High-Resolution Imaging From Space

A World-Wide Survey (Part II - Asia)

Asia is an area where currently there is a huge activity in terms of building and launching satellites with a high-resolution imaging capability. Already six high-resolution satellites have been built in Asiatic countries and are operational, including two each from Israel, India and Japan. Another high-resolution satellite belonging to Taiwan is due to be launched within the next month or so. A further five are scheduled to be launched within the period 2004-2005 and still more are planned to be orbited during the rest of the decade. As will be seen, the vast majority of these satellites are being launched with national security considerations in mind.

By Prof. Gordon Petrie

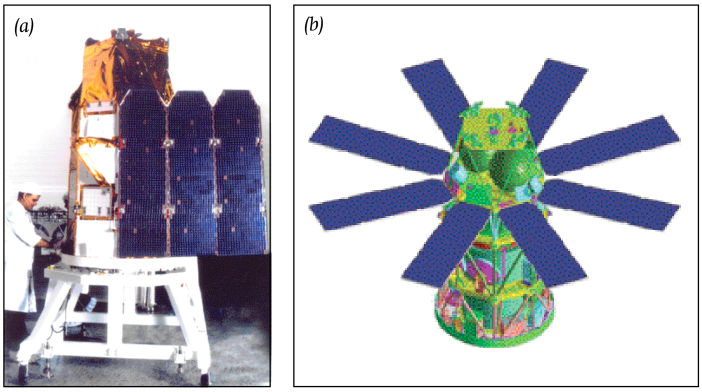

Figure 1. (a) The EROS-A1 high-resolution satellite during its ground testing. (b) A cut-away drawing of the new EROS-B higher-resolution satellite that is currently being built by Israel Aircraft Industries [IAI]. (Source: IAI)

II.1 Israel

Like most countries involved in the acquisition of high-resolution imagery from space, the Israeli efforts in this field, are tied up with the country's concern with intelligence gathering and national security, of which mapping forms a vital part.

Israeli Military High-Resolution Satellites

Israel's reconnaissance satellites are the Ofeq (Horizon) series, all of which have been launched from the Palmachim launch site in Israel using its own Shavit (Comet) launcher. First of all, two experimental satellites - Ofeq-1 and Ofeq-2 - with short lives of a few weeks were launched in 1988 and 1990 respectively. These were followed by an attempt to launch an operational Ofeq satellite in September 1994, which failed. However, in April 1995, the Ofeq-3 satellite was launched and operated successfully till 2000. It produced imagery with a 2m ground pixel size. Ofeq-3 was launched westwards over the Mediterranean, instead of in the usual easterly direction to take advantage of the boost given by the Earth's rotation. This was done to avoid the spent launcher rocket landing in Jordan or Saudi Arabia. So the satellite was placed in a retrograde orbit (with i = 143.4°) that could only cover the area between latitudes 36.6° N and S. However this includes all of its Arab neighbours plus much of Iran.

Ofeq-4 & -5

Following on from the success of Ofeq-3, a series of follow-on Ofeq satellites were authorized under a six-year plan. However an attempt to orbit Ofeq-4 failed at launch in 1998 and the whole programme fell badly behind. According to an investigation carried out in 2001 by the Israeli Comptroller-General, Judge Eliezer Goldberg, many technical problems occurred. Besides which, there was poor supervision and liaison between the constructors, IAI, and the military authorities. Costs soared with little to show for them. Eventually, in May 2002, Ofeq-5 was launched and apparently operates very successfully. According to the Israeli press, it produces imagery with a 1m ground pixel size.

Further Ofeq Satellites

It would appear that Israel's military reconnaissance programme, is now back on track. Ofeq-6, which is similar to Ofeq-5, is planned to be launched later this year (2004). Ofeq-7 is to be a new satellite design to produce very high-resolution imagery in the sub-metre (0.1 to 0.25m) range. In between Ofeq-6 and -7, it is planned to launch TechSAR, some time in the period 2005-2006. As the name suggests, it is a technology demonstration satellite equipped with a SAR, that is being developed by the Elta company, which already builds the airborne SARs used by the Israeli Air Force. Israel is also considering the development of a constellation of micro-satellites capable of being launched from F-15 fighter aircraft. It is interesting to note too that, in August 2003, Israel and Brazil signed an agreement that would allow Israel to use its Shavit rocket to launch the Ofeq satellites from the Alcantara Space Center in Brazil. This would provide an equatorial launch site to give the maximum assistance to the launcher from the Earth's rotation. Furthermore it would allow an easterly launch over the Atlantic, so removing the limitations of the current westwards launch from Israel over the Mediterranean.

