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Realizing the Full Potential of the Open Skies Treaty

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The Open Skies Treaty, which entered into force in 2002, provides a mechanism for enhancing arms control transparency, activity monitoring, and confidence building by allowing unrestricted, short-notice, aerial reconnaissance overflights.

This article explores the importance of realizing the full potential of the treaty to making progress in reducing the numbers and dangers of nuclear weapons, goals that have been endorsed by many world leaders. This effort will require expanding the membership of the treaty on a global scale and implementing modern technology for data collection and analysis.

When they first met on April 1, 2009, President Barack Obama and Russian President Dmitry Medvedev, the leaders of the two states with the largest nuclear arsenals, officially committed their countries "to achieving a nuclear-free world, while recognizing that this long-term goal will require a new emphasis on arms control and conflict resolution measures and their full implementation by all concerned nations." Toward that end, Russia and the United States resumed formal negotiations toward a step-by-step process of new and verifiable reductions in their strategic offensive arsenals, culminating a year later with the signing of the New Strategic Arms Reduction Treaty (New START). That treaty calls for modest reductions in deployed strategic forces and a commitment to move ahead with further and broader reductions in the two countries' respective nuclear arsenals. In particular, New START extends and simplifies the verification protocols and cooperative measures of the original START, which had expired. The new treaty requires data exchanges and transparency measures that are more comprehensive than those of its predecessor.

The progress made in this area of verification is breathtaking when one considers the confrontational situation 30 years ago with the former Soviet Union. It augurs well for efforts to verify deep reductions in nuclear weapons and even to abolish them. To make progress toward such goals, it will be necessary to negotiate multinational agreements for significantly more transparency and cooperation for detecting covert efforts to violate treaty restrictions on weapons activities.[1]

Projecting the state of science and technology in a world with a greatly reduced number of nuclear weapons and ultimately no nuclear weapons is necessarily speculative. The discussion in this article is based on the assumption that nuclear arms control and verification technologies most likely will exhibit evolutionary rather than revolutionary progress. In this context, it is suggested that the Open Skies Treaty, upgraded as discussed below, in conjunction with other elements of the verification system, is promising for strengthening the international community's ability to detect covert, illicit attempts to develop nuclear weapons or weapons-grade material. Yet, without a revolutionary new verification methodology, it seems unlikely to overcome the challenge of providing robust standoff detection of fissile materials encased in a deeply buried and unattended nuclear warhead. In the absence of necessary maintenance work, such systems lose military value over time. More pertinent to national security concerns will be the ability to detect potentially threatening activities involving nuclear weapons and materials, particularly as the arsenals decrease. It is the standoff detection of such activities by an expanded and upgraded treaty that is of particular interest.

Such activities would take place against a backdrop that is likely to include the following:

• Nuclear power will continue to play a role in meeting energy demands, despite the problems at Fukushima. Even with a tightly controlled and monitored nuclear fuel cycle at known sites, there is a need to develop and implement verification methods to detect a covert attempt to produce weapons-grade fissile material. At the front end of the fuel cycle, this means searching for uranium-enrichment facilities; at the back end, it means searching for spent fuel reprocessing facilities.

• The number, capabilities, and resolution of commercial and scientific remote-sensing satellites all are likely to increase, driven by the need for climate change monitoring, land and resource management and stewardship, and support of geological and atmospheric sciences. These data can help support the verification and monitoring program regimen.

Implementation of the Treaty

The Open Skies Treaty represents a remarkably successful implementation of shared technical means of verification and confidence building. The concept of Open Skies,[2] which was first proposed by President Dwight Eisenhower at the height of the Cold War in 1955, provides a mechanism for transparency and confidence building by allowing for short-notice, aerial reconnaissance overflights. The Soviet Union vehemently and immediately rejected the proposal, which was then largely ignored for more than three decades as U-2 overflights (1956-1960) and photoreconnaissance satellites (starting with Corona in 1960) proved effective in piercing the Iron Curtain. The descendants of those satellites remain an important part of the United States' national technical means.

