Ad hoc Group of Governmental Experts to Identify and Examine Potential Verification Measures from a Scientific and Technical Standpoint

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Summary of the examination

SURVEILLANCE BY AIRCRAFT (Off-Site)
(Rapporteur: Mr. Gordon Vachon)

Definitions

Remote sensing: A variety of techniques that enable, to varying degrees, the detection, description, measurement or identification of some property of an object of interest without actually coming into physical contact with the object. Categories of remote sensing techniques or equipment are often described as "remote sensors" or "sensors".

Aircraft: This term may include:
- aeroplane (mechanically driven winged heavier-than-air flying machine):
- helicopter;
- airship;
- balloon; and
- unmanned aerial vehicles (UAVs)/drones/remotely-piloted vehicles (RPVs).

An aircraft may be described as a "platform" carrying one or more sensors.

Without reference to any operational context, it was also mentioned that gliders and "ultra-light" aerial vehibles can be used to carry sensors.

Characteristics and technologies

State-of-the-Art

Prior to discussing technical matters, it was mentioned that the conduct of aerial overflights in a verification context would require the prior permission of the State being overflown.

For the purpose of introducing discussion of developments in the state-of-the-art of airborne remote sensing, remote sensors may be categorized, *inter alia*, by the following characteristics:

- technology base;
- location of operation;
- operating characteristics (including power requirements, required operator expertise, and maintenance schedules, ...);
- envisioned targets of the sensors;
- explanation of relevant experience with the sensors to date;
- ...

The discussion focussed on commercially-available, "off-the-shelf", aircraft-borne (airborne) sensor imagery.

The sensors mentioned in the examination phase were:
- optical (still photography, video cameras, multi-spectral cameras);
- infrared;
- synthetic aperture radar (SAR);
- remote optical spectroscopy - active and passive.

Aircraft can conceivably carry all of the afore-mentioned sensors simultaneously since space, weight and power requirements can be more easily fulfilled. The airborne sensors can generally achieve higher resolutions (in the case of various sensors, perhaps expressed as other performance criteria) than their commercially-available satellite counterparts due to human interaction and variable altitude capabilities. For example, aircraft are capable of carrying commercially-available:
(a) optical sensors with a resolution measured in centimetres to tens of centimetres;
(b) infrared sensors with a resolution measured at approximately half a metre; and
(c) synthetic aperture radar with a resolution of 3-6 metres (experimental SARs exist with a resolution of 1½-3 metres).

The key to any infrared (thermal) sensor is its "detector", which is made of different materials depending on the spectral region within which the detector is to operate. These spectral regions are chosen because therein the atmosphere is largely transparent, allowing radiation from the surface (and objects on the ground/sea) to reach the sensor. Outside of these spectral regions ("windows"), atmospheric gases and particles at least partially block the passage of radiation by absorption or scattering. (Atmospheric gases and particles can affect the performance of a variety of active and passive sensors, as discussed in WP.46.)

In discussing infrared systems, two types of "resolution" are important. "Spatial resolution" refers to the detector's ability to resolve two separate and distinct objects of similar size from each other - similar to what has been discussed elsewhere concerning optical and SAR sensor resolution. "Thermal resolution" of an infrared sensor refers to the ability to distinguish temperature gradients in the object being obsrved, and is influenced by the material in, and size of, the detector chip.

Infrared imaging may be conducted using two types of sensors: infrared line scanners (IRLS) or forward looking infrared sensors (FLIR), with each type having particular characteristics suited to particular missions. As a simplification of their respective capabilities, FLIR systems can be used when real-time imagery is required, with the possibility of manipulating the sensor to "spotlight" targets. The imagery is produced in a format similar to that of a video camera. IRLS systems, on the other hand, are usually used when hard copy images or image mensuration are required. There is little or no ability to manipulate the sensor without manipulating the platform.

Capabilities

Although individual sensors may generally be seen as providing more useful information when carried on aircraft versus satellites, it is clear that, in both cases, the comparison is based on the best commercially-available examples that can be carried on the respective platforms. In other general respects, such as broad area coverage, satellites are generally seen to have the advantage over aircraft.

The resolution of the various commercially-available airborne imaging systems has been mentioned and is indicative of the ability to detect, describe, measure or identify very small natural and man-made objects. The question still needs to be addressed as to whether there are clear indicators such that the enhanced capabilities of airborne sensors (versus space-based sensors) can be put to effective use.

The mix of airborne sensors provides for a wide range of capabilities. The systems (for example, optical systems such as still photography, video cameras - platform mounted or hand-held) can be keyed to provide date/time/location data of the imagery. Although the performance of optical systems is highly dependent on light and meteorological conditions, infrared systems can be used in daylight or at nighttime; can passively detect heat sources (penetrate) haze and smog; and can be used to detect camouglaged or obscured objects (even under forest canopies). Similarly, SARs have a 24-hour all-weather capability.

Multispectral systems (discussed in WP.46) permit imagery to be collected in a number of spectral bands at once. These bands may include wavelengths from ultraviolet, visible, reflected infrared and thermal infrared. By collecting and analyzing images in several spectral bands, it is possible to greatly improve the chances of distinguishing some features (UNIDIR/90/83).

