Aerial Observation to Help Prevent Conflicts Between Countries

Open Skies

Over the last few years, there has been a continuous stream of reports and discussions in the media about Open Skies treaties and agreements. Within this context, much of the media attention is focused on the long and tortuous negotiations between the United States and the European Union (EU) regarding the liberalization of transatlantic air travel and the vexed question of take-off and landing rights for airlines on both sides of the Atlantic. However there is what some people would regard as an even more important ***Open Skies Treaty*** *that receives much less publicity - even though its remit extends far beyond the U.S.A. and the EU bloc of countries.*

By Gordon Petrie & Hartwig Spitzer

Fig. 1 - The huge land area - from Vancouver to Vladivostock - that is covered by the Open Skies Treaty is shown in blue.

This particular Treaty is concerned with the monitoring of military sites from the air and has the following three main objectives:-

(I) First of all, it is designed to enhance openness and transparency with regard to the military activities being carried out in Europe, North America and parts of Asia.

(II) Its second objective is to help support the verification of the many international arms control agreements that have been reached in recent years.

(III) The third objective of the Treaty is to strengthen the international capacity for the prevention of military conflicts and for the management of political crises and disputes with a view to ensuring greater stability and peace over the vast land area of the northern part of the Northern Hemisphere lying between Vancouver and Vladivostock (Fig. 1).

The technology that has been adopted to try to achieve these ambitious objectives is ***aerial observation*** - using unarmed manned aircraft equipped only with cameras, scanners and SAR imagers to monitor military activities and sites on a cooperative basis between participating countries. The Open Skies Treaty was originally signed in 1992. However the ratification of the Treaty proved to be difficult in some countries. So the Treaty did not come into actual operation until January 2002. Indeed it has only become fully operational with the full set of permitted imagers since 1st January 2006. It is interesting therefore to report on the implementation, operation and achievements of the Open Skies Treaty to date and, in particular, to discuss the airborne imaging aspects of the Treaty.

Background

The original idea of having an Open Skies programme to make mutual use of aerial photography to monitor the weapons arsenals and military dispositions of the U.S.A. and Soviet Union during the Cold War - with the object of preventing surprise attacks by either side - was set out by President Eisenhower in 1955. This purely bi-lateral proposal was quickly rejected by the Soviet Union. However the idea was revived by President George Bush Sr. in 1989. On this occasion, the proposal was to carry out multi-lateral monitoring of all the countries in the NATO and Warsaw Pact blocs on an equable and strictly controlled basis. Times and attitudes had changed, the Cold War was coming to an end and the new proposal met with a much better response. After a long period of detailed negotiation starting in February 1990 and a series of conferences held in Ottawa, Budapest and Vienna, the terms of an acceptable treaty were reached. The Open Skies Treaty was formally signed by the foreign ministers of the 26 countries of the two blocs at a meeting held in Helsinki on 24th March 1992. Over the next two or three years, the Treaty was ratified by all of these countries except Russia, Ukraine and Belarus. Eventually the Ukrainian parliament formally ratified the Treaty in 2000, followed by Russia and Belarus in 2001 - which allowed the Treaty to actually come into force on 1st January 2002. Since then, a further nine European countries have signed up to the Treaty. The detailed coordination of the Treaty's implementation and the resolving of any disputes, procedural issues or technical issues is carried out by the ***Open Skies Consultative Committee (OSCC)*** which is based in Vienna.