In 1989, near the end of the Cold War, the negotiations on the Conventional Armed Forces in Europe (CFE) Treaty – putting limitations on deployments of conventional

forces in the Warsaw Pact and NATO countries – renewed interest in the Open Skies idea, with the motivation of using overflights to verify compliance with CFE provisions. This led to a speech by President George H.W. Bush calling for negotiation of an Open Skies treaty. His idea was quickly expanded by Canadian Prime Minister Brian Mulroney to include not just the United States and the Soviet Union, but all of NATO and the Warsaw Pact.

This idea caught fire. Following the conclusion of the CFE Treaty in 1990, an accord was negotiated, thereby resurrecting Eisenhower's Open Skies idea as a formal treaty. Twenty-seven states signed the treaty in 1992, but it did not enter into force until January 2002, after Russia ratified it.

Under the treaty, each party has a quota for the number of flights it may initiate annually; that number is equal to the number it must accept over its own territory. The treaty provides for reciprocal verification overflights, on 24 hours' notice, over any and all portions of the 34 states currently participating in the treaty. The United States and Russia (including Belarus) have the right to conduct and are committed to accept 42 annual overflights with trajectories that can extend over distances comparable to the distances between the borders of the inspected country. In particular, up to 21 overflights can be of each other, with the balance taken up by other parties to the treaty. At present, the Open Skies aircraft designated by the individual countries are equipped with film-based aerial reconnaissance cameras. Russia is in the process of outfitting new airframes with digital cameras, which is consistent with the treaty.

The treaty currently allows data to be acquired, subject to certain established resolution restrictions, with visible and infrared cameras, as well as with synthetic aperture radar (SAR, all-weather imaging radar), and the resulting data are available to all treaty participants. Between August 2002 and December 2010, 739 Open Skies flights were conducted.[3]

The second review conference for the Open Skies Treaty was held in Vienna in June 2010 to review and evaluate the treaty implementation thus far and to explore how the agreement might evolve in the future. The presentations at the review conference explored both augmentation of the sensors carried by the Open Skies-certified aircraft and the potential application of Open Skies collection capabilities to problems that are beyond the scope of the current treaty, such as natural disaster assessment and wildfire monitoring.[4]

The suite of sensors allowed under the treaty currently comprises optical and infrared cameras and SAR. The treaty currently limits the ground resolution obtained in overflights at optical, infrared, and radio wavelengths to 30, 50, and 300 centimeters, respectively.[5] Final notification of the desired flight path is provided 24 hours before takeoff. Mutual inspection of the aircraft and its sensors is permitted as a means to prevent a country from being subjected to any covertly added sensors. A country that has been notified of an upcoming flight over its territory also has the "taxi" option of using its own aircraft to carry out the data collection mission, if it so chooses. The crew

aboard the flight always includes personnel from the inspecting and the inspected countries.

Treaty implementation is overseen by the Open Skies Consultative Commission, which is composed of representatives from the member states. Periodic review conferences are held to administer the treaty and address issues that might arise.

Article IV of the treaty anticipates the possibility of an evolution of the sensor suite, stating that "[t]he introduction of additional categories and improvements to the capabilities of existing categories of sensors provided for in this Article shall be addressed by the Open Skies Consultative Commission pursuant to Article X of this Treaty."[6]

The treaty stipulates that decisions by the commission shall be on the basis of consensus, which is defined as no party raising an objection to an impending decision.

