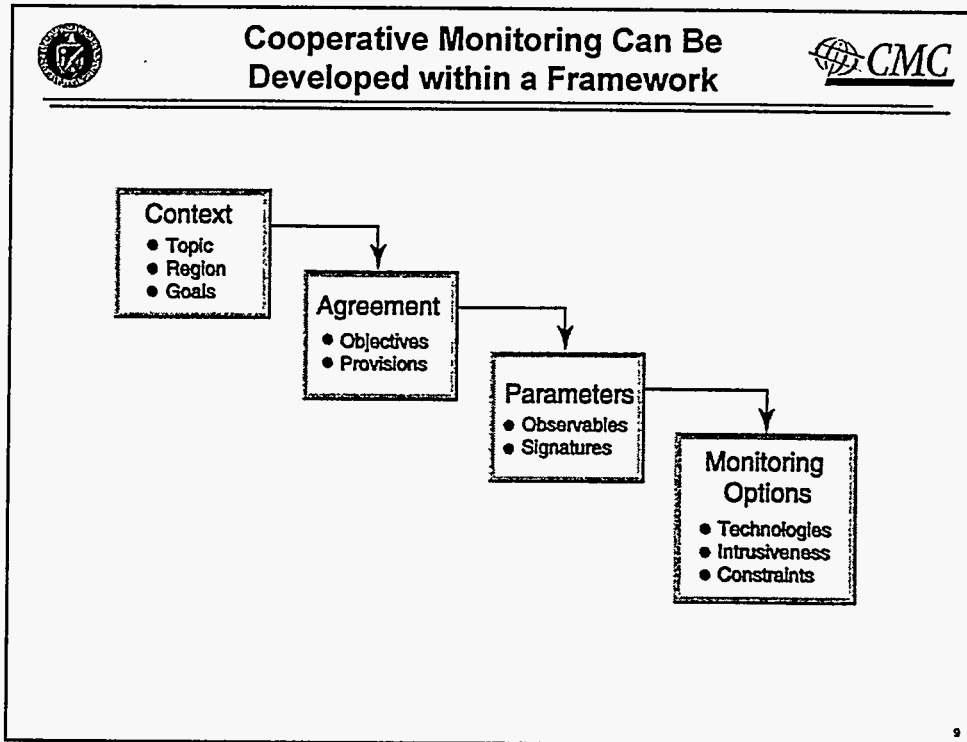
What Is Cooperative Monitoring?



- **Cooperative monitoring is the obtaining and sharing of agreed information among parties**
 - Uses sharable technologies
 - Assures *equal* access to results
 - Stipulates procedures for dealing with anomalies
- **Cooperative monitoring complements, but does not replace, national capabilities**

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- Cooperative monitoring is the obtaining and sharing of agreed information among the parties to an agreement. It makes use of technologies that are shareable among all of the parties to the agreement. This means that the technologies that collect, display, or analyze the data are not classified and are exportable to interested countries. The data collected as part of a cooperative monitoring agreement are equally accessible to all of the parties to the agreement. Procedures should exist for addressing anomalies in the monitoring information. In this way, questions or issues could be resolved to avoid escalation of concern that could lead to armed conflict.
- There are many examples of cooperative monitoring systems, including formal treaty verification systems as well as less rigorous confidence-building measures. The systems may consist of inspections or sophisticated sensor and data processing equipment accessed remotely. These systems are not limited to arms control or military applications, but may monitor a wide range of other regional concerns including natural resources, commerce and trade, the environment, or emergency response.
- The use of cooperative monitoring systems does not replace but rather supplements other national means of monitoring available to a country. Ultimately, compliance decisions on agreements are based on all available information. Cooperative regimes may permit information collection that is not available by other means, such as access to sensitive facilities.



- Establishment of a cooperative monitoring regime is a process. There is no single solution. The displayed chart shows a framework for evaluating monitoring options:
 - *Context* - The framework begins with a context for undertaking security or confidence-building measures (CBMs). The context includes: Topic (subject of interest), Scope (the region, parties involved, time frame, area of coverage), and Goals (the high-level purposes for which an agreement is being considered).
 - *Agreement* - A desire for improved relations will lead to specific agreements that form the basis of monitoring regimes. The agreements, whether formal treaties or less formal CBMs, have objectives and provisions intended to achieve the goals.
 - *Parameters* - The next framework step is to identify specific parameters of the agreement that are measurable. Observables are those items in the agreement that lend themselves to being monitored and observed. These may include objects, activities, processes, or movements. Signatures are the specific characteristics of the observables and may include optical characteristics, thermal profiles, chemical compositions, acoustic patterns, isotopic compositions, or other parameters.
 - *Monitoring Options* - Once the objectives and provisions of an agreement have been determined and the monitoring parameters defined, a wide range of monitoring system options using different types of technology is possible.
 - Although the chart shows the framework as a single flow path, there are many feedback loops as well. Understanding monitoring options and limitations may result in a need to modify the agreement to establish provisions that can be monitored.



