Commercial High Resolutio

A Very Long Gestation & A Troubled Birth!!

The last few weeks of the year 2000 have seen very considerable activity in the area of commercial high-resolution satellites. On November 20th, EarthWatch's QuickBird-1 satellite was launched and failed to go into orbit. On December 5th, the Israeli-backed EROS-A1 satellite was launched successfully. On December 18th, the American authorities granted licences to Space Imaging and EarthWatch to construct and operate satellites capable of producing space images with a ground pixel size of half-a-metre. Having, over the last year, visited the three main American companies that are engaged in this area and having seen and heard quite a lot about their activities at first hand, the editors invited me to take a long view and try to give a reasonably coherent and balanced account of what has become a very controversial area.

By Professor Gordon Petrie

Russian Initiatives

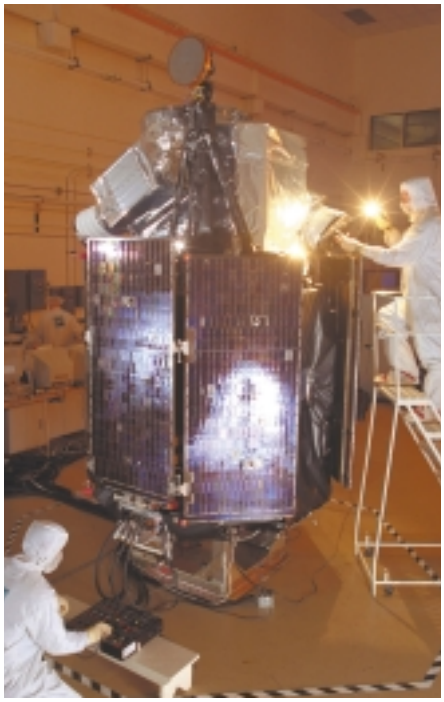
The story really begins back in 1987 - not long after the launch (in 1986) of the first SPOT satellite with its pan imagery having a 10m ground pixel size. Literally out of the blue sky, came the quite unexpected decision by the Russian government to allow space photography taken with its KFA-1000 film cameras to be sold commercially on a world-wide basis. This photography had been acquired originally for intelligence gathering purposes and had a true ground resolution of 5 to 10m. This totally surprising development was followed in 1992 by the even more unexpected decision by the Russian authorities to allow the sale of the still higher resolution space photography taken by the KVR-1000 and KFA-3000 film cameras and having a ground resolution of 2 to 3m.

American Reactions

The reaction of the U.S. government to the first of these decisions was an easing of the restrictions on the permissible ground resolution that could be used with American civilian Earth Observation satellites. However only one or two licences were granted to commercial companies on this basis - most notably, that issued to the WorldView Imaging Corporation in January 1993. After the second Russian initiative, the American response, made under Presidential Directive 23 issued in March 1994, was to allow the development of commercial satellites capable of producing imagery to the 1m ground pixel level.

Commercial Interest

On this new basis, there was very much more interest on the part of various American aerospace companies and groups that had been suppliers of hardware and software for use in American space reconnaissance programmes. Thus quite a number of licences were issued for the construction of satellites on what was seen from the commercial point of view as a much more viable specification. Re-reading the many press releases, articles and commentaries from this period, one can feel the excitement that all of this activity generated. Furthermore - given the considerable experience of the companies and groups involved in many of the projects - there was the feeling that soon we would be experiencing the many benefits of the resulting high-resolution space imagery. Numerous press statements indicated that the first imagery would be available at the end of 1995 and that most of the satellites would be operational by mid-1997. High-resolution space imagery would then be available widely to potential customers from a number of different suppliers on a competitive basis.



