VIEWPOINT: USING AIRBORNE REMOTE SENSING TO VERIFY THE CWC

by Greg D. Rowe[1]

The worst threat likely to be encountered by the United States in the future is that of weapons of mass destruction (WMD) in the arsenals of its rivals, and even in the hands of terrorists. These weapons—nuclear, biological, and chemical—have a twofold purpose. First, they act as force multipliers for outmanned armies, supplying both tactical and strategic advantages. Second, they have psychological effects on the enemy they are used against because they kill people in particularly inhumane ways—scorching flesh, attacking nervous or immune systems, or causing painful and slow deaths by radiation sickness or infectious disease. Third, they are indiscriminate killers affecting general populations as much as soldiers.

As a result, efforts have been made, especially since the end of the Cold War, to outlaw and eliminate WMD. Cold War efforts to reduce nuclear weapons have been accelerated through the Strategic Arms Reduction Treaty (START I) and the indefinite extension of the nuclear Non-Proliferation Treaty (NPT). Biological weapons have been outlawed by the Biological Weapons Convention of 1972 (BWC), which now has 135 parties. Moreover, the development, production, stockpiling, and transfer of chemical weapons are to be banned by the implementation of the Chemical Weapons Convention (CWC) of 1993. At least 20 countries currently possess chemical weapons (CW) or are attempting to produce them.[2] This viewpoint focuses on efforts to detect the illicit production of CW using the synergy between existing treaties, available technologies, and intelligence measures.

The CWC negotiations included discussion of aerial inspections to assist in verification of the convention. These measures were rejected when on-site inspections (OSIs) were deemed intrusive enough for the purposes of the treaty. However, the use of aerial inspections to verify the CWC has been studied as a possible addition to the treaty.[3] A different treaty that involves overflights for security confidence-building, the Open Skies Treaty (OST), was signed in 1992 and is awaiting entry into force. During OST negotiations, sensors capable of detecting specific chemical constituents in airborne effluents were discussed. These sensors were considered primarily for environmental monitoring, but were also considered for detection of CW production. The OST already complements the Conventional Forces in Europe Treaty (CFE). CFE jurisdiction is limited to west of the Ural Mountains, while the OST allows unrestricted territorial coverage of participating countries. The OST also is an intelligence supplement for many states, especially helping those with no national technical means (NTM) for arms control verification, such as satellites or reconnaissance aircraft.

This essay analyzes the question: Could remote chemical sensors incorporated into the OST sensor suite complement CWC verification? First, the background and intent of both the OST and CWC are examined. Second, the nature of CW and likely CW production scenarios, including models of detectable effluents, are laid out. Third, two technologies for chemical remote sensing—one laser-based and one infrared-based—are reviewed. Finally, different inter-treaty, international, and U.S. domestic political issues raised by this question are explored. The analysis spells out the difficult road this proposal would need to travel to be enacted, but finds the proposal to be beneficial to the OST, CWC, and the overall CW counterproliferation effort of the United States.

THE TWO TREATIES

Although both the OST and CWC are part of a larger

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body of arms control measures, the overlap between the two is tenuous. The OST is a confidence-building measure with broad territorial access but with sensors that are shallowly intrusive. The CWC is designed to eliminate a category of WMD through specific on-site and reporting procedures that are narrow in their focus but deeply intrusive. There are many complementary aspects of the OST for the CWC, but there are also many obstacles to integrating these treaties.

The Open Skies Treaty

The Open Skies initiative was conceived in 1955 by President Eisenhower as a confidence-building measure between the two Cold War blocs. It called for an exchange of unarmed reconnaissance flights to observe military and national security activities. It was a vehicle for transparency in the pre-satellite era. It was summarily rejected by Premier Khrushchev as tantamount to espionage. In 1989, the Bush administration revived the idea of reciprocal unarmed reconnaissance flights for three specific reasons:

> to offset Gorbachev's dramatic disarmament proposals, which had upstaged U.S. initiatives and sparked criticism of the administration's slow pace on arms control; to divert attention from the divisive intra-alliance debate over the modernization of short-range nuclear forces, which threatened to overshadow the May NATO summit in Brussels; and to test Gorbachev's *glasnost*.[4]

Ultimately, these political motivations became moot following the dissolution of the Soviet Union. However, the resulting instability in Eastern Europe and the former Soviet Union still gave the treaty a significant purpose—confidence-building. According to Dr. Thomas Karas, Senior Associate of the International Security and Commerce Program in the Congressional Office of Technology Assessment, "The Open Skies regime of mutual overflights should be seen primarily as a confidence-building measure, not an arms control monitoring or verification measure, nor as one that will add greatly to U.S. intelligence collection."[5]

The OST was revived as a bloc-to-bloc transparency measure. In the aftermath of the Cold War, however, it has evolved into a country-to-country confidence-building measure. In 1992, it was signed by all 16 NATO countries, all former Warsaw Pact countries (except East Germany which had ceased to exist), and four former Soviet republics—Russia, Belarus, Ukraine, and Georgia. The treaty is open to any other nation by consensus approval of the parties.[6]

Each participant nation has both a passive quota and an active quota for flights. The active quota, is the annual number of overflights a state may perform within the Open Skies regime. The passive quota is the annual number of overflights a state is required to accept by the treaty. A signatory's active quota will not exceed its passive quota. These numbers were determined by the geographic size and importance of each state. Russia-Belarus and the United States will accept 42 overflights of their territory each year, the most for any party.