Exploiting Opportunities

Because the Open Skies collection platforms are aircraft, they provide technical verification opportunities that simply are not possible from satellites, for example, airborne collection of trace gas and particulate samples. These data are important in searching for covert programs to develop weapons of mass destruction (WMD); the fact that Open Skies allows for full, unrestricted, territorial access is an important feature. Obtaining gas and particulate samples would require adding new capabilities to the Open Skies sensor suite, but the treaty spells out a clear path for enhancing the instruments. Particulate and gas collection and analysis are mature and demonstrated technologies and would become increasingly important for remote monitoring of nuclear material production activities as nuclear arsenals shrink in the longer-term future. The parties to the treaty should consider augmenting Open Skies sensor capabilities and increasing multiagency coordination of standoff detection instrumentation research and development with Open Skies platform capabilities.

Even though infrared and SAR imaging are allowed under the current treaty, U.S. Open Skies aircraft currently do not carry infrared cameras or a radar system. U.S. Open Skies aircraft should carry the full complement of currently allowed Open Skies sensors with contemporary technology. Having the Open Skies system operating at full capacity not only enhances the U.S. capability for monitoring nuclear weapons activities under New START, but also provides added assurance to the country's intelligence collection systems over a substantial fraction of the globe.

In particular, the United States should replace its current film-based cameras with digital imaging systems. Installation of modern digital cameras is long overdue and will facilitate full dissemination and exploitation of Open Skies images. Digital images can be more easily georegistered (aligned with map coordinates) and thereby fused with other data sources. Increased resolution, if future negotiations allow it, can be achieved by simply flying the aircraft lower and will not require new instruments and cameras.

This approach is far more cost effective than achieving high-resolution imaging from orbit. It is also limited in practice by the need to avoid air traffic congestion and the desire to maintain a sufficiently broad width of the reconnaissance ground swath. (For a given camera system, there is a trade-off between resolution and field of view. Flying lower achieves higher resolution but diminishes the extent of cross-track coverage.)

As noted above, the current spatial resolution for the optical wavelength surveillance systems on Open Skies collection aircraft is essentially comparable to what can be obtained from commercial imaging satellites. It is an important foundation on which to build a system of shared technical means of the future, primarily because of the potential for continuing advances in the sensor suite.

Expanding the group of signatory nations would allow verification access to an increasing fraction of the globe. Open Skies is an unclassified system. Both its sensors and the information it produces can be shared with all participating countries. At present, there is a nearly decade-old U.S. presidential directive that prevents the Department of State from pursuing expanded Open Skies participation. The U.S. government should re-evaluate this policy; in the past, it managed to negotiate reciprocal access with precisely those countries among the Warsaw Pact that were of prime concern.

There are several distinct and substantial advantages to building enhanced verification capabilities based on the success of the Open Skies Treaty.

1) Open Skies is an existing treaty with a track record of success. It allows the international community to expand verification capabilities using an existing framework. Building on an existing international agreement is more straightforward than embarking on a new one. As noted earlier, the structure of the Open Skies Treaty is very well suited to evolving verification needs, the most important of which are the collection of atmospheric gases and particulate samples, which are not accessible from satellites.

2) The size, weight, and power constraints for advanced sensor capabilities are minimal with existing Open Skies aircraft. The Open Skies collection platform currently used by the United States, the OC-135B, is essentially a Boeing 707 airframe that can accommodate the deployment of innovative sensor technologies that might be larger and heavier than currently available technologies and require more power and bandwidth to operate. Next-generation sensors will need to abide by the treaty's principle that all parties have the right to install commercially available sensors that can be certified for comparable performance.

3) The treaty produces unclassified data that may be shared among the parties for government use so that all states, both former nuclear-weapon states and countries that always have been non-nuclear-weapon states, can benefit in the future from the verification collections. This reduces information inequities among countries and avoids the problems associated with the sharing of classified data that are collected by states that wish to protect sensitive sources and methods. Since the treaty's entry into force,

the United States has requested copies of film from 84 missions conducted by other parties and processed 23 requests for imagery obtained during U.S. missions.

4) Although broader WMD considerations are beyond the scope of this paper, one could readily imagine augmented Open Skies sensors designed to search for evidence of biological or chemical weapons programs. In some cases, such as active laser spectroscopy, the same instruments could provide nuclear and non-nuclear WMD verification.