1. (a) The QuickBird-1 satellite under test in a clean room at Ball Aerospace in Boulder, Colorado. (b) An artist's impression of the QuickBird satellite operating in space. (Source: EarthWatch)

n Space Imagery

The Reality

However the reality has been very different. Several of the licensed projects (those by GDE Systems, Boeing, Motorola, etc.) have either progressed very slowly or not progressed at all; there have been numerous delays and cost overruns with those few that have gone ahead; and there have been several very expensive failures of the resulting satellites, either at launch or in actual operation. The first high-resolution satellite to be launched and come into operational use was IKONOS in September 1999 with the first images being released three weeks later. Now we have reached the year 2001 and, at last, a second satellite (EROS-A1) has been launched successfully. Hopefully it will come into full operation soon. But, taken overall, it has been a very sobering experience for all those concerned with the development of commercial high-resolution space imagery. Thus it may be instructive to review what has happened with each of the four main contenders - EarthWatch, ORBIMAGE, Space Imaging and ImageSat International.

1. EarthWatch

The origins of Earthwatch can be traced back to the WorldView Imaging Corporation which was established in January 1992. The principals of the company were a group of scientists who had worked on the Brilliant Pebbles satellite-based anti-missile project at the Lawrence Livermore National Laboratories in California. In January 1993, the new company received a licence from the U.S. Dept. of Commerce to construct two satellites (WorldView-1 and -2), each equipped with pan and multi-spectral digital frame cameras producing images with ground pixel sizes of 3m and 15m respectively. The launches were scheduled to take place in late 1995 and mid-1996. However the cost of developing these two satellites required additional resources. So, in 1994, the EarthWatch company was formed through a merger of the WorldView company with the remote sensing interests of the Ball Aerospace Corporation. Additional partners - Hitachi, Datron, Telespazio, MDA, etc. - also joined the project.

- EarlyBird

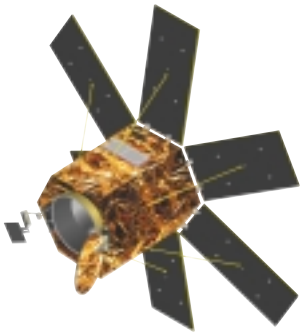
The launch of the first satellite, now called EarlyBird-1, was delayed by well over a year, but eventually, it was launched successfully in December 1997 by a Russian Start-1 launcher from Svobodny in Eastern Siberia. However, a few days later, the satellite itself failed due to problems with the on-board power supply. The results of this event were that the EarthWatch company had to retrench and a large number of its staff lost their jobs. Furthermore the company decided not to continue with the construction of the EarlyBird-2 satellite. Instead it decided to concentrate on the development of the two QuickBird satellites designed to generate higher resolution - 1m pan and 4m multi-spectral - imagery. The licences for these satellites had been issued to EarthWatch in September 1994. The QuickBird satellites and their pushbroom scanner imagers were both to be constructed by Ball Aerospace.

- Interim Period

Shortly afterwards, in June 1998, the company acquired a new president and CEO, Herb Satterlee, from the rival Boeing-backed Resource21 company. One of his main priorities was to secure substantial additional funding to enable EarthWatch to continue and complete the development of the QuickBird satellites and the company's Digital Globe database. This was achieved through a series of investments amounting to $186 million made by ITT Industries, the Morgan Stanley investment house and Capital Research in 1999. Besides which, EarthWatch received a number of contracts from NASA for the supply of airborne radar imagery of Central America and Alaska and from NIMA for the mapping of Panama. In fact, a large part of these projects has been carried out by a sub-contractor - the Canadian Intermap Technologies company - using its STAR-3i airborne SAR system. But still they have helped to generate revenue for EarthWatch.

- QuickBird

After some delays, QuickBird-1 was shipped to Plesetsk in Northern Russia for launch



2. (a) The OrbView-4 satellite under test at Orbital's facility in Germantown, Virginia. (b) An artist's impression of the OrbView-4 satellite as it will appear in flight. (Source: ORBIMAGE)

by a Cosmos 3M rocket. The launch took place a few weeks ago on 20th November 2000, but unfortunately it failed and the satellite re-entered the Earth's atmosphere N.E. of Brazil and was destroyed. Various reasons have been given for the failure. The most quoted version is that the final stage of the rocket either failed or suffered a premature shutdown. No doubt, the Russian commission of enquiry into the failure will determine the exact cause of the failure and issue its report soon. Whatever the reason for the failure, the immediate outcome is that 48 of EarthWatch's employees (25% of the company's work force) have lost their jobs. EarthWatch has announced that it will still continue with the development of QuickBird-2. But the company and its predecessor has now been around for seven or eight years and obviously, with two failed launches, it badly needs a success to generate revenue and stay in business.