Preparation

During the years between 1992 and 2001, a great deal of work was carried out in preparation for the coming into force of the Treaty. This included the setting up of Open Skies units in each country, the training of the appropriate personnel and the preparations for the certification of suitable aircraft and imagers that would fall within the strictly defined terms of the Treaty. Furthermore, over 350 trial overflights were conducted during this period before the Treaty actually came into operation. This provided much practical experience to the newly formed Open Skies units in all of the countries that had signed the Treaty. It also resulted in a real spirit of cooperation and a

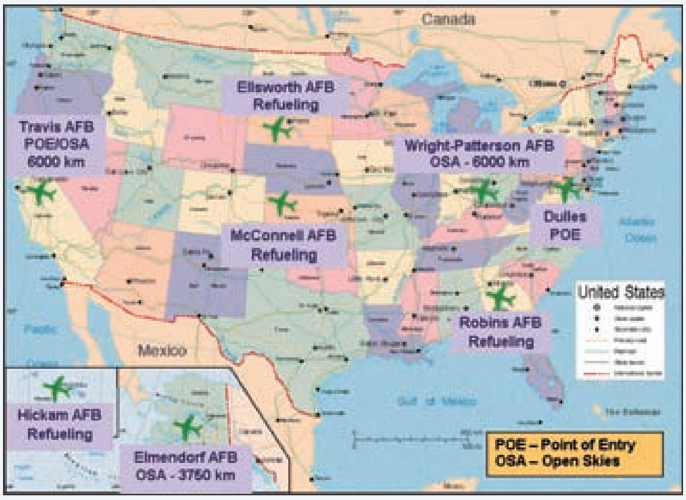

Fig. 2 - In the U.S.A., several airfields are designated for use by Open Skies observation aircraft. There are two Points of Entry (POEs) - in Washington, D.C. and California; three Open Skies Airfields (OSAs) where observation flights can start and finish; and four airfields where refuelling can take place. (Source: DTRA)

great deal of confidence and trust being built up between all the participants engaged in the Open Skies programme before the Treaty did formally come into force.

I - Treaty Rules & Requirements

(a) Quotas

The Open Skies Treaty operates on the basis of active and passive quotas of overflights for each participating country. These quotas have been set largely on the basis of the geographic dimensions and the military capabilities and strategic importance of each country that adheres to the Treaty. The so-called ***passive quota*** defines the number of overflights that a country (or state party) is obliged to receive from other countries. The ***active quota*** is the number of overflights that each country (or state party) has the right to conduct over other countries. The active and passive quotas of permitted overflights are usually equal in number for each country. Both the U.S.A. and the Russia/Belarus state party each have an annual quota of 42 overflights; Germany, France, Italy, Turkey, Ukraine and the U.K. each have a quota of 12 overflights; Sweden and Norway each have 7; and so on - with smaller quotas for each of the remaining signatory countries!

(b) Distances

In close association with the number of permitted overflights, there are also limits regarding the maximum distance that can be flown during a single individual overflight. The specific restriction that applies to a particular country is largely related to its size - the largest distances being 7,200 km in the case of the Russia/Belarus combination and between 5,000 and 6,000 km each in the case of Canada and the U.S.A. Each country has one or more airfields designated as its point of entry for the aircraft carrying out an overflight. Further airfields are designated as refuelling stops (Fig. 2).

(c) Missions

The rules and procedures for the conduct of each individual mission are also set out in detail by the Treaty. Each country wishing to conduct an overflight over another country must give a minimum notice of 72 hours before the arrival of its observation aircraft at the designated point of entry. Besides which, a mission plan must be submitted 24 hours before the intended flight, giving details of the intended route, distance and estimated flight time. Each overflight must then be completed within a period of 96 hours from the time of arrival of the aircraft at the point of entry. There are no territorial restrictions on the overflights. Thus any part of the full territory of each country can be overflown, except for a 10 km zone adjacent to the country's borders with a state that has not signed the Treaty.

