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

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EVALUATION
OFF-SITE: REMOTE SENSING, SURVEILLANCE BY SATELLITE

I. INTRODUCTION

A. DEFINITION. The Group of Experts definition of Surveillance by Satellite is the use of a satellite (described as an artificial body placed in orbit around the earth or other planet) as a "platform" carrying one or more sensors. Sensors include 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."

Remote sensing has been divided by the VEREX group into three specific measures. For the purpose of this evaluation of Surveillance by Satellite, remote sensing can be described as using equipment to record, at a distance, information that can be subsequently studied visually, usually in an image format. The remote sensors consists of all types of cameras, including television, and sensors for visible or infrared light, radar, and other portions of the electromagnetic spectrum. This paper addresses only remote sensing products currently available from commercial satellites; it does not discuss either ground sensors or chemical sampling devices.

B. CURRENT STATE OF THE ART. Requirements are heavily dependent on assumptions of the amount and types of imagery to be acquired. There are tradeoffs that must be considered between the amount of area imaged versus the spatial resolution, the amount of imagery that can be acquired versus the exploitation resources available, and the types of information available through different sensor types.

II. EVALUATION BY MANDATE CRITERIA.

A. REQUIREMENTS.

1. Technology, Material, Manpower, and Equipment.

a. Synthetic Aperture Radar (SAR)

Pros:

- SAR can image through clouds and fog and acquisition of imagery is independent of sunlight. It is thus able to acquire imagery whenever the imaging platform has line-of-sight access to a given area. SAR image acquisition is precluded only by extreme weather conditions such as hurricanes.

Cons:

- Currently, commercial SAR imagery from satellite platforms has a resolution of no better than 15 meters. This is adequate to identify large buildings and geographic features. It is inadequate for study of the appearance of buildings or the detection of vehicles. Analysis of SAR imagery normally requires conventional photography for comparison. Lastly SAR images are generally incomprehensible except to specialists; a SAR image is not persuasive evidence to policy-makers or to the general public.

b. Conventional photography.

Pros:

- Currently, commercial satellite imagery acquired in the visible light spectrum, similar to conventional aerial photography, has a resolution of no better than 2 meters. Analysis of such conventional photography produces the most detailed information about the physical appearance of the targets being studied. It is the most easily explained to the non-expert.

Cons:

- Conventional photography can only be acquired during daylight hours and is precluded by clouds and fog.

c. Infrared imagery.

Pros:

- Infrared imagery is similar to conventional photography in many respects but is best acquired at night. Night time infrared imagery reveals the level of heat emanating from a target; this helps to show whether a site is active and whether it operates at night. Infrared light penetrates haze slightly better than visible light.

Cons:

- Commercially available infrared imagery has a resolution of no better than 120 meters. Resolution of about 60 meters is expected to become available within the next two years. Imagery of either quality would show only the largest buildings or groups of buildings. It could not be used to study details of their structure or to determine the specific sources of heat, e.g., which of a group of vents on the roof of a laboratory building are warm.

d. Material. As a practical matter it is probably necessary to acquire and store both conventional film and digital data.

(1.) Conventional film.

Pros:

- Film can be filed and kept immediately available. It can be easily annotated, stored, and retrieved. Several images can be examined concurrently. Film is generally not at risk of accidental erasure.

Cons:

- Image data recorded on film is fixed; it cannot easily be manipulated to enhance features in the scene. Film can be scratched or otherwise damaged beyond use.

(2.) Digital data.

Pros:

- Digital data of multispectral imagery can be displayed and manipulated in soft copy on a cathode ray tube to bring out the spectra most useful for a particular application. Numerous digital images can be stored on magnetic or optical media in a smaller space than a comparable number of images stored on film.

Cons:

- Display and interpretation of digital data are highly dependent on the availability of computers, image processing software, and high-quality image display and printing capabilities, with all the attendant risks of downtime. Flipping through a pack of images stored in digital form is not easily done.

e. Manpower. Work force requirements are heavily dependent on assumptions of the amount and types of imagery to be acquired. A requirement to search imagery of the entire inhabited land mass of Earth would require far more people than a requirement to search for or to monitor specific sites suspected of treaty violations. Regardless of the sensing systems chosen, minimum requirements will include trained people to serve as imagery interpreters, remote sensing specialists, and photo lab technicians. The distinction between imagery interpreters, who analyze photography on light tables, and remote sensing specialists, who analyze digital data on computers, is a considerable one. In addition, computer specialists and photogrammetrists will almost certainly prove to be necessary.

f. Equipment. Minimum requirements will include light tables for conventional imagery, computers for digital imagery, computers for image display, manipulation, and measurement, filing cabinets suitable for the types of imagery to be used, filing cabinets for paper files, map files, flat files for large copies of photos. Floor space requirement per person for imagery interpreters and remote sensing specialists is substantially greater than for most office workers because of the space that their equipment occupies.