2. ORBIMAGE

The origins of the Orbital Imaging Corporation (or ORBIMAGE) and its high-resolution satellites can also be traced back to a very early proposal called Eyeglass that was made jointly by the Orbital Sciences Corporation, the Itek Corporation and GDE Systems. Orbital Sciences would build the satellite bus and supply the launcher; Itek would construct the optical imager; and GDE would develop and supply the image processing and data handling segments of the project. When the two latter companies dropped out, Orbital decided to continue largely on its own. Orbital received its licences in the summer of 1994 and the ORBIMAGE company was established later in 1994. Essentially the company has been run as an affiliate or subsidiary of the Orbital Sciences Corporation - which builds launchers and satellites both for U.S. government agencies and non-government bodies and has large interests in electronics and optical imagers.

- OrbView-1 and -2

ORBIMAGE began its operations with OrbView-1, launched in April 1995 using Orbital's Pegasus rocket. The satellite was air-launched from 40,000 ft. from a specially modified TriStar aircraft. OrbView-1 is a scientific satellite that is mainly oriented towards meteorological research, generating low resolution images of weather patterns (which are processed by NOAA) and allowing the mapping of lightning strikes. OrbView-2 was launched in 1997 and generates low to medium resolution imagery, mainly of oceanic areas, through its wide-swath SeaWIFS imager. The processing is carried out in ORBIMAGE's facility in Dulles, Virginia. The resulting imagery is used both for oceanic and coastal research by NASA and for operational purposes by the U.S. Navy - as well as by commercial fishing fleets.

- OrbView-3 and -4

These are ORBIMAGE's high-resolution satellites. However each will have different capabilities. While both will have the same 1m pan and 4m multi-spectral pushbroom scanner imagers, OrbView-4 will also carry an additional hyperspectral imager (WF-1) generating more than 200 channels with an 8m ground pixel size that has been supplied by the U.S. Air Force. This is based on the imager that was installed in the NASA Lewis satellite that was lost shortly after launch in 1997. Thus the two satellites are quite different in their design and construction. OrbView-3 is smaller and lighter, which will allow it to be launched by the Pegasus air-launched rocket. OrbView-4 is larger and requires the use of Orbital's more powerful Taurus ground-based launcher. The launches of the two satellites have been postponed first from late-1999 to mid-2000 and now to the current dates of June 2001 for OrbView-4 and three months later for OrbView-3.

- French Connections

As with EarthWatch, there has been a need for ORBIMAGE to generate revenue during the long period that has elapsed while the OrbView-3 and -4 satellites have been built and tested and the launches postponed. With this in mind, on the one hand, the company entered into an alliance with SPOT Image by which each would offer the other company's image products in certain markets. In addition, ORBIMAGE also launched its OrbView Cities imagery programme, at first based on aerial photography of 15 North American cities taken by various aerial photographic companies recruited as partners. Most recently, it has started to acquire further imagery of parts of Southern California using DLR's HRSC-A airborne pushbroom scanner. This has been done in collaboration with the French ISTAR company which is carrying out the image processing in France.

- Orbital's Subsidiaries & Affiliates

Besides ORBIMAGE, the Orbital Sciences Corporation has many other wholly owned or partly owned subsidiaries. These include the Magellan GPS company; MDA (the Canadian company supplying ground receiving stations and building the Radarsat satellites); and ORBCOMM in which it has a minority (32%) interest in partnership with Teleglobe of Canada which is the major (68%) shareholder. ORBCOMM has been a particular problem to Orbital. The company has launched a constellation of around 30 small Earth-orbiting satellites (that were built by Orbital) to provide wireless data communication, messaging and positioning services on a world-wide basis. However, business has not developed in the way that was originally envisaged. So, rather like the similar Iridium satellite-based wireless network backed by Motorola, ORBCOMM has been forced (in September 2000) to file for Chapter 11 protection to allow the company to be restructured and re-financed. Besides which, Orbital had already decided to build a large new facility on its campus at Dulles in Virginia. This would allow it to concentrate all of its satellite manufacturing facilities - previously spread over several sites in the