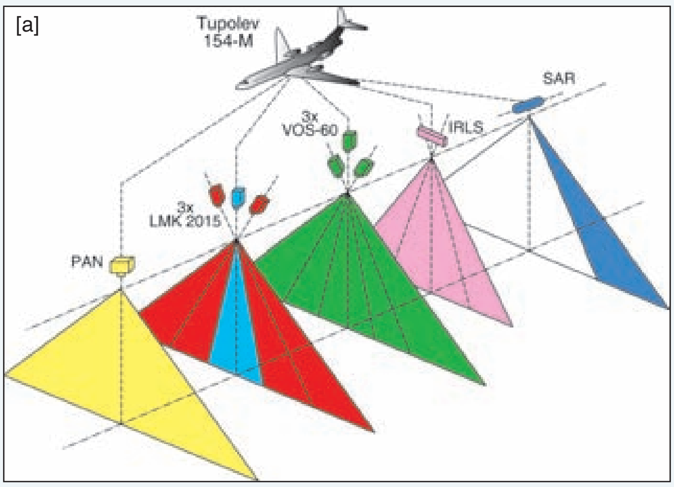

Fig. 3 (a) - The coverage of the full suite of permitted imaging devices - a panoramic film camera (yellow); 3 photogrammetric film cameras (red/blue); 3 video cameras (green); an infra-red line scanner (purple); and a SAR imager (blue) - as deployed on the German Tupolev Tu-154M aircraft. (Source: IGI)

Fig. 3 (b) - The three Zeiss Jena LMK photogrammetric film cameras and three Zeiss VOS-60 video cameras (pushbroom scanners) mounted in the German Tupolev Tu-154M aircraft . (Source: IGI)

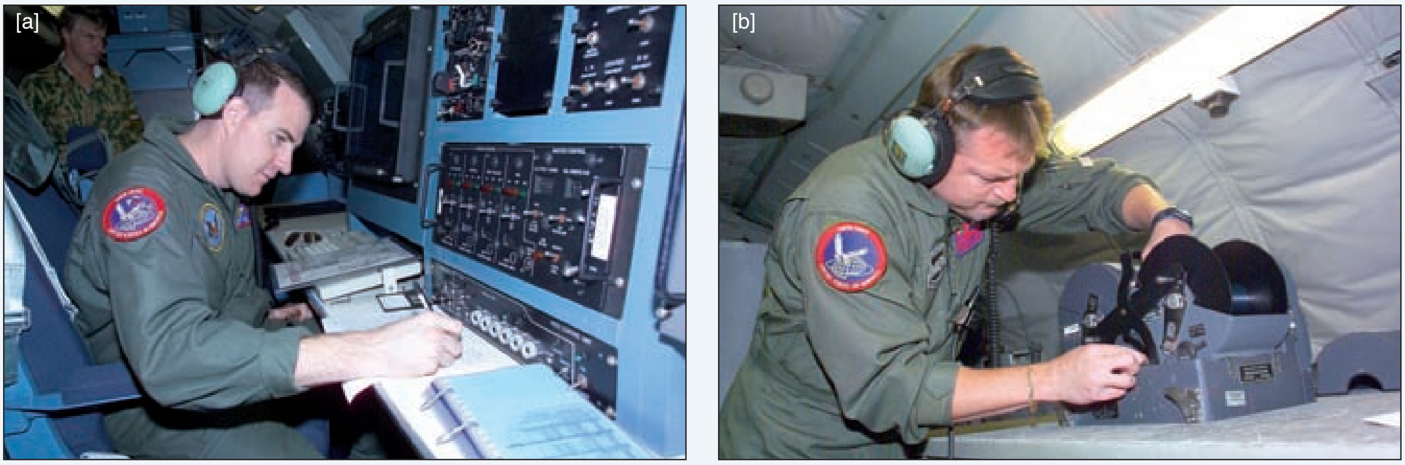

*Fig. 4 - A U.S. Open Skies team in action with **(a)** an operator working at an imaging control station; and **(b)** a film magazine being changed - on-board the Boeing OC-135B aircraft - and **(c)** the inspection of a processed film being carried out at the Open Skies Media Processing Facility (OSMPF) in Dayton, Ohio. (Source: OSMPF)*