Scenario Development Examples

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- This briefing section describes the nuclear transparency scenario for Northeast Asia and the environmental scenario for Black Sea monitoring and environmental restoration.



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- The nuclear status of states within the Northeast Asia region varies. Japan has a mature nuclear industry with a large installed base of nuclear power plants. Japan is developing a plutonium recycle fuel cycle to minimize future needs for uranium. South Korea has a nuclear industry with a significant and increasing base of nuclear power plants. Both Japan and South Korea plan to manufacture and export nuclear power plants. North Korea has a limited number of nuclear research facilities and has agreed to shut down some of their current facilities in exchange for the development of two nuclear power plants. North Korea's past use of a graphite reactor and a small reprocessing facility has raised nuclear weapon proliferation concerns among some of its neighbors. China is an NPT nuclear weapon state with a modest but very rapidly growing number of nuclear power plants. The nearby portions of Siberian Russia have a few nuclear facilities, most notably the naval facility in Vladivostok; their presence raises concerns about low-level radioactive waste disposal.
- The DOE has a long-standing collaborative relationship with the Japanese nuclear industry in areas of safety, transportation, and safeguards and a growing relationship with the South Koreans. Finally, a steady exchange of visits between DOE experts and their counterparts in China has set the stage for Sino-American cooperative efforts.
- *Image:* Map of Northeast Asia.



Context of Potential Northeast Asia Nuclear Agreements



- **Potential Topics**
 - Operational safety of nuclear reactors
 - Environmental impacts of nuclear operations
 - Proliferation potential of the plutonium fuel cycle
- **Region**
 - Northeast Asia (North and South Korea, Japan, China, possibly Siberian Russia)
- **Potential Goals**
 - Enhance regional reactor safety
 - Establish regional environmental monitoring for radionuclides
 - Reduce proliferation potential



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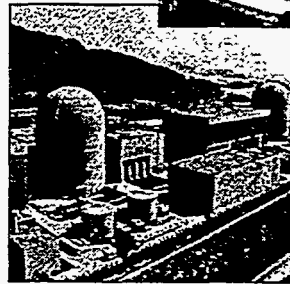
- Potential topics for a Northeast Asia nuclear transparency agreement are defined by the existing regional issues: Operational safety and potential environmental impacts that will be shared by most of the regional states because of the high population densities within the region and rapidly growing civil nuclear applications as well as the proliferation potential of the plutonium recycle nuclear fuel cycle, primarily currently associated with Japan.
- These regional issues lead to potential goals of regional agreements: enhancing regional reactor safety, establishing regional environmental monitoring for radionuclides, and reducing the proliferation potential of regional nuclear facilities. All of these goals fall within the DOE charter and utilize existing tools, technologies, and expertise. The DOE can make critical contributions to regional safety, environmental protection, and non-proliferation by collaborating with counterpart industrial and governmental units.
- *Photo:* JOYO Reactor Facility, O-arai, Japan.



Potential Northeast Asia Nuclear Agreements



- Objectives
 - Enhance reactor safety practices
 - Reduce environmental concerns
 - Control nuclear materials
- Provisions
 - Participate as a region in the IAEA reactor safety convention
 - Perform regional monitoring of environmental radionuclides
 - Share material accountancy data



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- Potential transparency agreements involve gathering and sharing information among the regional agreement partners. The information needs to contribute to the agreement objectives and be gathered and shared in a manner consistent with the agreement provisions. The information could be gathered from similar facilities in all states, or it could be gathered from different types of facilities in different states, depending on the regional issues and the provisions of the agreement.
- *Top Photo:* The South Korean Technology Center for Nuclear Control, established as a part of the Korea Atomic Energy Research Institute, supports national and international transparency programs.
- *Bottom Photo:* South Korean Light Water Reactor (LWR) power plants.