Washington area - on to a single site. The new development also includes a most impressive new command and control ground station for use with the OrbView-3 and -4 satellites, together with a large image processing centre. To help meet all of its financial obligations arising from these developments and events, in December 1999 and May 2000, Orbital first sold a substantial part of MDA to a group of Canadian investors. Then, in September 2000, it sold its Fairchild Defense electronics business to Smith's Industries from the U.K. ORBIMAGE has not been insulated from all of these events and recently the company has had to reduce its staff substantially. In summary, the last 18 months have been a very difficult time, both for Orbital Sciences and for ORBIMAGE.

3. Space Imaging

This company was founded in June 1994. Its principal owners are Lockheed Martin - one of the giants of the American aerospace industry - and E-Systems, a division of the Raytheon Corporation. At present, Lockheed Martin owns 46% of Space Imaging and E-Systems a further 30% of the company. Both companies have had extensive experience of building space reconnaissance and intelligence gathering satellites and processing systems, having, over the last 30 years or more, been major contractors to the U.S. government agencies involved in operating and utilizing such systems. In 1995, they were joined by the Mitsubishi Corporation as a major investor and partner in Space Imaging and by several other smaller companies. In November 1996, the company acquired the EOSAT (Earth Observation SATellite) company, which was a joint venture of Lockheed Martin and Hughes Aircraft created to commercialize the U.S. government's Landsat programme.

- Early Developments

In a preliminary study carried out in 1991, Lockheed Martin had already conceived the Space Imaging Satellite (SIS). With the issue of the appropriate licences in 1993 and 1994, Lockheed initiated the further development of its Commercial Remote Sensing Satellites (CRSS-1 and -2). Later, in 1997, these were renamed IKONOS-1 and -2. Like its two American rivals discussed above, these satellites were designed to carry pushbroom scanners that would produce 1m pan and 4m multi-spectral images. The satellites and their launchers were to be constructed by Lockheed Martin, while the ground stations and processing facilities were to be supplied by E-Systems. The imagers were to be purchased from Kodak. Originally, the launch of the first IKONOS satellite was scheduled for early 1997. In the interim, Space Imaging entered into an agreement with the Antrix Corporation - the commercial arm of the Indian Space Research Organisation (ISRO) - to both receive and distribute image data from its IRS satellites on a world-wide basis. Thus Space Imaging and its affiliates have continued to acquire medium-resolution space imagery from Landsat 5 and the IRS satellites throughout the second half of the 1990s up to the present time. This has provided a revenue stream over this period.

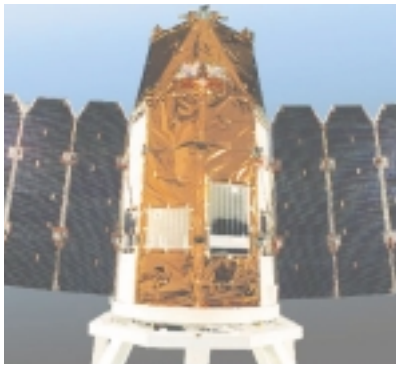
- IKONOS-1 and 2

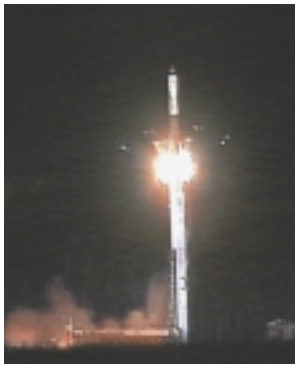
The construction and testing of the IKONOS satellites and the Athena launchers took considerably longer than expected, but eventually, after several delays and postponements, IKONOS-1 was launched on 27th April, 1999. However the launch failed due to the satellite's protective cover failing to separate from the rocket during the later stages of the launch. With quite remarkable and wholly admirable speed, Space Imaging (and Lockheed) made ready the replacement IKONOS-2 and its launcher within five months and succeeded in launching the second satellite successfully on 24th September, 1999. The first high-resolution image - a black and white pan image of Washington, D.C. was released - to great acclaim and world-wide interest - on 12th October, 1999. Since then, Space Imaging has had this field to itself. In a recent article published in the Denver Post (on November 19th, 2000), John Copple, CEO of Space Imaging, was quoted as saying that business has grown rapidly to 500 orders per week - which is really excellent news for the company.