Depending on organizational/operational scenarios and questions relating to the availability and pre-positioning of aircraft with appropriate sensors, the response time of aircraft may be considerably faster than reliance upon satellite passes. (However, this advantage must be qualified by the need to provide notification of overflights and of the need to file flight plans, both of which can lead to legitimate or artificial delays.) In addition, aircraft can fly below cloud cover that might frustrate space-based optical sensors.

Development:
Airborne surveillance could be used to monitor, over time, such matters as changes in outdoor storage or dump sites/sewage settling ponds; transportation links; power/heating/cooling lines ... .

Acquisition or Production:
There was no discussion of the capability of airborne remote sensing with regard to detection or monitoring in relation to these prohibited activities. The size and scope of any production activity may be considerably more difficult to conceal than research and development activities. Airborne surveillance could monitor, over time, the same peripheral matters as mentioned at the end of the preceding paragraph.

Stockpiling or Retaining:
Airborne sensing may be useful in detecting and monitoring weapons storage areas, but it remains to be discussed whether any useful indicators can be identified to assist in discriminating between legitimate and illegitimate material or weapon storage. (One suggestion related to air conditioning/refrigeration equipment, but this requires further consideration.)

Imagery compiled over time, whether of a facility/site or of an area, provides a history for future reference purposes. It allows one to look back in time.

<u>Limitations</u>

Some of the discussion of airborne sensor limitations is suggested in the preceding sections on "state-of-the-art" and "capabilities", including in relation to the three categories of prohibited activity.

Buildings and shelters of many types can be imagined into which the sensors cannot penetrate. To the extent that it was said that complete bio-facilities can be housed in buildings without external indicators, then even the highly capable airborne sensors could be defeated in detecting suspicious activity. It was mentioned that cuing from other sources might enhance the probability of successful detection of illegitimate activities by airborne systems, and this aspect needs to be examined further.

One paper (WP.46) mentioned that remote sensing of effluent plumes is done relatively near the earth's surface - so that the effectiveness of such sensors when carried on airborne platforms would not be as limited (i.e. would be more effective) when compared to satellite platforms. Examples were given in that paper of scenarios in which the sensors can now be useful, given the current state-of-the-art.

There was no discussion of limitations imposed by data storage/transmission capabilities of airborne systems. However, it was said that any such constraints may be much less severe in the case of airborne systems relative to their space-based counterparts. There was only very limited discussion of operational constraints derived from the aircraft's flight radius or flying characteristics, but these constraints may be circumvented by proper mission-planning. It was mentioned that certain airborne systems provide both real-time and recorded data, not least because of the human presence aboard the platform viewing the target as well as operating the sensors. There was no discussion of the requirements/capabilities/limitations in relation to analysis of imagery from such systems.

Development:
If one assumes that treaty violators would undertake offensive research, and certain development activities, in small enclosed structures having few if any distinctive external characteristics, then this might seriously impact on the effectiveness of airborne sensors in detecting such activities. Furthermore, the inherent delays involved in notifying overflights and filing flight plans could allow ample time for the cessation of outdoor development activities, such as may be involved in weapon testing.

Acquisition or Production:
For the same reasons mentioned in the previous paragraph with regard to hiding such activities in enclosed buildings, similar views may apply to the effectiveness of the sensors in detecting or distinguishing production activities.

Stockpiling or Retaining:
The discussion is reflected in the "capabilities" section.

Potential interaction with other measures

There is a significant qualitative difference between the imagery obtained by airborne sensors and that obtained by space-based sensors. It is possible to envisage airborne imagery as a primary mode of operation in the context of arms control agreements, as in the case of the Open Skies Treaty (mentioned but not discussed in any detail). The view was also expressed that the utility of information derived from this measure should be assessed as a complement to information gathered by other measures. It was further expressed by many participants that this measure may be particularly useful in the specification of on-site inspection activities as well as in direct support to on-site inspection activities. It was suggested that the aerial remote sensing measure could be seen as providing an additional (extra) operational capability to that provided by other measures.

With regard to the question of direct support to on-site inspection activities, the example of the Treaty on Conventional Armed Forces in Europe (CFE Treaty) was provided (see WP.67).

Information with respect to illustrative costs for airborne remote sensing was provided (see WP.63).

Documents introduced

BWC/CONF.III/VEREX/WP.31
"Capabilities and Limitations of Overhead Remote Sensing for Verification within the Context of the Biological and Toxin Weapons Convention (BTWC)"
(Canada)

BWC/CONF.III/VEREX/WP.46
"The Possible Relationship of Remote Sensing Technologies to BWC Verification"
(USA)

BWC/CONF.III/VEREX/WP.56
"An Introduction to Remote Sensing by Satellite and Aircraft"
(Canada)

BWC/CONF.III/VEREX/WP.63
"Airborne Remote Sensing: Illustrative Costs"
(Canada)

BWC/CONF.III/VEREX/WP.67
"Aerial and Space-Based Surveillance in the Context of Arms Control Agreements"
(Canada)

BWC/CONF.III/VEREX/WP.69
"Satellite and Aerial Surveillance as a Verification Measure for the Biological Convention: Advantages and Limits"
(France)

Other useful publications

Banner, Allen V., Andrew J. Young, Keith W. Hall. UNIDIR/90/83, United Nations, 1990. Aerial Reconnaissance for Verification of Arms Limitation Agreements: An Introduction. (Comment: This publication explains several technical concepts that are also applicable to space-based sensors.)