Potential Northeast Asia Nuclear Monitoring Options



● Example Technologies

- Temperature sensors
- Flow sensors
- Radiation detectors
- Motion sensors
- Video cameras
- Satellite communications
- Managed access to a common data base



● Example Constraints

- Approval by regulatory and operating authorities
- Communications and maintenance resources



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- Many existing technologies can be used to acquire and share information relevant to agreement objectives. For example, motion sensors can be used to trigger video coverage of the reactor and fuel storage pool.
- These motion sensor and video technologies have been used and tested in the DOE's International Remote Monitoring Project (IRMP) at a Swedish reactor shown in the *top photo*. Airborne radionuclide monitors, like the one shown in the *middle photo*, also could be included in a remote monitoring system. The monitor at the Finnish Centre for Radiation and Nuclear Safety may become part of the IRMP in the future. Temperature and flow sensors could be used to remotely monitor the thermal output of a nuclear power plant. The cooling towers of a nuclear power plant are shown in the *lower photo*.
- The example constraints indicated on this slide may differ state by state and are an important component of the agreement negotiations.



Technical Collaborations and Experiments to Prepare for an Agreement



- **Regional technical experts can collaborate with U.S. monitoring personnel through the CMC**
 - **Conduct workshops for hands-on technical overview at the CMC**
 - **Propose agreements through Framework for Agreements**
 - **Host extended visits to design and prototype monitoring system at CMC or other U.S. sites**
 - **Field experiments at one regional site**
 - **Extend system to partner states**
 - **Exchange experimental information**
 - **Confirm that monitoring system conforms to proposed agreement**
 - **Support negotiation of final agreement**

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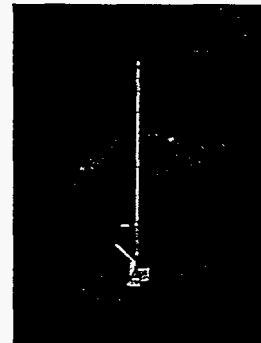
- The DOE's Cooperative Monitoring Center can bring together DOE technical experts and regional participants in a variety of ways including conducting workshops, proposing potential agreements, designing hardware and/or software in support of a proposed agreement, and prototyping monitoring systems and technical methods of sharing information. The points noted above are one possible chronology of such a series of interactions.



A Regional Transparency Experiment



- **Assume an agreement for Light Water Reactor Transparency**
 - Safety, environmental, and/or non-proliferation data are shared between agreement partners
- **Experimental parameters chosen for low intrusiveness**
 - Reactor thermal output
 - Reactor stack radiation
 - Airborne gamma radiation
 - Reactor dome and fuel pool video coverage



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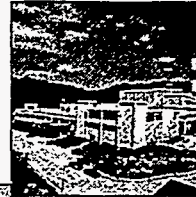
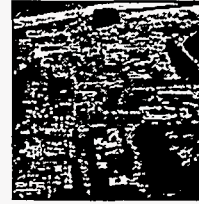
- One example of a possible regional transparency experiment is based on light water reactor monitoring. Light water power reactors are common throughout the region. Existing reactors in South Korea and planned reactors in North Korea are based on an existing U.S. design. Generic equivalents are operating in China and Japan. Thus, technically equivalent measurements could be made in all regional countries.
- Several topics of transparency are possible including areas of safety, environmental protection, and nonproliferation concerns. As an early step in building confidence, experiments can be defined that collect and share data. For each of these potential areas of cooperation and data sharing, a range of experimental parameters is available to address the needs of the regional participants. Example monitoring may include reactor thermal output, reactor stack radiation, and airborne gamma detection. Remote video systems to monitor the reactor dome area and fuel pool are also possible. Regional participants can choose appropriate monitoring to achieve the desired level of transparency.
- *Top Photo:* Remote monitoring as a means of sharing transparency information.
- *Bottom Photo:* Sensor used to monitor airborne gamma radiation in a Los Alamos National Laboratory environmental network.



Another Regional Transparency Experiment



- Assume an agreement for Plutonium Transparency
- Experimental topics chosen to alleviate proliferation concerns
 - Japan -- Assure that only high burn-up plutonium is separated in reprocessing plant
 - Gamma spectroscopy for $^{240}\text{Pu}/^{239}\text{Pu}$ ratio
 - South Korea -- Assure that radioisotope production in research reactor does not include separated plutonium
 - Gamma spectroscopy for ^{239}Pu
 - North Korea -- Assure that reprocessing plant remains shut down
 - Power monitors on motors



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- Proliferation concerns over plutonium production could also be addressed through transparency experiments. The specific proliferation concerns may vary by country, by activity and by facilities available. Monitoring experiments that address different concerns in different countries are possible.
- For instance, in Japan where reprocessing is done commercially in support of power production activities, it is possible to monitor the plutonium isotope ratios to ensure that only high burn-up fuels with high ^{240}Pu content are being reprocessed. This material is not as desirable for weapons purposes as that associated with low burn-up fuels. In the case of South Korea, the goal might be to ensure that irradiation activities in their research reactor are limited to producing non-plutonium products. A comparable monitoring experiment in North Korea might include assurance that reprocessing capabilities remain shut down.
- *Top Photo:* Aerial view of the Tokai Reprocessing Plant in Japan.
- *Middle Photo:* HANARO research reactor in South Korea.
- *Bottom Photo:* IAEA inspectors at a graphite reactor in North Korea.