- Customer Reactions

The author has discussed the matter of the IKONOS imagery in detail with a number of re-sellers and customers, both in Europe and North America. To be fair, a number of those interviewed have stated that they are indeed quite satisfied with the service and quality of the imagery that they have received from Space Imaging. But others have been dissatisfied, more especially with the customer service aspects of the operation. Apparently late delivery and the failure to fulfil orders lie at the root of their dissatisfaction. Closely associated with this is the feeling or perception (whether justified or not!) that U.S. government customers get preferential treatment. Other customers complained about the high cost of the IKONOS imagery, especially to customers located outside North America. The matter of Space Imaging's refusal to supply stereo-imagery to non-government agencies and to release the calibration data for its pushbroom scanner imager is yet another major concern for certain customers. The contrast between this negative attitude of Space Imaging with the very positive attitude of LH Systems - which has released the corresponding calibration data in respect of its new airborne pushbroom scanner system, even to its rivals in the DPW field - is one that is being quoted by these customers. Expressing a purely personal opinion, the refusal to release the calibration information seems quite pointless. There are enough ingenious photogrammetrists around to overcome this lack of information and correctly model the main geometric characteristics of

3. (a) The IKONOS satellite being mounted on its Athena rocket prior to launch.
(b) An IKONOS pan image of the Westminster area in London showing the Millennium Wheel, the Houses of Parliament and Buckingham Palace. (Source: Space Imaging)





4. (a) The EROS-A1 satellite, based on the Ofeq reconnaissance satellite and built by Israel Aircraft Industries. (b) The launch of the EROS-A1 satellite from Svobodny, Eastern Siberia took place on 5th December 2000 using a Russian Start-1 launcher. (Source: Israel Aircraft Industries)

the IKONOS imagery - as Toutin of CCRS and Cheng of PCI have already shown in their article published in the July 2000 issue of EOM.

- Space Imaging Europe

Of especial concern to European customers have been the reports of a deterioration in the relationship between Space Imaging and its European affiliate, the Greek-owned Space Imaging Europe (SIE). According to customers and re-sellers, this has resulted in the down-link from IKONOS to the European ground station in Athens being switched off in October 2000. SIE is reportedly unhappy, partly about the comparatively limited market for high-priced IKONOS imagery and products in Europe, but also at the news - made public in a news release from Space Imaging on 21st November 2000 - of a new affiliate, Space Imaging Eurasia, being formed. This is based in Ankara, Turkey and will have a ground station that can task the IKONOS satellite and receive the imagery directly in Ankara. The new station is expected to become operational during the first quarter of 2001. Obviously the footprints of the Athens and Ankara ground stations overlap greatly. Since the SIE Web site states that "SIE has the exclusive right to market, sell and distribute IKONOS products to all customers, including National Government Entities, regional government entities and commercial customers, within SIE's territory (indicated by the red line in the picture below)", one can see the potential basis for a dispute. According to some of the re-sellers, the matter is now in the hands of the respective lawyers.

4. ImageSat International

This is the new name of the company that is undertaking the EROS (Earth Remote Observation System) high-resolution satellite project. It was formerly called West Indian Space.