Specific Technical Opportunities

This section highlights the potential technical opportunities for enhancing the verification capabilities of the Open Skies sensor suite and, where appropriate, identifies the research and development needed to support these options. Because the goal of the section is to map out the technical opportunities, it presents concepts that span a range of levels of intrusiveness. It is not intended to be an exhaustive or comparative survey of all possible methods for detecting covert uranium-enrichment or plutonium-recovery efforts, but rather is meant to illustrate the potential benefits of enhancing Open Skies for future verification applications.[7]

The verification opportunities presented below eventually must be carefully assessed in terms of their technical readiness, their verification utility, and the likely political (U.S. and foreign) barriers to adoption. The Open Skies verification effort would presumably augment and complement other methods, such as on-site inspections and wide-area monitoring, methods that are employed today by the Comprehensive Test Ban Treaty Organization's International Monitoring System.

One important verification application of enhanced Open Skies is the problem of covert fissile material production. For covert enrichment programs, the analysis below will concentrate on the detection of uranium and its compounds, while for plutonium, it will focus on how to exploit the krypton-85 (Kr-85) signature of reprocessing.

Atmospheric Gas Sampling. The detection of trace gases has long been considered to be a potentially useful method for detecting clandestine production of fissile materials.[8] The ability to collect and store gas samples along an aircraft's flight path would be a powerful augmentation to the Open Skies collection suite. The aircraft's ability to enter and exit the suspect territory rapidly allows for the gas analysis to be performed on the ground in an appropriate laboratory setting with minimal delay.

A particularly interesting verification method is to search for the unstable noble gas isotope Kr-85, which is produced in the consumption of uranium in reactors and is released when fuel rods are reprocessed for plutonium extraction. By monitoring Kr-85, researchers have claimed the ability to sense plutonium separation activity of a few hundred grams per week from a standoff distance of 39 kilometers.[9] Thus, an Open Skies flight should have the ability to map out a swath of terrain that spans tens of kilometers on either side of the flight path. This is probably not enough area coverage

per flight to perform a rapid survey of an entire large country, but it should allow for samples to be collected from sites that are suspected (from image analysis or other sources) of harboring clandestine reprocessing activity.

Given the 24-hour notification time, the detailed flight plan (altitude and path) can take wind forecasts into account, and the flight can be tailored to maximize the system's sensitivity to detect emanations from a region of particular interest. One measurement challenge for an airborne Kr-85 sampling system is the varying natural background concentration. Therefore, the task is to discriminate spatial and temporal variation in pre-existing backgrounds from the signature arising from weapons-related activities. Making a differential measurement of Kr-85 concentration along the flight path should facilitate this. A ground-based network of Kr-85 sensors is likely to be an element in a verification protocol for "nuclear zero," and the combination of ground-based and aircraft-collected data will be more powerful than either data set in isolation.

Scientists currently do not have a detailed understanding of the propagation and diffusion of noble gases from reprocessing activity, especially if conducted underground, but deeply buried facilities will have an increased diffusion timescale compared to activities on the surface. Thus, even if reprocessing were shut off in response to an Open Skies overflight notification, one would not anticipate an instantaneous termination of detectable Kr-85.

On the U.S. side, the sister aircraft to the OC-135B Open Skies collection platform is the WC-135 Constant Phoenix, which apparently already has a gas sample capture and storage capability.[10] The implementation of an atmospheric gas sampling scheme is not technically demanding and could be undertaken in short order. The samples presumably would be subjected to laboratory analysis on the ground.

Particulate/Aerosol Sampling. The Constant Phoenix also has a particulate sampling capability. Adding this verification technique to the Open Skies aircraft is therefore presumably a fairly straightforward undertaking. An automated particulate sampler has been developed for use in verifying the Comprehensive Test Ban Treaty.[11] This is a mature technology.

