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OPEN SKIES AND MONITORING A FISSILE MATERIALS CUT-OFF TREATY

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Open Skies and Monitoring A Fissile Materials Cut-Off Treaty

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ABSTRACT

The Treaty on Open Skies (Open Skies) is intended among other things to provide, in the words of its preamble, means "to facilitate the monitoring of compliance with existing or future arms control agreements." Open Skies permits overflights of the territory of member states by aircraft equipped with an array of sensors of various types. Their types and capabilities are treaty-limited. To find useful application in monitoring a cut-off treaty Open Skies would need to be amended. The number of signatories would need to be expanded so as to provide greater geographical coverage, and restrictions on sensor-array capabilities would need to be relaxed. To facilitate the detection of impending violations of a cut-off convention by Open Skies overflights, the data base provided by parties to the former should include among other things an enumeration of existing and former fuel cycle and research facilities including those converted to other uses, their precise geographic location, and a site plan.

INTRODUCTION

Open Skies was first proposed in 1955 by President Eisenhower as a bilateral agreement between the U.S. and the Soviet Union. It was reformulated as a multilateral proposal in 1989. Formal negotiations began in 1990. It was signed on March 24, 1992, by 23 European nations in addition to the United States and Canada. The territories of the signatories (States Parties) cover the entire European and North American land mass from Vladivostok to Vancouver, with the exception of Finland, Sweden, Switzerland and the Central American nations. It is based on the use of unarmed observation aircraft, on sensors aboard these aircraft and on quotas of observation flights which State Parties are entitled to conduct and are obliged to accept.

Unlike other arms control treaties which prohibit specific weapons or weapons systems, Open Skies is intended among other things, in the words of its preamble, "to facilitate the monitoring of compliance with existing or future arms control agreements." Open Skies complements its possible extension to future arms control treaties by authorizing the Joint Consultative Commission (JCC) to introduce additional categories and improvements to the capabilities of existing categories of sensors provided for in the Treaty. In addition Open Skies mandates the JCC to consider requests "from the bodies of the Conference on Security and Cooperation in Europe and from other relevant international organizations to facilitate the organization and conduct of extraordinary observation flights over the territory of a State Party with its consent." The JCC may also admit additional States Parties to Open Skies.

The Conference on Disarmament has a mandate to negotiate an agreement for cut-off of special nuclear materials production for use in nuclear weapons (Cut-off Agreement). This paper explores how Open Skies might be adapted for monitoring a Cut-off Agreement.

Monitoring Objectives

The terms of a Cut-Off Agreement can only be postulated at this time. In all likelihood they would require, upon entry-into-force of the agreement, signatories (State Parties) to declare fuel cycle facilities of various kinds and to provide certain base line data. Updates of these data either when changes occur or at specified intervals would also be required. Table 1 enumerates fuel cycle facilities which, for the purpose of this paper, are considered to be subject to declaration. It also lists the kinds of facilities which are not likely to be declared.

Data which as a minimum would appear to be required for each declared facility are as follows:

- Identity, location (geographic coordinates), status (decommissioned, shutdown, cold standby, operating)
- Product characteristics, production history
- Site Plan

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The objectives of monitoring would be to verify base line data and subsequent data updates. These objectives include the goals of detecting proscribed activities at both declared and undeclared sites.

Approach to Monitoring

Open Skies observational flights would be employed to detect changes in the signatures of declared nuclear activities. Where a suspicious undeclared facility is detected by National Technical Means (NTM) including Human Intelligence (HUMINT), a subsequent Open Skies observational flight might be directed to the site for further investigation. It is anticipated that the identification by an Open Skies observational flight of a change in a declared fuel-cycle activity signature or the presence of such a signature in association with an undeclared activity would lead to a challenge inspection under the Cut-off Convention. Alternatively, an Open Skies flight might provide sufficient data to ensure that a violation is highly unlikely to have occurred or to be impending, thus, making a challenge inspection unnecessary.

Airborne Sensors

To obtain agreement to the treaty by the former Soviet Union which feared that Open Skies might expose it to excessive intrusiveness, the type of sensors which are permitted on the aircraft used for observational overflights and their maximum ground resolution are strictly limited. Sensors which were considered during Open Skies negotiations are listed in Table 2. Those which were rejected at the insistence of the former Soviet Union are shown separately.

The Department of Energy has identified optical and electro-optical sensors as well as devices for effluent identification for inclusion in its Airborne Multisensor Pod System (AMPS). Several of these are briefly described below. Note that they are typically among the types of sensors rejected in the Open Skies negotiations.