- Ofeq and Shavit

The origin of this mainly Israeli-backed project lies, like so much of this story, in developments that took place in the late 1980s. In September 1988, the Ofeq-1 (Horizon-1) satellite was launched from the Palmachim site in Israel and was followed by a similar Ofeq-2 launched in 1990. They were launched by Israel's own Shavit (Comet) launcher - which is a development of its Jericho medium-range ballistic missile. Ofeq-1 and -2 were experimental satellites with quite short lives (lasting a few weeks). An attempt was made to launch another Ofeq satellite in September 1994, but this failed. However, in April 1995, the first fully operational Ofeq-3 reconnaissance satellite was successfully placed in orbit using the Shavit launcher. It was placed in a very unusual retrograde orbit (with i = 143.4˚) to ensure its launch westwards over the Mediterranean Sea rather than eastwards over the territories of Israel's Arab neighbours. Since the satellite therefore travels from east-to-west around the Earth (instead of the usual west-to-east direction to take advantage of the Earth's rotation), Ofeq-3 has been the subject of great interest to amateur satellite watchers and trackers. They have reported various changes in its orbit - which apparently has been boosted from time-to time to ensure its continued operation until 1999. Only recently (in October 2000) has it re-entered the Earth's atmosphere and burned up. An attempt to launch a replacement satellite (Ofeq-4) in January 1998 failed.

- Greensat

During the 1980s, a close collaboration took place between South Africa and Israel. South Africa provided uranium and test facilities for the Israeli weapons programme. In return, Israel provided knowledge and technology about rockets and satellites. Copies of the Jericho ballistic missile (called RSA-1 and -2) were made in South Africa and an additional motor was added to produce the RSA-3 satellite launcher - which is similar to the Shavit launcher. This was to be used to orbit a high-resolution reconnaissance satellite (producing pan imagery with a 2m ground pixel size and two-band (red/IR) multi-spectral imagery with a 16m ground pixel) to monitor events in Angola and other southern Africa countries. With the end of the apartheid regime, the departure of Cuban troops from Angola and the withdrawal of South Africa from Namibia, the objectives of the project changed. The Howteq company (which was formed in 1985 to construct the satellite) re-packaged it as Greensat, emphasizing its potential use for environmental monitoring and resource mapping. The engineering test model of Greensat was shown at the Paris Air Show of 1993. The overall configuration and the very distinctive operational characteristics were similar to those of the Ofeq-3 satellite. (See the diagram of the EROS/Ofeq imaging arrangement included in my article on West Indian Space published in the Oct./Nov. 1999 issue of GeoInformatics). In the end, the funding dried up for the development of the launcher and the satellite and the project had to be terminated in 1994. Much of the inside story of this development has only come to light recently and been reported in the South African press. The full story has still to be told!

- West Indian Space

As my previous article described in some detail, the West Indian Space (WIS) project to supply commercial high-resolution imagery got under way in 1996, not long after the successful launch of Ofeq-3. It was initiated by a group of companies - Israel Aircraft Industries (IAI) with 44% of the WIS company; Electro-Optics (El-Op), also from Israel, with 12%; and Core Software Technology (CST) from the U.S.A. with 44%. A large bond offering of $250 million that was arranged by the Merrill Lynch finance house supplemented their investment. A constellation of eight satellites - two EROS-A and six EROS-B - based on the Ofeq design has been planned, with IAI as the contractor for the satellites and El-Op supplying the imagers. Instead of the Shavit launcher, use is being made of Russian launchers and facilities. These have the great advantage of allowing a near-polar, Sun-synchronous orbit to give global coverage, instead of being restricted to the ground coverage between 36.6˚ N and S latitude - which was a consequence of the i = 143.4˚ retrograde orbit of the Ofeq satellite. However, like the American projects, the EROS project has been burdened both by technical and financial problems. Originally the EROS-A1 satellite

was to be launched in December 1999. This was then postponed till February 2000.

- ImageSat International

The financial problems were solved through the provision of an additional $90 million package by a group of U.S. and French investors in July 2000. However this also resulted in the reorganisation of the company. This included a change in the top management and the renaming (or re-branding) of the WIS company as ImageSat International NV, which is now incorporated in the Netherlands Antilles. Following on from this reorganisation, EROS-A1 was then to be launched in October 2000. However a further short delay took place before it was launched successfully by a Russian Start-1 launcher from Svobodny on December 5th, 2000. The first images (which have a 2m ground pixel size) were received successfully four days later. The first images to be shown publicly were released on 18th January 2001. Since the EROS satellites have no on-board recording and storage capabilities, they rely entirely on their images being transmitted in real-time to suitably equipped ground receiving stations. Quite a number of existing ground stations have already been signed up to do this. However, given the comparatively low data rates from the EROS-A satellites, the use of transportable ground stations such as the Anglo-Dutch RAPIDS system (discussed in the July/August 2000 issue of GeoInformatics) would seem to be a good solution to plug the many gaps occurring between these fixed stations.