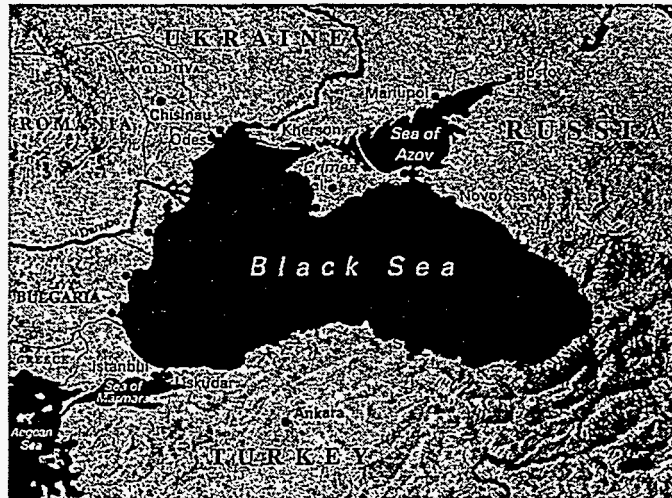
Potential DOE Contributions to Nuclear Transparency in Northeast Asia



- **Education and Training**
 - Workshops on nuclear monitoring technologies and techniques
- **Analysis**
 - Evaluation of proposed or potential nuclear agreements
- **Experiments**
 - Definition of monitoring/transparency experiments
 - Implementation of experiments

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- The Department of Energy and its laboratories have extensive expertise in designing, developing, producing and deploying nuclear monitoring technologies and systems. DOE and the labs have also played key roles in the negotiation and implementation of nuclear treaties and agreements including the monitoring aspects of those agreements. In addition, through activities such as the Cooperative Monitoring Center, DOE supports the development of regional and international regimes to address safety, environmental and nonproliferation concerns. As a result, much of this expertise is available to parties in Northeast Asia to promote nuclear transparency.
- This can be accomplished in a variety of ways including training, analysis and experimentation. By providing general or focused workshops and training classes, regional participants can become familiar with monitoring options available for use in transparency agreements. Analysis can be performed to evaluate existing or potential agreements for the ways in which monitoring and inspection can provide increased transparency. Finally, DOE can support the establishment of monitoring experiments that demonstrate the applicability of monitoring systems to specific regional concerns. In all of these ways, DOE can contribute to improving the climate of trust and cooperation in the region.



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- In recent decades, the Black Sea has undergone severe environmental degradation, its entire ecosystem coming perilously close to collapse. In the last few years, however, the Black Sea also has been the focus of a major effort at international environmental cooperation, including an ambitious program for remediation. Application of procedures and technology for cooperative monitoring developed by DOE could greatly enhance this program's prospects for success.
- *Image:* Map of Black Sea region.



Context: An Ecosystem in Crisis



- Receives wastes from nine countries, 162 million people
- Poor or nonexistent coastal and fisheries management
- Severe impact of pollution
 - Algae and plankton blooms
 - Oil spills
 - Radioactive contamination
- Catastrophic decline in biodiversity
 - Invading invertebrate reaches 900 million tons biomass
 - 18 of 23 commercial fish species no longer viable
- Fishing and tourist industries endangered

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- In the past thirty years, the Black Sea has suffered catastrophic degradation of its natural resources. The sea receives drainage from an area inhabited by over 162 million people in nine countries. Poor or nonexistent pollution controls in the Soviet Union and Eastern Europe, frequent oil spills, and radioactive contamination from Soviet defense activities also compounded the problem. By the 1980s, many commercial fish species faced destruction (of 23 species harvested in 1965, only 5 existed in viable numbers by 1990) and a jellyfish-like invertebrate accidentally introduced from the eastern coast of the United States quickly consumed fish larvae and most of the zooplankton that native species depended upon for food.
- At the start of the 1990s, the environmental picture of the Black Sea was bleak. Contaminants made sea and estuary water unhealthy for human and animal life. Fishing industries in some littoral countries were devastated. (For example, Turkish Black Sea fisheries landed 338,000 tons of anchovy, mackerel, and other species in 1984; by 1989, the catch had collapsed to 15,000 tons). Most of the coastal states were experiencing wrenching political, economic, and social changes, and efforts toward regional environmental cooperation were hampered by disagreements over related regional issues. The only hope for the Black Sea's ecosystem lay in concerted international action.
- *Top Photo: Mnemiopsis leidyi*, invading jellyfish-like invertebrate.
- *Bottom Photo: False-color map of plankton blooms near Crimean Peninsula.*