The collected particulates can be analyzed for any hint of weapons-grade fissile materials. In particular, the radionuclides that adhere to particulates and aerosols can be analyzed to determine the ratios of the isotopes of elements of interest, which is extremely valuable information for plutonium and uranium. The results from studies focusing on the releases from covert fuel-cycle facilities imply that a monthly Open Skies aerosol collection flight over a region the size of the Middle East, in conjunction with high-sensitivity laboratory analysis techniques, should provide good monitoring of clandestine fissile material production activity over such a region.[12] The studies consider only fixed ground stations, but an Open Skies flight can collect aerosols along the entire flight path and from an optimized altitude.

Higher-Resolution Optical and Infrared Imaging. The ability to increase imaging resolution would be significant from a verification standpoint.[13] Attaining better resolution from orbit requires larger-diameter mirrors. The satellite cost scales faster than the square of the mirror diameter,[14] while the resolution increases only linearly with diameter. High-acuity imaging from space therefore is very expensive. From airborne platforms, one can just fly lower to obtain sharper images; the ground resolution distance is simply proportional to the aircraft's height above the ground. This makes the acquisition of high-resolution images from aircraft much more affordable than from space. The highest resolution images of urban areas in Google Earth are from aerial photography, not from commercial satellite images.[15]

The high-resolution camera system currently used on the U.S. Open Skies collection platform, the KA-91C camera, is operated from an altitude of 35,000 feet in order to abide by the treaty's stipulations on ground resolution.[16] The potential for higher-resolution imaging already exists and will continue to exist if and when the Open Skies participants change from film to digital imaging systems. Maximum allowable ground resolution and minimum allowable flight altitude were topics of considerable discussion.[17] Although the political challenges of obtaining higher resolution images from Open Skies platforms should not be underestimated, the technical aspects of this upgrade are fairly straightforward: the parties simply need to agree to take aerial photography from lower flight altitudes.

Laser-Illuminated Time-Resolved Imaging Spectroscopy. Various techniques are under development for the optical standoff detection of uranium and its compounds. A full exploration of the dual challenges of signal-to-noise ratio (sensitivity) and discrimination (rejection of natural backgrounds and clutter) is beyond the scope of this article.

Activity Monitoring With SAR. An advantage of radar imaging with SAR is its unique all-weather, day and night access to targets of interest. This could play a valuable role in monitoring activity and detecting changes at suspect sites, such as possible weapons caches. Further work should be pursued on this potential.

Conclusion

Implemented in the waning days of the Cold War era, the Open Skies Treaty is a laudable example of transparency and confidence building and can provide an important framework for implementing broader verification methods in a nuclear-zero era.

Toward achieving that goal, the United States should initiate diplomatic and technical steps to implement a modern upgraded suite of all three currently allowed Open Skies Treaty sensors (optical, infrared, and SAR), work to enhance the scope of collections undertaken from treaty platforms, and expand international participation in the treaty.

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ENDNOTES

1. The scope of this paper specifically excludes technical issues that are unique to countering nuclear terrorism. Preventing a nuclear version of the September 11 attacks is a top priority but a different technical problem from the elimination of existing national nuclear weapons arsenals. Continuing reductions in the number of nuclear devices that must be safeguarded and steady progress in limiting access to fissile materials will help to suppress the likelihood of a nuclear terrorist event. However, the classical concept of strategic deterrence is likely of little use in countering an attack by suicidal nonstate actors using weapons of mass destruction. In the nuclear terrorism context, a nuclear arsenal (and the radioactive materials within it) is arguably more of a liability than an asset. [back to story]

2. Not to be confused with Open Skies agreements that pertain to civil aviation and landing rights. [back to story]

3. For a listing of Open Skies flights through June 4, 2010, see www.osce.org/secretariat/68315. [back to story]

4. See, for example Mike Betts and Don Spence, “Potential Non-Treaty Applications for Open Skies Assets” (presentation, 2nd Open Skies Review Conference, OSCC.RC/11/10, June 2, 2010). [back to story]