- More Ofeq!

In the meantime, it appears that the Ofeq/Shavit combination is still alive, since various press reports mention an Ofeq-5 satellite currently awaiting launch. However, over this last autumn (2000), the press in South East Asia has been agog with the news (not yet officially confirmed!) that the Singapore government has signed an agreement to fund the development and construction of more advanced Ofeq reconnaissance satellites. Singapore's neighbours are not happy about this development, having noted also that the powerful CRISP ground receiving and processing station with its 13m diameter antenna (funded by the Singapore government) has already been signed up as a partner to receive the image data from the EROS satellites. At the same time (in August 2000), Israel offered to supply two more Ofeq satellites to the Turkish government for reconnaissance and intelligence gathering purposes - in an intense competition with the French Alcatel company.

Still Higher Resolution Satellites

As mentioned in the introduction to this article, on 18th December, NOAA - on behalf of the U.S. Dept. of Commerce - announced the granting of additional licences to EarthWatch and Space Imaging. These will allow them to construct and operate commercial satellites that can produce images with a 0.5m ground pixel size. It could well be that this particular development is a response to the statement made by the head of NIMA (quoted in Space News of 8th January 2001). This asserted that the U.S. defence and intelligence agencies would be more interested in acquiring commercial imagery with a higher resolution than the present imagery with its 1m ground pixel size. Space Imaging plans to have its new satellite ready for launch in 2004. However obviously this will require a substantial (and somewhat risky) additional investment from its owners. Apparently the new licences prohibit the companies from providing images to customers within 24 hours of the time of their acquisition - presumably until they have been vetted on security grounds. The licences also reserve the right of the U.S. government to shutter the imagers mounted on these new commercial satellites to protect "national security" and the country's "foreign policy interests".

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Conclusion

From the discussion above, it can be seen that much of the initiative, finance and drive for the introduction of the new commercial high-resolution space imagery has come from the aerospace companies that have previously built the satellites, launchers, imagers and ground receiving and processing facilities for those government agencies that operate reconnaissance satellites. Originally these have been constructed and operated for intelligence gathering purposes without any thought of an economic justification or cost recovery. Now, however, with the new high-resolution satellites, the aerospace companies are both the constructors and operators of these satellites. Each of the four companies have spent many hundreds of millions of dollars on their projects and they need to recover this vast expenditure from their customers. Of course, a substantial proportion of their revenue will (or should) come from defence and intelligence agencies for whom the ability to acquire imagery of areas that would otherwise be inaccessible is paramount. In this context, the new commercial satellites supplement the dedicated in-house capabilities of these intelligence agencies. A similar requirement regarding accessibility will also apply to companies engaged, for example, in oil, gas and mineral exploration - especially in those countries in North Africa, the Middle East and South and South East Asia where access to existing maps and imagery is severely restricted. Doubtless they will also be willing to pay a substantial premium to overcome these difficulties.

However, for those other customers who do not have these special requirements, the alternative coverage of an equal or better ground resolution produced by aerial photographic cameras and the new airborne digital imagers - together with their inherent flexibility - will almost certainly offer severe competition to the satellite operators. This will be the case, especially if the final product is cheaper. Furthermore, the operators of airborne imaging systems do not run the same risks of delays and potential interruptions to the supply of their imagery and the considerable financial losses that have so far been the experience of those involved in launching and operating commercial high-resolution satellites. In view of this experience, it is now open to question as to whether, at the present time, commercial high-resolution space imagery is economically viable. We may have to wait until the reliability of the technology improves substantially and its costs get much lower before it can become truly competitive.

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