The most sensitive Open Skies negotiations involved intrusiveness. As negotiators considered the sensors proposed, they were interested in determining what level of intrusiveness would be permitted during an overflight.

The OST sensors finally agreed upon were:

1. Optical panoramic and framing cameras, resolution of 30 centimeters.
2. Video cameras with real-time display, resolution of 30 centimeters.
3. Infrared line-scanning devices, resolution of 50 centimeters.
4. Side-looking synthetic aperture radars (SARs), resolution of three meters.[7]

A resolution of 30 centimeters (roughly one foot) for optical cameras was selected because it will enable an observer to distinguish between, for example, a truck and a tank, but not the *type* of truck or tank. The infrared devices allow for effective sensing when vision may be obscured. Through their heat-sensing, infrared sensors can determine the operational status of airports, military bases, and industrial sites such as chemical facilities.[8] Infrared sensors complement optical devices during clear weather, but if used as a primary sensor, they do not have the resolution to distinguish between certain objects. The relative insensitivity of the SARs, with a resolution of approximately 10 feet, is intended to allow only for the detection of concentrations of trucks, tanks, artillery, or other armaments. SARs need to be supplemented with other sensors to amplify their findings. Similar to the infrared sensors, SARs are capable of detection at night and during bad weather.

Some parties expressed concern that the United States would exploit its technological advantage and possibly place illegal sensors on its aircraft. This led to the inclusion of the "taxi" option, allowing a host party to insist on the use of its aircraft with a comparable sensor suite on board. This measure would prevent unauthorized sensors from being used during an overflight.

The final agreement led to full access of all territories. John Hawes, United States negotiator to the OST, stated,

> All parties are obligated to permit observation of their entire territory. The observation flights will be conducted on the basis of a mission plan submitted by the observing party, which may only be modified in the event of specific threats to flight safety.[9]

This is the first treaty to ever grant complete territorial to all participants, essentially "challenge" inspections for each overflight. An important feature of this comprehensive access is that it will supplement the CFE. Whereas the CFE zone of application is limited to areas of Russia, the OST will allow areas east of the Urals to be monitored.

Data collected on overflights will be shared by the observing and observed parties, in the form of raw film or magnetic tape. The treaty does not allow the use of film that may be computer-enhanced because this would defeat the purpose of the agreed-upon crude resolution. Since participants are limited to their annual active overflight quotas, copies of this raw data can be purchased by any participant in the Open Skies regime. Under the treaty, this data will not be made available to nonparticipants.

The OST attempts to raise the level of trust among states and avert conflict through its broad access and quasi-intrusive sensors. It does not verify any specific actions or items, but can be used in a larger sense for confidence-building and as a tacit complement to other arms control treaties.

The Chemical Weapons Convention

The CWC is the most comprehensive and intrusive multilateral treaty ever signed. The CWC prohibits the development, production, acquisition, stockpiling, retention, transfer, and use of CW.[10] The CWC calls for the destruction of any CW stockpiles and production facilities. The CWC even prevents assistance to other states in acquiring a CW capability. It involves the monitoring of both government and commercial sectors of chemical production, requiring extensive reporting by each. Only three states have admitted CW programs, the United States, Russia, and Iraq; however, many more states are suspected of having CW or attempting to acquire them.

The CWC was extremely difficult to negotiate because of the dual-use nature of many precursor chemicals and chemical processes. The verification provisions had to be intrusive enough to determine compliance without violating proprietary rights, causing excessive shutdown costs for industry, or intruding on states' sovereignty.

The CWC has been signed by 160 states. However, as of June 1996, only 52 states had deposited their instruments of ratification with the United Nations. The CWC will not enter into force until 180 days after the 65th instrument is deposited.[11] Of the states that have not signed, the majority are either small, poor states, or Arab states refusing to sign in protest against Israel's refusal to sign the NPT. The CWC does not require universal adherence to be effective, but universality would enhance its effectiveness.

Negotiators of the CWC devised three schedules of controlled chemicals according to toxicity and military and commercial utility. The chemicals with high toxicity levels and almost singular purpose as CW, with little or no commercial utility, were placed on Schedule 1. Schedule 2 chemicals have low to moderate commercial application, but are considered high risk because they can be used as CW or as precursors to CW. Schedule 3 chemicals are used in large quantities by commercial industry, but still pose a risk because they have been used as CW or as precursors for CW.

Once the CWC is ratified by the 65 countries needed for its entry into force, the Organization for the Prohibition of Chemical Weapons (OPCW, the CWC's administrative organization) will establish a baseline database. States will declare CW production, storage, and destruction sites, and commercial declarations will also be made for sites with capabilities to produce CW. This baseline database will be updated annually.

The CWC verification procedures include two types of inspections: routine and challenge. Routine inspections will encompass declared production, storage, processing, and destruction facilities on a predictable time schedule. Challenge inspections are short-notice, intrusive inspections of any site, declared or undeclared.

Scope, timing, and depth of routine inspections will depend on the schedule of the chemicals involved. Schedule 1 facilities allow for the most intrusive inspections. These inspections will be conducted on short notice with unimpeded access, allowing inspectors to mark and seal items for future reference. Schedule 1 sites may be continuously monitored by on-site monitoring devices such as those used in Iraq—video surveillance and electronic sensors.