(d) Allowable Imaging Devices

The imaging devices that are allowed under the Treaty for use in the overflights are also strictly regulated. Optical photographic film cameras can be used in either a vertical or oblique mode of operation provided that the ground resolution of the resulting image is not finer (smaller) than 30 cm. Up to three (one vertical and two oblique) frame cameras and a single panoramic camera can be used during a specific overflight. Video cameras giving a real-time display of the ground on-board the aircraft may also be used, again with the same ground resolution limit of 30 cm. With the full implementation of the Treaty from 2006 onwards, infra-red and SAR imagers may also be used during overflights with minimum ground resolution values of 50 cm and 3 m respectively for the resulting images. It should be said that only Russia plans to operate its Open Skies aircraft with the full suite of permitted imaging devices (Fig. 3). Indeed many of the Treaty countries operate their observation aircraft fitted with only one or two film cameras and a video camera.

(e) Certification

A very important matter for all Open Skies flights is the certification of the whole of the observing system that is being used to collect the imagery. This involves the validation of both the aircraft and the imaging devices that it carries. This is achieved in the first instance through the detailed inspection of the aircraft and its imaging devices that is carried out at the certification site by a wide ranging team drawn from many of the Treaty countries. This procedure is then followed by flights over a test field of calibration (bar) targets from a designated flying height in order to demonstrate that the ground resolution values of the resulting images do not exceed the limits defined by the Treaty. This is checked through the subsequent analysis of the image data that has been collected in-flight over the test field. Besides this overall certification carried out at the certification site, prior to each individual operational flight, the observation aircraft and its imaging systems are inspected thoroughly by a team from the country being observed to ensure that they are in exactly the same condition as when they were certified. A team from the observed country is also present in the observation aircraft during the actual flight to ensure that the criteria and procedures laid down in the Treaty are indeed being followed. The exposed films and magnetic tapes (the latter from the infra-red and SAR imagers) are certified in-flight by both parties. The films and tapes are then processed and duplicated at a laboratory on the ground (Fig. 4). These operations are carried out in the presence of both teams with certified copies being handed over to each team. All the Treaty countries receive a report on each mission. If requested, further copies of the films and tapes resulting from the flight can be supplied (at an agreed cost) to any other Treaty country. Thus the Treaty embodies both equity and transparency: every state can see what every other state has observed.

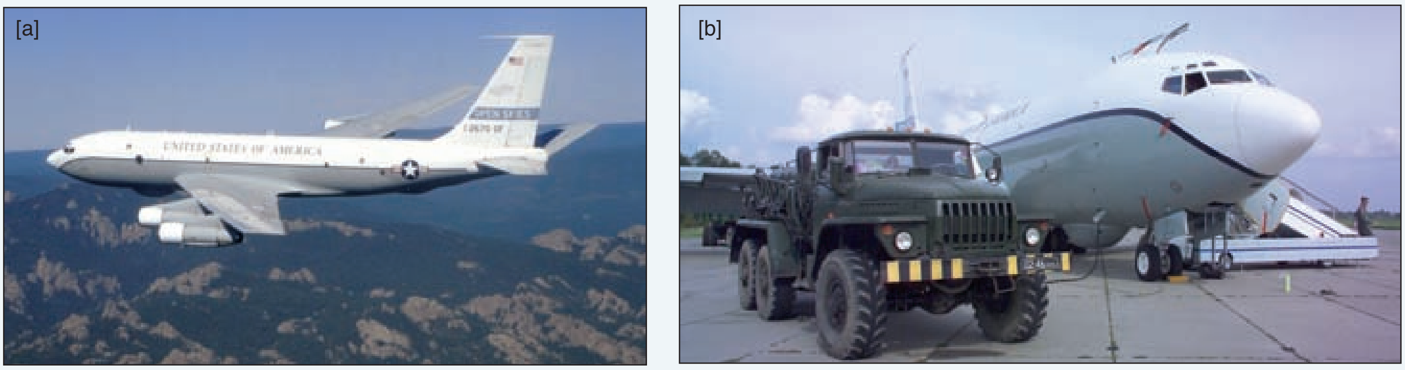

*Fig. 5 **(a)** - A Boeing OC-135B Open Skies observation aircraft in flight. **(b)** - A Boeing OC-135B aircraft being prepared for flight - the "canoe" or bulge on the underside of the fuselage behind the front wheel of the aircraft undercarriage houses the SAR antenna. However the radome and antenna have since been removed from the aircraft. (Source: DTRA)*