Regional Agreement: The Black Sea Environmental Programme



- Founded 1993 with support from UN, European Union, World Bank, IAEA, NATO
- All coastal states participate
- Istanbul Commission established to coordinate
- Detailed action plan for remediation
- Action plan includes provisions for monitoring
 - Responsibility for monitoring divided among participating countries
 - Black Sea Information System (BSIS) database created

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- With the help of international agencies, the coastal states agreed in the 1992 Bucharest Convention to set rules for limiting pollution, develop plans for managing fishing and coastal resources, and undertake a program for environmental monitoring and restoration. In 1993, with funding from the World Bank's Global Environmental Facility, the European Union, the governments of the Netherlands, France, and Japan, and other donors, a three-year Black Sea Environmental Programme (BSEP) began to coordinate work to characterize the sea's environmental status and begin planning for remediation and sustainable development. Under the BSEP's guidance, international working groups developed an action plan for environmental restoration, and, with the support of the IAEA and NATO's Science for Stability program, a network of scientific institutes received equipment and technical training for environmental research and monitoring. The BSEP cooperates with national environmental ministries, private industry, non-government organizations (NGOs), and other international environmental programs, including the Danube Action Plan and the UN's Mediterranean Action Plan. Beginning in 1997, its work will be continued by a permanent secretariat, the Istanbul Commission.
- *Image:* Black Sea Environmental Programme Logo.



Regional Agreement: Current Problems and Challenges



- Funding ends 1996, may not be renewed
- Political and ethnic conflicts
- Monitoring capabilities limited
 - No deployed sensors
 - No real-time monitoring
 - No monitoring center
 - Inadequate provisions for standardizing and sharing data
 - Monitoring institutions face economic and infrastructure problems

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- The success of this ambitious program to save the Black Sea is far from assured, however. As with any international agreement, the establishment of goals and steps to be taken does not guarantee that they will be carried out. The contracting parties have already realized what is politically possible in this area, but they may not fully appreciate what is economically and technically feasible. In particular, the technical capabilities of many institutions charged with monitoring the Action Plan are underdeveloped, particularly in their ability to employ sensors, orbital and aerial platforms, and real-time monitoring. Additionally, under the existing Action Plan, responsibility for monitoring various sources of pollution is dispersed among the littoral states, primarily for political reasons. While being careful not to criticize these existing arrangements, DOE specialists could acquaint the parties with the political, economic, and scientific advantages of collecting and fusing remotely sensed data in a monitoring center staffed by experts from the participating countries.
- *Top Photo:* Ukrainian scientists examine analysis equipment provided by the BSEP.
- *Bottom Photo:* Satellite image of the Black Sea region.

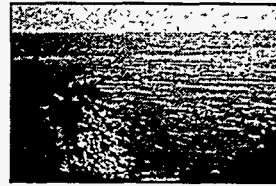
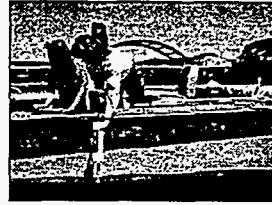


Black Sea Environmental Monitoring Experiments



A selection of proposed activities:

- Automated anoxic/oxic water boundary position monitoring via buoy/sensor/telemetry systems
- Continuous nutrient/pollutant influx monitoring at Black Sea river mouths
- Remote sensing of phytoplankton blooms via remote sensing aircraft and satellites
- Development of decision support software to better understand and communicate economic impacts from Black Sea ecological decline



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- A number of possible experiments that utilize various areas of expertise within the DOE laboratory system are presented for environmental monitoring and assessment activities in the Black Sea region.
- All these proposed experiments are designed to complement on-going activities by participant countries and scientists associated with the Black Sea Environmental Programme - a consortium of neighboring countries with a stake in the ecological and economic future of the Black Sea region.
- Important limitations of existing programs noted in many of the publications dealing with Black Sea environmental issues include:
 - Inadequately trained scientists and technicians
 - Inadequate equipment and technology for monitoring activities
- The proposed experiments are designed to specifically address these issues by providing new technologies and training in their use through close scientific interactions.
- *Top Photo:* Automated water quality measurement probe proposed for two of the DOE-supported research activities in the Black Sea region.
- *Middle Photo:* Black Sea coastline.
- *Bottom Photo:* Orion P3 aircraft (similar to the one flown by the U.S. DOE for a variety of remote sensing research projects).