Challenge inspections go beyond routine inspections by seeking detecting noncompliance at undeclared sites. As Amy Smithson of the Stimson Center writes, "Challenge inspections are designed to detect and deter activities prohibited by the Convention, namely the development, production, storage, acquisition, transfer and use of chemical weapons."[12]

Challenge inspections are limited through negotiated "managed access." Managed access ensures that each challenge inspection will be different because of negotiations between inspectors and host-country officials. If the OPCW Executive Council finds that the state party requesting a challenge inspection has abused the intent under the CWC, it can recommend that that state bear some or all of the financial burden of the inspection.

DETECTION OF CHEMICAL WEAPONS PRODUCTION

The production methods for chemical weapons are harder to detect than those for nuclear weapons. The feed chemicals used for production of CW have myriad commercial uses such as production of pesticides, pharmaceuticals, fertilizers, and even pen ink. Much of the equipment and processes are also used in commercial enterprises.[13]

Developed countries with many diverse commercial chemical production plants could hide illicit production. Underdeveloped countries would attract more attention in their procurement processes through the types of raw materials they purchase or produce domestically. The types of plant facilities they import and assemble, such as high-quality, corrosion-resistant reactors, piping, and valves or sophisticated filtration systems may also attract attention. Still, supply-side nonproliferation is extremely difficult because of the dual uses of chemicals and equipment.

Chemical weapons may be unitary or binary in design. Unitary weapons are ready to use, but can be less stable and may have a shorter shelf life. Binary weapons have two separate component chemicals that are mixed just prior to launch to form a lethal agent. In advanced binary munitions, the two chemicals combine while the shell or warhead is en route to the target. Binary precursors are listed under Schedule 2 of the CWC, but the component chemicals of some binary chemical weapons may not be on any CWC schedule. According to Bailey, the Soviets developed a new binary agent purportedly more toxic than the most deadly form of the highly-lethal nerve agent VX after they declared unilaterally in 1987 that they would cease development and production of CW agents.[14]

In the process of detecting CW production, there are two types of effluents released from a chemical plant: controlled smokestack emissions and "fugitive" emissions.[15] Smokestack emissions are planned emissions from the production facility and would be filtered. Fugitive emissions are stray emissions in either production, testing, or storage and would be unintended. Chemical weapons production would be easier to detect through the unintended or accidental release of effluents since they would not be filtered or disguised and probably would be in greater concentration than planned emissions. However, essentially perfect timing would be required to catch fugitive emissions; thus this essay considers only smokestack emissions.

There are two basic noncompliance scenarios for the production of chemical weapons. The most likely scenario involves the diversion of an existing chemical manufacturing plant to produce CW. If the plant were located within a heavily industrialized region, the emissions could be masked by effluents from nearby legitimate chemical industrial plants, creating background "noise" that hinders verification. A second noncompliance scenario would resemble what occurred in Libya during the 1980s. In September 1988, the U.S. State Department stated that it believed Libya had established a CW production capability near the town of Rabta and was on the verge of full-scale production.[16] The Rabta facility was located in a remote desert location with tight security, under the cover of a pharmaceutical plant.

These two scenarios were modeled for detectable planned chemical emissions in a report done for the Defense Nuclear Agency.[17] The two scenarios were developed to determine whether in the process of producing a CW agent, precursors, degradation products, or CW agent itself could be detected. Parameters such as emission rate, stack gas exit velocity, stack dimensions, and configuration of the stacks were modeled. These variables were used to determine first-order estimates of the concentration of the stack emissions, and to conduct limited performance analysis of remote sensing techniques.

The conclusions of the models showed detectable levels emitted for many of the by-products and even the chemical weapons themselves. The dual-use scenario modeled sarin produced in a pesticide plant, estimating emission rates for five chemicals, two of which were modeled scrubbed and unscrubbed. Of these seven variants, five were detectable. The remote production scenario modeled mustard gas produced at an isolated desert facility. In this model, four of the eight effluent chemicals were detectable.

The assumptions and limitations of this model are important. The two noncompliance scenarios involve planned emissions, that is, emissions normally in the effluent plume and expected by the producer to be released into the air. The scenarios assume continuous operations, 24 hours a day, seven days a week, which may seem unrealistic. The OST allows for roughly 100 hours notice before the start of an overflight, potentially allowing illicit CW production to shut down to avoid detection. But the forced shutdown of batch CW production may ruin the batch and thereby promote CW counterproliferation goals even though detection is not achieved. This model holds promise for future detection of noncompliance given conditions similar to the model.

Two detection technologies are considered here: laser-based sensors and infrared sensors. Each approach is currently under development by the United States for use in spectral analysis and detection of chemical and biological agents. Additionally, each is being researched and developed commercially by many firms worldwide. The technologies are widely available and generally unclassified.

Both of these sensors exploit the electromagnetic spectrum to detect and identify chemical constituents.[18] Detection ranges can be extended by putting these sensors aboard aircraft. Aircraft experience less interference from water vapor, dust, smoke, and other interferants, which are in greater concentration lower to the ground. Detection horizontally through the interferants is inhibited, whereas vertical detection encounters only a fraction of the interferants and extends the range of the sensors. This may be especially true for infrared sensors, which exploit temperature differentials. The background for a horizontal look at an effluent plume is mostly atmosphere or possibly hills or mountains; from a vertical aspect, there would usually be a greater temperature differential between the ground, which is the background, and the plume.