Fig. 6 (a) - The Russian Tupolev Tu-154M Open Skies jet aircraft. (b) - The Tupolev Tu-154M aircraft about to be boarded by a Canadian and U.S. inspection team prior to its Open Skies overflights over North America. (Source: Canadian Forces)

II - Observation Aircraft

The various types of aircraft that are used in military aerial reconnaissance operations play no part in Open Skies overflights. The use of high-flying U-2 "Dragon Lady" aircraft or high-speed, low-flying Tornado aircraft would give everyone quite the wrong impression about an Open Skies flight. Besides which, none of these aircraft could accommodate the monitoring teams from both the observed and observing countries as well as the flight crew. Similar remarks about accommodating these teams can be made about the small single- or twin-engined photographic aircraft that are used in civilian aerial mapping operations. So, based on purely practical considerations, the operational Open Skies aircraft are all multi-engined ***transport aircraft*** that have been modified to act as platforms for the imaging systems with seating for a minimum of 14 to 16 persons.

(a) Jet Aircraft

The two major powers - the U.S.A. and Russia - together with Germany all opted to use long-range ***jet aircraft***. In the case of the U.S.A., two Boeing 707 four-engined jet aircraft - labelled as type OC-135B - were modified for the purpose (Fig. 5), while Russia and Germany each opted to utilize a single Tupolev Tu-154 tri-engined jet aircraft (Fig. 6). Russia is preparing to bring a new Tupolev Tu-214 twin-engined jet aircraft into service quite soon. All of these aircraft are capable of flying the Atlantic Ocean without refuelling and of undertaking long duration flights across the vast lands of Russia and North America. Unfortunately the German Tupolev aircraft was lost in a mid-air collision with an American C-141 Starlifter cargo aircraft off the coast of south-west Africa in 1997 with the loss of both crews.

(b) Turbo-prop Aircraft

Turning next to propeller driven ***turbo-prop aircraft***, since most NATO countries operate the Lockheed C-130 Hercules long-range military transport aircraft, a group of ten of them - Belgium, Canada, France, Greece, Italy, Luxemburg, Netherlands, Norway, Portugal, Spain - formed the so-called "Pod Group". In this context, they share a single "pod", which is a modified C-130 fuel tank converted by Lockheed to accommodate a suite of frame, video and panoramic film cameras (Fig. 7). The "pod" is mounted under the wing of the C-130 four-engined turbo-prop aircraft which has a range of up to 5,000 km. The other Open Skies aircraft are all twin-engined turbo-prop types with a much shorter range. Several of the former Warsaw Pact countries - Bulgaria, Czech Republic, Hungary, Romania, Russia and Ukraine – have all used Antonov An-26 and An-30 survey aircraft (Fig. 8 (a)). Sweden uses a modified Saab 340 airliner and Turkey a CASA CN-235 transport aircraft (Fig. 8 (b)). After the loss of its Tupolev jet aircraft, Germany has used the Swedish Saab 340 and various aircraft from other countries to undertake its overflights. The U.K. uses a modified HS Andover military transport aircraft. The remaining Treaty countries do not operate their own observation aircraft. Instead they hire or lease a certified aircraft and imaging system from one of the other countries or they make suitable arrangements with the country that will be overflown - the so-called "taxi" option that is permitted by the Treaty. Thus, for example, the U.K.'s Andover aircraft has been used for flights over Russia on behalf of Georgia (which does not posses a suitable aircraft) and flights over Georgia on behalf of Russia. The Andover has even been used to fly over the U.K. on behalf of Russia with a Russian observing team on board executing the Russian mission plan (Fig. 9)!