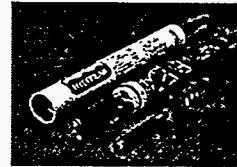
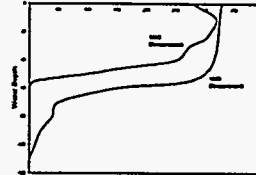
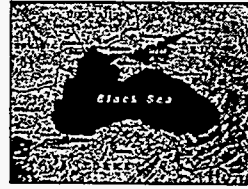


Automated Monitoring of the Black Sea Anoxic Boundary Level



Monitor the upper boundary of the oxygen-depleted water layer in the Black Sea using an automated sensor system:

- Deploy buoy(s) with a string of sensors to continuously measure dissolved oxygen, temperature, and salinity
- Transmit the data to a central location using telemetry or satellite data link
- Carry out statistical and trend analyses on the data
- Use data to gain a better understanding of anoxic layer movement and its resulting ecological implications



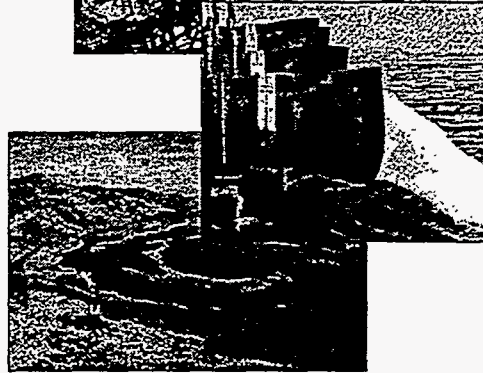
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- The Black Sea is composed of an oxygenated water layer near the surface that supports marine life and an underlying oxygen-depleted layer in which few marine species can survive.
- Scientists have observed upward movement of the anoxic (oxygen-depleted) boundary of the Black Sea and speculate that if this movement continues, the already threatened marine ecosystem in the upper layer may totally collapse.
- Commercially available water quality measurement technology could be combined with data transfer and processing techniques to provide low-cost, continuous monitoring of these boundary layer movements.
- The data would be used for trend analysis and would provide important information for the on-going scientific debate as to whether significant position changes in the boundary are occurring.
- *Top Photo:* Map of the Black Sea and surrounding countries.
- *Middle Photo:* Plot of two sets of dissolved oxygen readings at various depths taken from the Black Sea in 1969 (red) and 1988 (black). In 1969, the zero-oxygen level was measured at about 100 m; in 1988, the zero-oxygen level was reported at 60 m. At issue is whether or not these changes are significant and whether a directional (upward) trend exists. Data are adapted from J. W. Murray and others, *Nature*, Vol 338, pp. 411-413, 1989.
- *Bottom Photo:* Hydrolab (Austin, Texas) probe suitable for long-term, low-cost unattended monitoring of various water quality parameters relevant to this issue. The data from these probes can be easily linked to the research scientist's desktop by RF telemetry using local antennae or by satellite link.



Continuous automated monitoring of important pollutants at river inlets to the Black Sea

- Monitoring for phosphate, nitrate, chemical oxygen demand, and selected heavy metals at river mouth
- Automated data collection and transfer to a central site
- Prompt data dissemination to BSEP participants
- Useful for trend analysis, sea pollutant input modeling, pollution reduction assessment, and sampling standardization



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- A number of major rivers including the Don, Dnieper, and Danube flow into the Black Sea. Many of these rivers flow through heavily populated and industrialized regions of Eastern Europe and consequently are heavily polluted with untreated sewage, industrial waste, and agricultural fertilizer runoff.
- These significant freshwater inputs to the Black Sea are largely responsible (along with shore-line sewage discharge) for significant eutrophication of the Northwest Shelf of the Black Sea. *Eutrophication refers to the existence of excess nutrients such as phosphates and nitrates in the water such that the normal water ecology is disturbed.* Under these conditions, widespread algae growth occurs, disrupting the penetration of light into the water, disrupting the food chain, threatening fish populations, and so on. Dead algae falls to the bottom and further complicates the normal ecology of the lake.
- Automated monitoring of selected river inlets to the Black Sea could be used to gain information on the extent of the nutrient input problem as well as to understand the long-term trends in the major rivers. Commercially available instruments can be used to routinely monitor the phosphates, nitrates, and other toxic materials in the rivers. Data can be automatically transmitted to research centers for further processing and analysis.
- *Top Photo:* Upper Danube as it flows through Romania.
- *Middle Photo:* Typical sewage treatment plant outfall along a shoreline.
- *Bottom Photo:* A Turkish river flowing into the Black Sea.