Using a technique known as LIDAR (Light Detection And Ranging), a laser beam is directed into an effluent plume and the reflected coherent light used to identify chemical constituents. Using other optical detection techniques such as infrared DIAL (Differential Absorption LIDAR), real-time analysis can be done on smokestack or fugitive emissions released from a facility. These techniques rely on spectroscopy for detection. Spectroscopy measures the chemical contents of an effluent by directing a laser through the plume that potentially contains the target chemical(s) and analyzing the extent to which the chemicals absorb the coherent light of the laser. Just as each color of visible light has a unique frequency in the electromagnetic spectrum, each chemical has a discrete frequency signature and can be identified by spectrum analysis.

Dr. Bernard Stupski of the System Planning Corporation describes the use of laser frequency differentials to identify constituents:

> An observation is made at a wavelength corresponding to (resonant with) a quantum transition in the atmospheric molecule of interest in either a passive or active mode. A second observation, slightly off-resonance, is then made of the same spatial location to measure the background signal. The difference between the two measurements is taken as the signal due to the molecule of interest. Two separate wavelengths must be probed for each molecule interrogated.[19]

If the chemical sought is present, the resonant frequency will return a spectral "spike," whereas the off-resonant frequency will give a lower return. LIDARs must be tuned to specific frequencies to detect chemicals, targeting rather than searching.

Research done at the Battelle Memorial Institute concluded that a probability of detection of 95 percent and a probability of false alarm of five percent could be reached using DIAL systems, given certain detectable minimums of effluent chemical concentrations. These concentrations are similar to or above those modeled in the Battelle study for the Defense Nuclear Agency.[20]

There are currently two programs to develop infrared DIAL technology. The first, CALIOPE (Chemical Analysis by Laser Interrogation of Proliferation Effluents), is sponsored by the Department of Energy (DOE), and is being studied by Lawrence Livermore National Laboratory. A spin-off of CALIOPE is the Project N-able, which is a joint effort by the DOE, the U.S. Army, and the U.S. Air Force.[21]

LIDAR technology has existed for over 30 years.[22] Over 40 countries are currently involved in research and development of LIDAR systems. The Russian military has the world's only fielded CW laser remote-sensing system; the Hungarian military has developed a helicopter-mounted system; the Czech Republic has developed a truck-mounted system; and the Slovak military has developed a man-portable system for battlefield use.[23]

The same electromagnetic window of 8 to 12μm exploited by laser technology to detect chemical constituents is also used by infrared technology for detection and identification. In this sensitive fingerprint region, different chemicals in an effluent can be discerned because of their unique molecular structures. These systems require application of the Fourier transform algorithm for accurate detection, thus they are known as FTIR spectrometers (Fourier transform infrared). An FTIR spectrometer employs the Fourier transform algorithm (wavelength/time) to reduce signal acquisition time and improve the signal-to-noise ratio. A FTIR scans a broad spectrum of frequencies, but it is limited in what it sees by what its electronic processors are programmed to look for.

FTIR sensors operating in the spectral region of interest have been tested for U.S. Army battlefield use but not extensively tested for fixed-wing platforms. These systems are designed for short-range, battlefield detection of CW clouds threatening troops. The current system being tested by the Edgewood Research, Development, and Engineering Center (ERDEC) is known as the LSCAD, or Lightweight Standoff Chemical Agent Detector.[24] The LSCAD[25] is the successor to the M21, a vehicle-based FTIR used by the U.S. Marines during the Gulf War. It is intended for use on a potentially contaminated battlefield, scanning the close environment for CW agents, with an alarm system to alert troops of their presence. This technology has been flown on unmanned airborne vehicles and should be readily adaptable for use on an airborne platform such as the Open Skies aircraft.

The LSCAD views a vapor cloud by receiving a line-of-sight spectral emission or absorption signature in the 8 to 12 μm region. The relative temperature differential between the target cloud and the background determine whether the vapor will absorb or emit spectral energy. A large temperature differential will significantly enhance detection sensitivity. Detection sensitivity is expressed as the average concentration of the cloud multiplied by the effective pathlength, or CL, the same as the LIDAR measurement.

Whereas a LIDAR system may cost at least $300, 000, a commercial FTIR system may cost as little as $40,000.[26] Both LIDAR and FTIR systems need to be aimable, using a gimbal to maintain a scan on an effluent for chemical constituent identification. Each system would require a scan time on the effluent plume of approximately 90 to 120 seconds, much longer than the time required to fly over a facility.[27] On the whole, Steve Gotoff of ERDEC felt infrared sensors held more promise for use in remote airborne sensing.[28] Dr. Joseph Leonelli of Battelle concluded in the CW non-compliance study that an FTIR should have no problem detecting and identifying sarin, although his modeling was done at a range of one kilometer, well short of the ranges desired or required for an OST aircraft.[29] FTIR technology is being used to monitor fugitive emissions by the chemical industry within facilities. Like LIDAR, it is a widespread technology, being developed in many foreign nations.[30]

Leonelli has stated that both of these technologies have similar implementation concerns for airborne use, especially from Open Skies altitudes:

> For airborne applications, at 30,000 feet or 10 km [OST altitudes], either at slant angle or looking straight down, [Battelle's] analysis indicates that DIAL systems will out-perform FTIR for slant angle applications, but performance is comparable looking straight down. This has more to do with atmospheric and background effects than range and instrument configuration.[31]

Gotoff felt that FTIR has more potential, but that both of these technologies are capable of airborne chemical detection.[32]

In sum, both LIDAR and FTIR sensors have the capability to detect chemical constituents in an airborne effluent. These could be used to monitor environmental pollution or search for CW production-related constituents. Cost, accuracy, and operating constraints must be considered for each of these technologies. Each of them would need specific targeting information on sites to be effective in detecting CW production, not only for the facility in question, but the specific plume to be scanned within a facility. Therefore, to accomplish airborne detection of CW production effluents, intelligence coordination is required. Although intelligence may be sufficient to detect and target illicit CW production, using diplomatic measures such as the OST or CWC treaties allows multilateral condemnation of the cheating state rather than isolated responses.

Intelligence coordination of NTM, such as satellite and reconnaissance products or human intelligence (HUMINT) in-country, are required to give the aforementioned technologies specific targeting information. Not only would the facility in question need to be targeted, but also specific stacks within that facility. This would be true for either dual-use facilities located in industrial regions or for remote, isolated plants.

A combination of satellite products and HUMINT identified the CW production and storage facility at Rabta, Libya in 1988.[33] Reconnaissance photographs indicated an unusually large pharmaceutical plant at Rabta, with multiple barbed-wire fences, sand revetments, and extraordinarily large effluent filtration systems. HUMINT agents sought information from foreign technicians and construction workers who worked on the Rabta plant about plant layout, design, and capabilities. Finally, agents intercepted frantic calls from Libyan foremen to German plant designers asking about emergency clean-up of a spill. Satellite imagery revealed a dead pack of wild dogs downwind of the plant, unscavenged (indicating the presence of poisons). These actions helped confirm the production of CW at Rabta. Although developing countries like Libya are more likely to draw attention with the construction of a new plant, lessons from the intelligence coordination of this case may assist in solving other cases.

Positive detection usually cannot be determined through any single method but rather through a synthesis of remote sampling, on-site inspections, reporting procedures, and intelligence collection. The level of internal control, secrecy, emissions filtering, and safety procedures installed by a state attempting to produce these weapons illegally affect the ability of inspecting parties to detect them. In June 1994, James Woolsey, the head of the Central Intelligence Agency, told Congress that American intelligence was not sure that it would be able to detect all violations of the CWC, yet he still urged ratification to assist in deterring proliferation.[34]

OPEN SKIES SENSORS FOR CWC VERIFICATION

Benefits

Would the incorporation of remote chemical sensors into the Open Skies sensor suite complement CWC verification? The OST, through its broad territorial coverage but shallowly intrusive sensors, can assist in the verification of other treaties. The preamble of the OST notes, "the possibility of employing such a regime to improve openness and transparency, [and] to facilitate the monitoring of compliance with existing or future arms control agreements."[35] The OST is a *de facto* complement to the CFE treaty because its unrestricted territorial access allows observation of all of Russia.

Similarly, OST overflights could aid CWC verification. All members of the OST are signatories to the CWC. Open Skies aircraft could overfly facilities of interest to the CWC inspectorate, using available sensors. CWC activities include monitoring declared CW stocks, facilities, and the single small-scale production facility allowed by the CWC. Other tasks include monitoring transfers of permitted quantities of agent; movements of CW stocks to demilitarization sites; destructions of CW stocks, associated equipment, and facilities; and commercial chemical production.[36] As Amy Smithson and Michael Krepon write,

> The large number of sites to be covered, the difficulty in pinpointing CW monitoring signatures, and the legitimacy of commercial operations that could subsequently be reoriented to military applications make the verification tasks facing the CWC inspectorate dwarf those of other treaties.[37]

Many of these tasks could be facilitated through the use of aerial inspections. Overflights could make major cleanup operations, movement of equipment and stocks, or other ambiguous activity more difficult and noticeable at suspect sites.[38] Overflights could provide facility layout photographs to assist planning inspections. With existing OST infrared sensors, overflights could sense facility operating temperatures to assist with the identification of production processes or of active pipelines within a facility. With the addition of remote chemical sensors, the OST could further assist verification of the CWC through searches for specific chemical constituents.

The producer of CW would need to weigh the risk of detection against the urgency for the CW. If not shut down, this production may risk airborne detection and trigger a CWC challenge inspection. In all probability, the long notification period under the OST and the need for precise timing are the key hindrances to effective remote sensing for CW production. To detect CW from an aircraft, the timing would need to be very fortuitous, and the producer must take the risk of detection. Even so, airborne remote sensors on OST aircraft can be effective even if they never detect a "smoking gun." Remote chemical sensors will make CW production more difficult and risky for those states not choosing to comply. As the Canadian government commented, "When adequate verification increases the risk of detection that a violator would face, the temptation to seek advantage violating an agreement is reduced and deterrence is enhanced."[39]

Another benefit of remote airborne sensing would be that it could perform many verification functions from afar, without placing inspection teams in country. An inspector for the United Nations Special Commission on Iraq (UNSCOM) said that aerial sensors may help to keep inspectors from harm if the inspected nation becomes belligerent.[40] These sensors cannot replace on-site inspectors, but may assist at critical points in the inspection process. Future sensor enhancements that increase their range and sensitivity or place them on higher flying platforms and even satellites, may expand their role.