- The Aerial Krypton Sampler collects whole air for later analysis at ground facility. The collection altitude is 2000 meters.
- The Echelle Grating Spectrometer (EGS) can remotely sense and identify a wide array of molecules using reflected sunlight to determine molecular absorption in an effluent plume. Clearly this sensor would be useful only during daytime and under favorable meteorological conditions.
- The Air Concentrator-Ion Mass Spectrometer operating at altitudes below 5000 feet is capable of sample collection and mass spectrometric analysis while airborne of volatile and semivolatile chemical compounds.
- The AGEMA Thermal imager operates unconstrained by altitude for nighttime imaging of heat generating objects. The minimum resolvable temperature is $< 0.1^\circ$ C.
- The Real-Time Airborne Radionuclide Analyzer and Collector operating at 50-9000 meter samples air and collects radioactive particles for near real-time analysis. It is especially useful in detecting and analyzing halogen radionuclides and daughter decay products of the noble gases.

Table 1. Fuel Cycle Facilities Under a Cut-Off Agreement

Facilities Declared
Operating enrichment plant
Operating reprocessing plant
Operating MOX facility
Operational but shutdown centrifuge facility
Inoperative gas centrifuge plant generating material from decontamination operation
Commercial reactor
Commercial spent fuel storage site
Commercial non-MOX fabrication facility
Research reactor
Operating production reactor (e.g., for tritium, ^{238}Pu)
Shutdown production reactor
Shutdown fuel-fabrication facility
Purification facility for weapons recycle
Shutdown ex-weapons fabrication/recycle facility
Reprocessing plant in cold standby
Hot cells used for non-SNM chemistry
Calutron facility used to separate non-fissile isotopes
Sensitive weapons-related facility that once housed calutrons
Experimental isotope separation facility
Facilities probably not declared
Weapons storage
Stockpile storage
Weapons assembly/disassembly
Naval reactors
Naval fuel fabrication

Table 2 Sensors in Open Skies Negotiations

Accepted Sensor Types*
Optical, Panoramic, and Framing Cameras
Video Camera
Infra-Red Line Scanning
Sideways-Looking Synthetic Aperture Radar
Rejected Sensor Types
Electro-optical
Infra-red Forward Looking
Air Sampling
Multispectral
Gravimeters
Magnetometers
Low Light TV
Laser Spectrometer

*See Reference 1 for sensor capability.

Signatures

The signatures of greatest potential relevance for Open Skies are those based on infrastructure, effluents, and emanations because there is possibility of observing or detecting them from airborne platforms. For purposes of illustration, these types of signatures are listed in Table 3 for two types of fuel-cycle facilities - a gaseous diffusion uranium isotope separation plant and an irradiated fuel reprocessing plant.

Effluents include radiological isotopes, stable isotopes and process chemicals. These materials may be airborne so that the more volatile might be detectable in a plume extending some distance from the release point. Airborne effluents are also deposited on the surface through various mechanisms, and effluents may be released directly into surface waters. Effluents on the surface may be detectable from airborne platforms. Neutron and gamma radiation emanating directly from facilities may also be detectable from the air.

For the facilities listed in Table 3 (and in other fuel-cycle and weaponization activities), enriched uranium and plutonium are the least ambiguous signatures of nuclear activities which could be related to weapons development. At facilities with no declared nuclear activities, plutonium and enriched uranium become "smoking gun" signatures. Non-nuclear uses of uranium, such as ballast, radiation shielding, pigments, and armor-penetrating projectiles, employ natural or depleted uranium, not enriched uranium. The isotopic composition of plutonium may identify activities which are inconsistent with declared activities and could possibly be related to weapons development.

The radionuclides ^{129}I, ^{85}Kr, and tritium may be effective indicators of irradiated fuel dissolution. Since they are volatile, their escape can be difficult to prevent. They are radioactive and, therefore, easier to detect than, for example, stable noble-gas fission-product isotopes. Their half-lives are sufficiently long that these isotopes will not decay to undetectable concentrations during a pre-dissolution cooling period of practical length.

A combination of several effluents may be required to distinguish nuclear activities from normal industrial activities. This is particularly true for chemical, rather than radiological, effluents where the signature may be based on the relative concentrations as well as the identities of the individual constituents.

Infrastructure signatures are derived from physical and engineering requirements. Consider the following:

• A reprocessing plant can be distinguished from a hot cell facility by the amount of shielding. The amount of shielding could be assessed through visual imaging during the construction phase and perhaps later with instrumentation (e.g., radars) having capability to measure wall thickness and composition. "Canyon-like" construction is typical of large reprocessing plants.

• Gaseous diffusion plants require large areas for the process equipment and UF6 cylinder storage and handling, large amounts of electrical energy with appropriate generation equipment nearby, and appropriate delivery systems such as transmission lines, substations, and transformers. During plant operation the dissipation of heat in the environment may be detected through hot-air or water-vapor plumes from the cooling towers or warm-water plumes from surface-water heat exchangers. With appropriate instrumentation heat dissipation may be measured quantitatively and compared for consistency with declared operation, possibly in combination with other available information. Some heat signatures may persist for a time even if energy consumption within the facility is suddenly reduced.