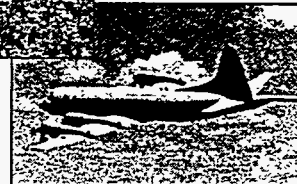


Black Sea Water Quality Monitoring by Satellite/Airborne Remote Sensing



Use the DOE/Navy P-3 Aircraft and Airborne Monitoring Pod System to collect sea color data:

- Multi-spectral sea surface color and temperature using airborne spectral radiometers
- Airborne data set comparable to available satellite data
- Airborne data suitable for improvement of satellite data processing models
- Improved remote sensing data quality and wide-scale monitoring and trend analysis of Black Sea water quality

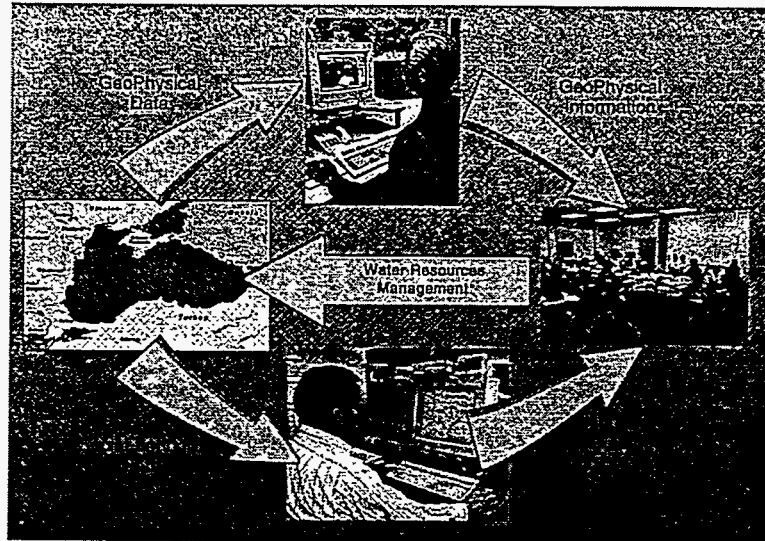


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- Research scientists have used various U.S. and European satellites equipped with multi-spectral scanners to observe changes in Black Sea color and temperature. Sea color measurements can be related to the movement and growth of algae, which in turn is caused by discharge of pollutants, such as raw sewage, into the Black Sea. In this sense, satellite data can provide a "big picture" of Black Sea water quality.
- Satellite scanner data processing requires knowledge about light transmission effects caused by the atmosphere that lies between the source (Black Sea surface) and the detector (satellite radiometer). Airborne observations of sea surface color using instrumented DOE aircraft imbedded at various locations in the atmosphere overlying the Black Sea could provide useful information for improvement of processing algorithms used to convert raw satellite data into relevant scientific parameters suitable for pollution trend analysis.
- *Top Left Image:* Map of the Black Sea and surrounding territory
- *Top Right Photo:* Typical earth observation satellite
- *Bottom Left Image:* False color map of Black Sea surface color obtained from the Coastal Zone Color Scanner flown aboard the Nimbus-7 satellite. This scanner produced sea color data from selected global coastal sites throughout the early and mid-1980s. These types of data are useful for assessing extent of pollution, sea currents, sea temperature, and other parameters of ecological interest.
- *Bottom Right Photo:* Orion P-3 aircraft similar to the one flown by the U.S. Navy for the Department of Energy. This aircraft is equipped with a number of pod-mounted systems that include a range of spectral scanners and other imaging hardware suitable for sea surface color measurements.



Decision Support Systems for Environmental Resources Management



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- A Decision Support System (DSS) to improve understanding of the economic impacts resulting from Black Sea ecological decline could be developed. The Decision Support System would be a software product based on integration of a regional vital issues process, biological, oceanographic, and socioeconomic data, and simulation of the process and effects of contamination and specific options for restoration.
- Implementation of an environmental quality Decision Support System would offer a number of benefits to countries participating in the Black Sea Environmental Programme, including promotion of transparency and international confidence building through data collection and exchange, timely provision of economic and environmental data, neutral evaluations of options to assist decisionmakers, and establishment of a cooperative training tool for regional environmental scientists and officials.