Possible Drawbacks

Conversely, the use of airborne remote sensors to verify the CWC would modify the basic confidence-building intent of the OST. Instead of broad-brush surveys, OST overflights would move beyond a role of transparency and into verification. In Russia, where the intrusiveness of OST was repeatedly challenged during the negotiation process, there may be opposition to expanding OST mandates. Even with rigidly negotiated limits for chemical sampling through sensor tuning limitations, the operation of the OST would cross over into the verification realm.

Also, the memberships of the OST and the CWC are different. The OST has only 26 members, including the United States, Canada, Europe and the former Soviet states. The CWC, in contrast, aims at attracting members from all over the globe. Attempting to interweave these two treaty regimes through complementary overflights could cause uneven application of a potentially crucial verification measure. An additional problem may arise from how the inspections are conducted. Open Skies overflights are conducted by a flight crew from the inspecting (or inspected) state. CWC inspections, on the other hand, will be carried out by a nonpartisan international inspectorate. In the case of challenge inspections, none of the inspectors are allowed to be from the requesting or hosting states, although an observer from the requesting state may accompany a CWC inspection. These differences could cause administrative problems at best, and continuity and compliance problems at worst.

The OST negotiations were long and arduous, with compromises reached on each point. An especially difficult point of compromise was the sensor suite and corresponding resolution for the sensors. The Soviets/Russians pressed for a minimal sensor suite with limited resolution. The Americans pushed for a broad spectrum of sensors with intrusive capabilities. Air sampling sensors were discussed during the negotiations, but were excluded. They were considered for environmental sensing, but testing for chemical and biological weapons was also discussed. The OST can expand its sensor suite to include air samplers, but only by a consensus of member states. Environmental sensing may be acceptable as a negotiating point, but the use of enhanced sensors for CW production verification would be unacceptable to most parties. There is no formal mechanism in either pact for cross-treaty coordination or complementary roles.[41]

For Americans, the CW sensors may pose a technical problem: how to fit new equipment onto the OC-135 aircraft. All available space is already taken by approved sensors or operators and their equipment. Neither LIDAR nor FTIR sensors are very large, but room would have to be made to include these sensors and an operating station within the aircraft. A related issue is time and money needed to train operators of these new sensors.

Within the United States, the legality of extreme intrusiveness has also been questioned, especially as it relates to the Fourth Amendment of the U.S. Constitution, addressing illegal search and seizure of private property. Even though the Open Skies proposals deal with remote sensing as opposed to on-site sensing, their intrusiveness may constitute illegal search under the laws of the United States and other signatories to the OST. The CWC was negotiated with the stringent measures of the U.S. Constitution in mind, yet it still may face legal challenge after it enters into force. It is estimated that there are over 20,000 chemical companies in the United States alone. Their concerns about maintaining a competitive edge and minimizing regulatory oversight are most likely shared by the international chemical industry.[42]

This intrusiveness also concerns many industrial entities trying to protect proprietary information. Their major concern is that data collected may exceed inspection requirements and be tantamount to industrial espionage. This is especially true for enterprising companies experimenting with new technologies in direct competition with foreign companies. These concerns are mitigated by the fact that both laser-based and infrared sensors can sample exclusively for chemical warfare agents or by-products. Laser-based sensors require tuning to specific frequencies to search for specific chemicals.[43] The processing for infrared sensors can search exclusively for those chemical constituents included in a negotiated list.

The final issue is whether the signatories of the OST and CWC have the political will to implement such a measure. The OST was re-initiated by President Bush in 1989 to balance all the arms control initiatives brought to the table by Mikhail Gorbachev and to garner political capital. The end of the Cold War facilitated signing of the OST and the CWC. But has the momentum necessary to ratify and enter these two treaties into force waned? Russia and many Eastern European states have other financial and political difficulties that take priority over the OST or CWC. The CWC can be an effective regime, but not nearly as effective if its signatories included such states as Iraq, Syria, Egypt, Libya, and Taiwan. Without the impetus to enter these treaties into force, the prospect for placing air sampling sensors on OST aircraft is moot. The U.S. position on this proposal is classified, but interagency negotiations have taken place to discuss it.[44] When the OST and CWC do enter into force, this is an issue that the United States should reconsider, both for cost savings and enhancement of the United States counterproliferation policy.

CONCLUSION

Significant contributions to arms control could be realized from the incorporation of airborne remote sensors into the OST sensor suite. Technologically, air samplers at OST altitudes (approximately 30,000 feet) can detect effluents suggesting CW production. They have the valuable potential to narrow the focus of CWC inspections and thus assist in the efficient use of OPCW resources. The use of airborne remote sensors, while making the Open Skies regime more intrusive, could allow the on-site inspection provisions of the CWC to become less intrusive and hence more acceptable to some states. The incorporation of airborne remote sensors could also help those signatories without their own sophisticated intelligence assets to build confidence with neighboring states through expanded transparency.