Despite the fact that infrastructure signatures may be difficult to analyze both because of similar requirements for other industrial processes and because of the variety of design alternatives available, it is important to consider infrastructure signatures for at least two reasons. First, effluent signatures may appear only after a facility has become operational; therefore, they may not provide adequate warning of proscribed activities. Second, with sufficient preparation, the facility operator may be able to suppress or disguise effluent signatures.

Countermeasures and Counter-Countermeasures

Although the treaty requires that all parts of a host country be subject to observational overflight, the fact that overflights and flight plans are announced, although not simultaneously, may provide opportunity to cover or suppress signatures. Note that the U.S. On-site Inspection Agency developed the Defense Treaty Readiness Program with a view to identifying critical information and countermeasures to protect sensitive facilities and programs.

Even if some signatures can be suppressed during an overflight, Open Skies can provide valuable support for monitoring activities from fixed locations. For example, Open Skies flights can establish a baseline for certain signatures relative to wind patterns and directions from specific facilities. These signatures can be remeasured at later times and compared with the previously measured signatures. The interruption of processing activities in anticipation of an Open Skies overflight in order to suppress a signature may provide a valuable time dependent perturbation to a signal detectable at a remote location. Open Skies might be modified to permit release of materials - such as perfluorocarbons which can be detected at ultralow concentrations - in order to support quantitative modeling of a signature being detected at a remote station.

Open Skies provides the opportunity to collect samples of emissions closer to their source where concentrations are higher. Emanations (e.g. of gamma-rays, neutrons, or electromagnetic signals) from facilities can be measured closer to a potential source where the signal-to-noise ratio is likely to be higher.

Geographic Coverage

To be credible a Cut-off Agreement would need to include regions not presently covered by Open Skies. Certainly it would be desirable to include in such an agreement many countries in the southern hemisphere as well as countries in the northern hemisphere south of the land mass presently subject to Open Skies overflights. In fact it might be useful to require that states adhering to a Cut-off Agreement be required to apply for admission to a geographically expanded Open Skies.

Modifications of Open Skies for Cut-off Verification

In addition to modifications to Open Skies designed to greatly extend its geographic coverage, the following modifications would improve the effectiveness of Open Skies for monitoring a Cut-off Convention and for detection of activities associated with any aspect of nuclear materials production or weaponization.

- Permit longer hover or circling time over specific facilities to enable longer measurement times, e.g., for gamma-ray emanations.

- Allow flexible flight plans to permit measurements up- and downwind of facilities

- Permit release of materials which will facilitate quantitative modeling of emissions at remote detection points

- Allow lower altitudes flights (could be restricted to certain instrument combinations)

- Allow better resolution, more sensitive instruments, e.g., for detection of hidden or underground facilities, for measurement of wall thickness, for evaluation of shielding, and for improved estimation of source strength

- Permit spectroscopic instrumentation which can identify specific chemical compounds and measure their concentrations

- Allow instrumentation for collection and concentration of trace materials from air during Open Skies flights.

Note that permitting certain of the instrumentation presently contemplated for AMPS would accomplish many of these objectives.

Table 3. Potential Air-Observable Signatures

<u>Gaseous Diffusion Uranium Enrichment</u>
Infrastructure Signatures
• Multiple large-area process buildings
• Storage yards for UF_6 cylinders
• Electrical generation facilities nearby
• Electrical infrastructure: transmission lines, substations, transformers
• Cooling towers, other means to dissipate heat to environment
• Compressors, diffuser housings
Effluent signatures
• UF_6: natural, depleted, enriched
• UF_6 decomposition products: UO_2F_2, HF, UO_2^{++}, F^-
• Freons, other fluorinated refrigerants
• Fluorinating agents: F_2, ClF_3
• Fluorides of Ni, Al, Fe
• Solvent extraction for U recovery: HNO_3, TBP, kerosene
• Transformer fluids: biphenyls, silicone oils
• Heat equivalent to electrical input
Emanations
• Gamma-rays: ^{238}U, 1001, 766 keV
• Neutrons
<u>**Irradiated Fuel Reprocessing**</u>
Infrastructure Signatures
• Canyon-like structure
• Buildings with thick walls, vent stack(s)
• Underground facilities
• Tanks for liquid waste
Effluent signatures
• Plutonium isotopics
• Fission and activation products: ^{137}Cs
• Volatile radioisotopes: ^{129}I, ^{85}Kr, tritium, ^{14}C, ^{99}Tc
• Stable Xe, Kr isotopes
• Process materials: TBP, kerosene, HNO_3, NO_x
• Valance-adjustment reagents: hydroxyl amine, sulfamic acid, peroxide, (many possibilities)
Emanations
• Gamma-rays: ^{137}Cs, 661 keV; fission products
• Neutrons

References

1. J. Allentuck, "Open Skies: Facilitating The Many Dimensions Of Transparency," INMM 34th Annual Meeting Proceedings, Volume XXII, July 1993, p. 784.

2. Department of Energy, "AMPS - Airborne Multisensor Pod System." (Brochure)