5. The ground resolution obtained by Open Skies images is stipulated in the treaty. At visible wavelengths, it is roughly comparable to that obtained by commercial satellites and presumably inferior to that of U.S. national technical means (NTM). This may be one reason that U.S. engagement and investment in Open Skies is currently rather precarious, because it adds little to current NTM satellite capabilities. [back to story]

6. Article X of the Open Skies Treaty defines the structure, responsibilities, and function of the Open Skies Consultative Commission. The prospect of an enhanced sensor suite is explicitly cited in this section of the treaty as well. Changes and additions to the sensor systems require only commission approval and do not require an amendment to the treaty. [back to story]

7. An interesting opportunity that this article does not explore is the possibility for “bi-static” techniques, with two Open Skies aircraft operating in tandem. One aircraft could contain an optimized light source, and the other a detector system. The atmosphere between the aircraft could then be sampled in transmission, at high spectral resolution and high signal-to-noise ratio. [back to story]

8. See Paul R.J. Saey, “Ultra-Low-Level Measurements of Argon, Krypton and Radioxenon for Treaty Verification Purposes,” *ESARDA Bulletin*, No. 36 (2007). [back to story]

9. Martin B. Kalinowski et al., “Conclusions on Plutonium Separation From Atmospheric Krypton-85 Measured at Various Distances From the Karlsruhe Reprocessing Plant,” *Journal of Environmental Radioactivity*, Vol. 73, No. 2 (2004): 203. See also Martin B. Kalinowski, Heiner Daerr, and Markus Kohler, “Measurements of Krypton-85 to Detect Clandestine Plutonium Production,” *INESAP* Bulletin, No. 27 (December 2006). [back to story]

10. U.S. Air Force, “WC-135 Constant Phoenix,” February 11, 2009, www.af.mil/information/factsheets/factsheet.asp?id=192. [back to story]

11. See S.M. Bowyer et al., “Automated Particulate Sampler for Comprehensive Test Ban Treaty Verification (The DOE Radionuclide Aerosol Sampler/Analyzer),” *IEEE Transactions on Nuclear Science*, Vol. 44, No. 3 (June 1997): 551. [back to story]

12. On uranium-conversion facilities, see R. Scott Kemp, “Initial Analysis of the Detectability of UO2F2 Aerosols Produced by UF6 Released From Uranium Conversion Plants,” *Science and Global Security*, Vol. 16, No. 3 (2008): 115-125. On uranium-enrichment and spent fuel reprocessing facilities, see P.W. Krey and K.W. Nicholson, “Atmospheric Sampling and Analysis for the Detection of Nuclear Proliferation,” *Journal of Radioanalytical and Nuclear Chemistry*, Vol. 248, No.3 (2001): 605-610. [back to story]

13. See Sidney D. Drell and Raymond Jeanloz, “Nuclear Deterrence in a World Without Nuclear Weapons,” in *Deterrence: Its Past and Future*, eds. George Shultz, Sidney Drell, and James Goodby (Stanford, CA: Hoover Institution Press, 2011), pp. 21-29. [back to story]

14. This is because of the added weight and volume needed to accommodate a larger primary mirror. The typical cost scaling assumption is D2.5, where D is the mirror diameter. [back to story]

15. Google, “Imagery Partner Program,” 2011, http://maps.google.com/help/maps/imagery/. [back to story]

16. U.S. Air Force, “OC-135B Open Skies,” September 28, 2007, www.af.mil/information/factsheets/factsheet.asp?id=120. [back to story]

17. See Mark David Gabriele, “The Treaty on Open Skies and Its Practical Applications and Implications for the United States” (Ph.D dissertation, RAND Graduate School, 1997). [back to story]