Potential DOE Contributions



- **Cooperative monitoring can strengthen the existing regional agreement**
 - Remote and deployed sensors
 - Monitoring center
 - Decision support system
- **Potential DOE activities**
 - Vital issues workshops
 - Monitoring experiments
 - Technical training
- **DOE units with specialized expertise**
 - Cooperative Monitoring Center, SNL
 - Center for Environmental Security, PNL
 - Other DOE activities



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- By undertaking one or more of the experiments proposed above in cooperation with the BSEP and regional scientific institutions, DOE researchers can make a significant contribution to the restoration of the ecologically unique and economically important Black Sea. Experiments with remote and deployed sensors and technical training in their use will help monitoring organizations make maximum use of their limited resources, which is an especially important consideration for the region's developing economies. Additionally, a Decision Support System could help environmental scientists and officials to ascertain the effectiveness of the remediation plan and determine the best options for continued progress.
- Overall, the Black Sea case offers an excellent opportunity for DOE to contribute to the success of an important international environmental agreement by developing and facilitating measures for cooperative environmental monitoring. The scientific, technical, and regional expertise concentrated in the Center for Environmental Security at Pacific Northwest Laboratories, the Cooperative Monitoring Center at Sandia National Laboratories, and other DOE research facilities is an important resource that can be applied to advance both environmental and political cooperation in the Black Sea region.
- *Top Photo:* Sunset over the Crimean Peninsula.
- *Bottom Photo:* Dolphins from the Romanian coast of the Black Sea.



Conclusions

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- This section is devoted to conclusions of the study and ways in which DOE and the Cooperative Monitoring Center can contribute to the regional cooperative security issues outlined in the briefing.



Summary



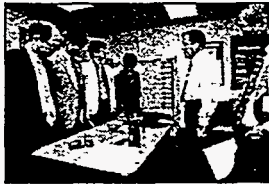
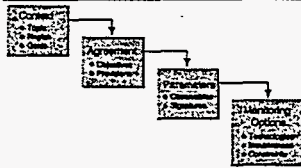
- **Regional security is taking on new importance as a U.S. national security concern**
- **Enhancing regional cooperation can reduce tensions including those that lead to proliferation of WMD**
- **Cooperative monitoring technologies and procedures offer promise of help in building regional confidence and implementing cooperative agreements**
- **Experiments in areas such as nuclear transparency and environmental monitoring can contribute to acceptance of technology in regional security**

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- Regional security is taking on new importance as a U.S. national security concern. Escalation of regional conflict to a larger scale and the linkages with proliferation of weapons of mass destruction are two of the reasons for this growing concern.
- Cooperative monitoring offers an opportunity for countries to engage in meaningful collection and exchange of information that can increase transparency and reduce tensions. The nuclear and environmental scenarios presented in this report represent examples of the use of monitoring to further regional cooperation. As indicated, work is already underway in the regions described to engage in cooperative efforts. Enhancing the use of monitoring systems may speed implementation of agreements.
- Monitoring experiments offer an opportunity to establish a familiarity with the technology. This builds confidence and can address concerns such as technical asymmetry in a region. Experimental programs also permit establishment of some of the infrastructure required for more comprehensive monitoring regimes. They also allow establishment of a cadre of experienced personnel in the region who are trained in monitoring technology design, installation, operation, and evaluation.



The CMC Can Help Countries Prepare for Regional Monitoring Agreements



- **Analysis of Issues**
 - Framework approach
 - Monitoring options
- **Technology Education and Training**
 - Workshops, training courses, visiting scholars
- **Experiments and Technical Collaborations**
 - Deployed field experiments

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- The Department of Energy and its national laboratories have a long history of developing and deploying monitoring systems. Programs such as the Cooperative Monitoring Center at Sandia are examples of efforts by the DOE to make some of the technology and expertise of the national laboratories available to address a broad range of national and international security concerns.
- Contributions by the CMC and other DOE programs to these regional and global efforts can include analysis and training to familiarize others with technological systems and their use in implemented agreements. Joint research efforts to address or analyze specific regional concerns are also possible. Finally, efforts to carry out experiments or assist in implementing monitoring regimes for specific agreements offer an additional mission for DOE, allowing DOE to leverage the technologies and experience of its laboratories to numerous new areas of national security concern.
- *Top Image:* Framework for Cooperative Monitoring
- *Middle Photo:* Cooperative Monitoring Center workshop.
- *Bottom Photo:* Video image of monitored facility in Australia.

Cooperative Monitoring and Its Role in Regional Security

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