Despite the benefits of this proposal, the problems encountered in its implementation are several. The shift of intent for the OST from confidence-building to verification may be unacceptable to many signatories, possibly forcing renegotiation of the treaty.[45] The memberships of the OST and CWC differ, and application of the use of airborne remote sensors would therefore be uneven. Although remote sensing might make it more difficult to cheat on the CWC, the timing provisions for OST overflights could prevent the detection of a "smoking gun" unless host nations chose to risk detection. Finally, there is currently no political impetus for this proposal. However, once the two treaties have entered into force and the OST becomes a viable confidence-building tool, the political will might develop to push for its expansion.

A first step in incorporating airborne remote chemical sensors into the OST sensor suite might be using this category of sensors for environmental sampling, thereby proving their utility and effectiveness. The negotiations for the OST included a debate over a role for the regime in monitoring, considering the capabilities of the sensing suite and the ability to cover large areas in each overflight. The preamble of the OST "envisag[es] the possible extension of the Open Skies regime into additional fields, such as the protection of the environment."[46] A study done by the Defense Nuclear Agency examined the uses of the OST sensor suite for remote chemical sensing.[47] Further, it recommended additional sensors to make the sensor suite adequate for collecting scientifically useful data on environmental monitoring problems, including LIDAR and

FTIR systems.[48] If the reliability and accuracy of these sensors can be proven through chemical detection in an environmental monitoring role, an expanded role as a detector of CW production might be considered.

Because of the timing problem of detecting CW production with an OST overflight, the argument for remote chemical sensors would need to focus on deterrence rather than detection. In either case, the sensors would enhance CW counterproliferation efforts.

Only a few years ago, the development of LIDAR and FTIR for remote chemical sensing appeared bleak. The end of the Cold War, advances in the technologies for air sampling, and concentrated efforts such as the RELIENTS and CALIOPE projects have made these sensors a viable option for airborne detection of CW production.[49] While some drawbacks remain to be overcome, the shared attributes of the OST and CWC suggest that coordinating these pacts makes good sense.

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[2] Anthony H. Cordesman, "One Half Cheer for the CWC: Putting the Chemical Weapons Convention into Military Perspective," Brad Roberts, ed., *Ratifying the Chemical Weapons Convention* (Washington, D.C.: Center for Strategic and International Studies, 1994), p. 37; U.S. Congress, Office of Technology Assessment (OTA), *Proliferation of Weapons of Mass Destruction: Assessing the Risks*, OTA-ISC-559 (Washington, D.C.: U.S. Government Printing Office, August 1993), p 14; correspondence from Dr. Joseph Leonelli, Battelle Memorial Institute, Columbus, Ohio, October 18, 1995.

[3] This is the theme of Amy Smithson and Michael Krepon, *Strengthening the Chemical Weapons Convention Through Aerial Inspections,* Occasional Paper No. 4 (Washington, D.C.: The Henry L. Stimson Center, 1991).

[4] Jonathan B. Tucker, "Back to the Future: The Open Skies Talks," *Arms Control Today* 20 (October 1990), p. 20.

[5] Thomas Karas, Senior Associate, International Security and Commerce Program, Office of Technical Assessment, prepared statement to the Senate Committee on Foreign Relations, *Treaty on Open Skies*, 102nd Cong., 2d sess., September 22, 1992, p. 28.

[6] Statement released by the White House Press Secretary, November 3, 1993, *U.S Department of State Dispatch*, November 15, 1993, Vol. 4, No. 46, p. 792.

[7] The Open Skies Treaty.

[8] WEU Document 1364, "Technical co-operation in the framework of the Open Skies Treaty," May 17, 1993.

[9] John J. Hawes, prepared statement to the Congressional Committee on Foreign Relations, United States Senate, 102nd Congress, Second Session, September 22, 1992, p. 4.

[10] Amy Smithson, *The Chemical Weapons Convention Handbook* (Washington, D.C.: The Henry L. Stimson Center, 1993), p. iii.

[11] Michael Moodie, "Ratifying the Chemical Weapons Convention: Past Time for Action," *Arms Control Today* 26 (February 1996), p. 3. Preparatory Commission for the Organization for the Prohibition of Chemical Weapons, Provisional Technical Secretariat, "Costa Rica Ratifies the Chemical Weapons Convention," Press Release No. 100, June 3, 1996.

[12] Smithson, *The Chemical Weapons Convention Handbook*, p. 8.

[13] See OTA, *Technologies Underlying Weapons of Mass Destruction*, OTA-BP-ISC-115 (Washington, D.C.: U.S. Government Printing Office, December 1993), p. 6.

[14] Kathleen Bailey, "Why the CWC Should Not Be Ratified," in Brad Roberts, ed., *Ratifying the CWC* (Washington, D.C.: Center for Strategic and International Studies, 1994), p. 54. This development was also reported in *The New York Times*, January 28, 1994, p. A5.

[15] OTA, *Technologies Underlying Weapons of Mass Destruction*, p. 65.

[16] David B. Ottaway, "Behind the New Battle With Libya," *The Washington Post*, January 8, 1989, p. C4; referenced in OTA, *Technologies Underlying Weapons of Mass Destruction*, p. 43.

[17] Joseph Leonelli and B. Thomas Smith, "White Paper on Analysis of Stack Emission Signatures from Chemical Agent Production Sites" (Columbus, Ohio: Battelle Memorial Institute, May, 1993).