B. FINANCIAL, LEGAL, SAFETY, AND ORGANIZATION IMPLICATIONS.

1. Financial. Landsat images cost about $4,500 (US) each and cover an area about 185 kilometers square (34,225 square kilometers). SPOT images cost about $1,600 (US) each and cover an area about 60 kilometers square, (3,600 square kilometers). As an example of the relative costs involved, imaging all of Texas, which occupies 678,357 square kilometers would require

20 Landsat images with a total cost of $90,000 (US), or 189 SPOT images with a total cost of $302,400 (US). In practice it would be necessary to acquire more images. The images have straight boundaries but political territories usually have irregular ones. It is unlikely that a territory can be covered by satellite images without overlapping. Experience shows that not all images would be cloud free. Thus the cost to acquire complete coverage of an area would exceed that suggested by arithmetical calculations.

2. Legal. There are no legal concerns anticipated.

3. Safety. There are no workplace hazards involved in remote sensing.

4. Organization. Once again, requirements are heavily dependent on assumptions of the amount and types of imagery to be acquired.

C. IMPACT ON SCIENTIFIC RESEARCH, COOPERATION, AND INDUSTRIAL DEVELOPMENT. There would currently be no impact on the scientific research arena but this could change if spatial resolution significantly improves in the next decade.

D. AMOUNT AND QUALITY OF INFORMATION. Existing commercially-available satellite surveillance systems produce images that are inferior to aerial photography for the purposes of detecting and monitoring BW sites. No satellite system likely to become available in the foreseeable future will contradict the preceding statement. The best commercially available satellite images have a resolution of about 2 meters. Commercial remote sensing satellites were developed for mapping and collecting data on large areas. Although the available satellites carry a variety of sensors, none of them is well adapted for detailed studies of academic or industrial sites. Satellite imagery can be used for locating sites reported by other sources and for showing the boundaries of those sites. Satellite systems capable of resolving objects of a few meters in size may prove useful in monitoring construction or razing of buildings. With the possible exception of a newly available Russian system, no commercial satellite system produces imagery with sufficient spatial resolution to identify structural details of buildings (presence/absence of vents, specialized air handling equipment, windows, etc.), security features (fences, walls, etc.), or other relevant details.

An aspect of satellite imagery often overlooked is its capacity to assist in establishing a chronology of events by comparing spectral signatures from images from different dates of the same geographical area. Such a capability to establish when construction of a suspected site begins and ends and the pace of its construction may help to establish the credibility of a source reporting on a site. Although commercially available imagery is inadequate to reveal significant details of buildings under construction, the accumulation of imagery over time adds another dimension that could potentially aid in the analysis of facilities.

Although it is possible to identify some types of industrial plants on imagery with resolution of more than a meter, this resolution can not help to determine the specific function of most industrial structures. For research institutes the requirements are even more stringent. Although it may be possible to use imagery with resolution of more than a meter to identify a large group of institutional buildings, such as a major university, it is impossible to identify biological research buildings with such imagery.

E. <u>ABILITY TO DIFFERENTIATE BETWEEN PROHIBITED AND PERMITTED ACTIVITIES.</u> It may be possible to find microbiological laboratories or production plants that have a suspicious appearance on satellite imagery but it is impossible to demonstrate that a laboratory is doing prohibited research or that a production plant is producing prohibited substances. Scientific open air BW weapons testing requires large test grids that may be visible on high resolution imagery. To avoid detection however, states may accept cruder testing measures or may use only indoor tests. Storage of living BW agents may require refrigerated bunkers. It would not be difficult to conceal refrigeration equipment.

F. <u>ABILITY TO RESOLVE AMBIGUITIES ABOUT COMPLIANCE</u>. Given the current state of imaging technology, we know of no instance in which a suspected BW research, testing, production, or storage site could be conclusively shown to be either in compliance or in violation of the BWC solely through remote sensing techniques. Imagery might provide tips to suspicious activities, circumstantial evidence for prohibited activities, or provide validation of information on the existence of specific facilities known through other sources of information. However, imagery would likely not provide conclusive proof of activities that are inconsistent with treaty obligations.