Fig. 7 (a) - A French C-130 Hercules turbo-prop aircraft about to undertake an observation flight over Bosnia. (Source: NATO-SFOR)
(b) - The SAMSON "Pod" that is attached to the wing of C-130 aircraft. A video camera is mounted in the nose of the "Pod". Behind this, on the underside of the "Pod" are the windows for the KS-116A panoramic camera and the nadir-pointing KS-87B frame camera, followed by the two windows for the two KS-87B frame cameras pointing obliquely to the left and right of the flight line. (Source: Canadian Forces)

III - Imaging Systems

(a) Frame Cameras

While civilian mapping aircraft play no part in Open Skies overflights, by contrast, standard ***photogrammetric film cameras*** producing 23 x 23 cm frame photographs are used widely during these flights. Thus Leica RC30 cameras are used by Bulgaria, Romania and Hungary; Zeiss Jena LMK cameras were used by the Czech Republic and in the German Tupolev aircraft; and a Zeiss Oberkochen (now Intergraph) RMK-TOP camera is mounted in the Swedish aircraft. The attraction of using these metric cameras is that they can also be used to undertake aerial photography for mapping purposes besides the relatively few Open Skies Treaty flights that form the quota for smaller countries. The American Recon/Optical KS-87 ***reconnaissance film camera*** producing 12.5 x 12.5 cm frame images is also used quite widely on Open Skies overflights. For example, three of them (one vertical and two oblique) are used both on the American OC-135B and the Turkish CN-235 aircraft and in the SAMSON "Pod" that can be attached to C-130 Hercules aircraft.

(b) Panoramic Cameras

Panoramic film cameras are widely used in military reconnaissance aircraft in general,

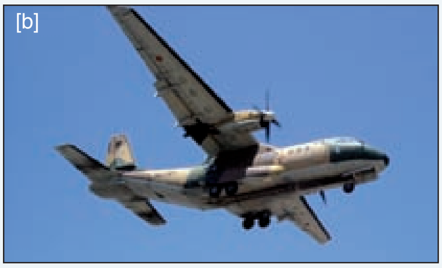

***Fig. 8 (a) -** The Antonov An-30 twin-engined turbo-pro survey aircraft used by Romania for Open Skies observation flights. (Source: Temesvari Archiv)*
***(b)** The Turkish CASA CN-235 twin-engined Open Skies aircraft in-flight. (Source: Turkish Air Force)*

combining high ground resolution (at least around the nadir) with very wide angle coverage of the ground. Quite a number of Open Skies aircraft carry these cameras, most manufactured in the United States by Recon/Optical, Fairchild, etc. Thus each of the American OC-135B aircraft has a KA-91 camera fitted; while both the SAMSON "Pod" and the Turkish CN-235 aircraft each utilize a KS-116A camera. The U.K. Andover aircraft has a KA-95B camera (Fig. 10 (a)). The Bulgarian An-30 aircraft has a British-made Vinten 900B panoramic camera. If these panoramic cameras are fitted with long focal length lenses, then, if they are operated from low altitudes to get below the cloud cover, they will generate images with very high ground resolution - much higher than the 30 cm limit that is set by the Open Skies Treaty. Thus these cameras may have to be fitted with special optical image degrading filters to ensure that the resulting images do fall within the prescribed limits (Fig. 10 (b)).