[18] The most useful transparent spectral ranges of the atmosphere are: the visible (0.4 - 0.7µm), near infrared (0.7 - 1.5 µm), and infrared (3 - 5µm and 9 - 13µm [µm = one micron, or one-millionth of a meter {10-6}]). Within these spectral regions, laser radiation is not appreciably attenuated except by the molecular species of interest, thus remote sensing over long ranges may be achieved. The higher range, from 8 - 12µm, is sometimes referred to as the "fingerprint" region, with its higher frequencies and shorter wavelengths allowing optimal spectral clarity and accuracy. Hughes Corporation, Proprietary Proposal for the RELIENTS System Consortium, prepared for the U.S. Army, undated 1994 paper, p. 2.

[19] Bernard A. Stupski, *Evaluation of the U.S. Open Skies Aircraft for Environmental Monitoring* (Arlington, Virginia: Systems Planning Corporation, August 1, 1994), p. C-1.

[20] Leonelli and Smith, "White Paper on Analysis of Stack Emission Signatures from Chemical Agent Production Sites," p. 6.

[21] Correspondence with Joseph Leonelli, October 18, 1995.

[22] LIDAR systems designed for army battlefield detection can weigh from 75 to 250 pounds, occupy from three to 12 cubic feet, and require two kilowatts and a 28 volt DC, 110 volt AC power supply. (Hughes Corporation, Proprietary Proposal for the RELIENTS System Consortium prepared for the U.S. Army, undated 1994 paper, pp. 12 and 16.) Airborne systems must remain small and can use aircraft power. Costs of laser-based systems range from $300,000 to over two million, depending on capabilities and processing. (Correspondence with Leonelli, September 29, 1995.)

[23] Correspondence with Joseph Leonelli, November 30, 1995.

[24] William Lagna, "Lightweight Standoff Chemical Agent Detector," ERDEC, undated point paper. This entire paragraph is taken from information in this paper.

[25] The LSCAD weighs 46 pounds and consumes 23 watts at 24 volts.

[26] Correspondence with Joseph Leonelli, September 29, 1995.

[27] *Ibid.*

[28] Author's interview with Steve Gotoff, ERDEC, April 4, 1995.

[29] Leonelli and Smith, "White Paper on Analysis of Stack Emission Signatures from Chemical Agent Production Sites," p. 6. An OST aircraft has a nominal overflight altitude of 30,000 feet AGL, or roughly 10 kilometers. Slant ranges would be more.

[30] Correspondence with Joseph Leonelli, November 30, 1995.

[31] Correspondence with Joseph Leonelli, October 18, 1995.

[32] Author's interview with Steve Gotoff, April 4, 1995. Gotoff felt that FTIR was a less mature technology, and therefore had the potential for more devel-

opment and greater ranges and tolerances.

[33] OTA, *Technologies Underlying Weapons of Mass Destruction*, pp. 42-44.

[34] Michael R. Gordon, "C.I.A. Backs Arms Treaty On Chemicals," *The New York Times*, June 21, 1994, A9.

[35] The Open Skies Treaty, Preamble, p. 1.

[36] Smithson and Krepon, *Strengthening the Chemical Weapons Convention Through Aerial Inspections*, p. 2.

[37] *Ibid.*

[38] Amy Smithson and Michael Krepon, eds., *Open Skies, Arms Control and Cooperative Security* (New York: St. Martin's Press 1992), p. 229.

[39] *Verification in All Its Aspects: A Comprehensive Study on Arms Control and Disarmament Verification Pursuant to UNGA Resolution 40/152(o),* Government of Canada (Ottawa: April 1986), p. 16

[40] Author's interviews with UNSCOM inspector, not-for-attribution, April 1995.

[41] The OST allows designation of "hazardous" flight areas, which must be excluded from flight paths and can be submitted by signatories, with proper justification, at any time.

[42] Amy Smithson, ed., *Implementing the Chemical Weapons Convention: Counsel from Industry*, Report No. 10 (Washington, D.C.: The Henry L. Stimson Center, January 1994), pp. i and ii.

[43] Detection of other chemicals is still possible. The off-resonance frequency could become the *primary* frequency and vice versa, spiking on the off resonance frequency to test for chemicals which are not agreed upon. This could specifically test for chemicals that are "on" the off-resonance frequency, using the "primary" frequency, tuned to test for the CW constituent, as the off-resonance frequency by design.

[44] Author's phone conversation with Lt. Col. Jim Chamberlain, USAF, Arms Control and Disarmament Agency Bureau of Multilateral Affairs, October 6, 1995.

[45] The Defense Nuclear Agency notes that "Sensor configurations are specified by agreed text in the Open Skies treaty, the inclusion of an airborne CW sensor would require reopening agreed text of the treaty to renegotiation." Correspondence from Lt. Cdr. Brent Ditzler, DNA, to author dated November 15, 1995.

[46] The Open Skies Treaty, Preamble, p. 1.

[47] Bernard A. Stupski *et al.*, *Evaluation of the U.S. Open Skies Aircraft for Environmental Monitoring*, prepared for the Defense Nuclear Agency, August 1, 1994.

[48] *Ibid.*, pp. v and 13.

[49] RELIENTS is an Army program spearheaded by Hughes to develop ground based CW battlefield detectors to protect troops; CALIOPE is a program spearheaded by the Lawrence Livermore National Laboratory to develop airborne laser and infrared sensors to detect WMD production.