(c) Non-Photographic Imagers

With regard to the non-photographic imagers that have been allowed by the Treaty to come into operation from January 2006 onwards, these have not proven to be attractive to most users. ***SAR imagers*** with their all-weather and day/night capabilities would appear to be very suitable for Open Skies operation. However they are expensive, complicated and power hungry. Furthermore the ground resolution of SAR imagers is set by the Treaty at 3 m - which is regarded by most users as being too low to be useful. Indeed SAR images with a 1 m ground resolution will be available from the newly launched TerraSAR-X satellite. The U.S.A. developed its SAROS (Synthetic Aperture Radar for Open Skies) and fitted these to its OC-135B aircraft as early as 1994. The work was undertaken jointly by the Loral company and Sandia National Laboratories. However, according to the DTRA Web site, they have not been used to any great extent till now. Russia is also developing a suitable SAR, but this has not been certified so far. The situation regarding ***infra-red scanners*** is rather similar. Till now, few countries have opted to deploy these devices. Turkey is using the old Honeywell AN-AA5 infra-red line scanner. Russia is also developing its own IR scanner, but again this has not been certified as yet.

(d) Positioning & Navigation Systems

Besides the actual cameras, the aircraft are fitted with ***positioning and navigation systems*** to ensure that the Open Skies flights follow the planned paths and the photography is taken in the correct positions. Thus the American OC-135B aircraft are fitted with twin

***Fig. 9 (a) -** The U.K.'s Andover aircraft about to undertake a flight over Georgia on behalf of the Russian Federation.*
***(b) -** The operation of the cameras on-board the Andover aircraft is being monitored by Russian observers.*
***(c) -** The pre-flight inspection of the underside of the Andover aircraft being carried out in Lithuania - note the camera lens protruding just below the belly of the aircraft. (Source: U.K. Open Skies Unit)*

Fig. 10 ***(a)*** *- The KA-95B panoramic film camera used in the U.K. Andover aircraft, mounted on a cradle with its film magazine lying on the floor to the left.* ***(b)*** *- The image degradation filter used with the KA-95B panoramic film camera to ensure that the resolution of the resulting frame images falls within the 30 cm ground resolution limits of the Open Skies Treaty. (Source: U.K. Open Skies Unit)*

Litton LN92 integrated GPS/IMU systems for this purpose, together with a radar altimeter to provide precise measurements of the height of the aircraft above the ground. The U.K. Andover aircraft is fitted with a similar LN-92 unit and a pair of Garmin 420 GPS receivers. However these are of the single-frequency C/A type rather than the more accurate dual-frequency type.

(e) Digital Imaging Devices

Currently a very important issue for the Open Skies Consultative Committee (OSCC) and its sensor working group is that of trying to accommodate, within the Treaty rules, the airborne digital imaging devices that have become so well established within the civilian mapping community over the last five years. In dealing with this matter, one should remember that the Treaty was negotiated during the period 1990-92, when digital imaging devices were in their infancy and photographic film cameras were used almost universally for aerial reconnaissance purposes. Only digital video cameras were recognized for the purposes of the Treaty - including, quite remarkably, the Zeiss VOS-60 pushroom line scanner under this heading! Besides these video devices, the infra-red and SAR imagers that gained approval could record their images on magnetic tape. However the current types of digital frame cameras and pushbroom line scanners do not appear on the list of airborne imagers approved for use under the Treaty. In the meantime, during the period that has elapsed since the Treaty was signed, the manufacture of airborne photogrammetric and reconnaissance film cameras has almost ceased and their use is now in sharp decline. As a result of this development, some types of aerial photographic film are no longer made. Furthermore the availability of spare parts and the lack of technical knowledge and expertise to keep film cameras in service is beginning to be a problem. At a recent Open Skies seminar held in Berlin, at which the present authors made presentations about these new airborne digital imaging systems, there seemed to be a general acceptance among the participants of the need to add them to the list of approved imaging devices. The difficulty lies in converting this overall consensus into the formal decisions that need to be made by the OSCC. Tough negotiations about the detailed proposals, approvals and certification of acceptable airborne digital imaging systems lie ahead!

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