Israel's Commercial High-Resolution Satellites

Although the ImageSat International company (formerly called West Indian Space) is registered in the Netherlands Antilles and has its main office in Cyprus, the majority holding by IAI and ElOp is Israeli; the top management is Israeli; and its EROS satellite and the ElOp pushbroom scanner have been built in Israel. Furthermore, quite recently, the company's main image archive has been moved from Cyprus to Israel.

EROS-A

The original programme was to construct eight EROS satellites - models A1 and A2 to

Space

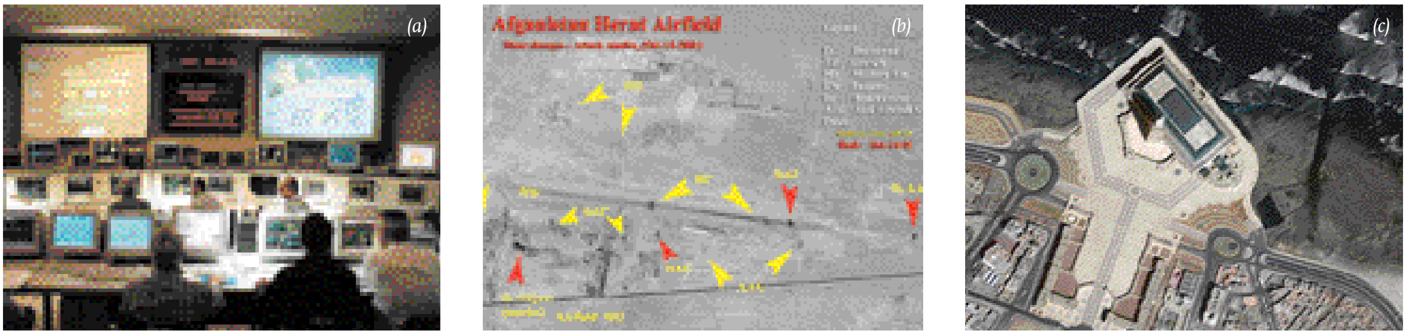

Figure 2. (a) The control room and operations centre for the EROS satellites located in Israel. (Source: ImageSat Intl. NV), (b) An EROS-A1 high-resolution pan image showing bomb craters on the runway, anti-aircraft guns and destroyed aircraft on Herat Airfield in Afghanistan during the war against the Taliban in October 2001. (Source: Metria Satellus; Copyright: ImageSat Intl. NV), (c) A colourized version of an over-sampled EROS-A1 pan image with 1m ground pixel size showing part of Casablanca, Morocco, with the Great (Hassan II) Mosque jutting into the Atlantic Ocean. (Source: ImageSat Intl. NV)

be launched in 1999 and 2000 respectively, followed by the larger and more capable B1 in 2003, B2 and B3 in 2004, B4 and B5 in 2005 and B6 in 2006. However there were long delays during the construction of EROS-A1. Besides the initial $250 million funding raised by the Merrill Lynch finance house in the U.S.A., a further $90 million had to be raised from U.S. and French investors at the beginning of 2000 in order to keep the project running. Eventually EROS-A1 was launched and came into successful operation in December 2000. By all accounts, it is very similar to the Ofeq-3 satellite. Its pan images have a 1.8m ground pixel size. However images with a 0.9m ground pixel size can be obtained through over-sampling. A big difference compared with Ofeq-3 was that EROS-A1 was placed in a near-polar Sun-synchronous orbit using the Russian Start-1 launcher from the Svobodny site in Eastern Siberia, so giving world-wide coverage.

EROS-B

Obviously, the originally planned schedule for the EROS-programme has fallen badly behind. The EROS-A2 satellite was dropped and construction of the EROS-B1 satellite has commenced, aided by a further $70 million of finance from the Bank Leumi in Israel made in July 2001. The EROS-B1 satellite is now scheduled for launch towards the end of 2004. It is a very different design to that of EROS-A1 - being much heavier (350kg v. 250kg). It will produce multi-spectral imagery with a 3.5m ground pixel size as well as pan imagery with a 0.9m ground pixel. It will also use much larger linear arrays - with 15,000 to 20,000 pixels, instead of the 7,000 long linear array used on EROS-A. This specification is said to be similar to that of Ofeq-5. With regard to the launch of EROS-B1, the first option is to again use a Russian rocket, but other options are being considered.

Summary - Israeli High-Resolution Satellites

As with all high-resolution space imagery programmes, national security considerations play a very large part in Israel's programmes. Like the programmes in other countries, development has been slow due to technical problems, failed launches and financial over-runs - though the final imagery, when eventually realized, has been well received. It is very noticeable that quite a number of the ground receiving stations that have been licensed to take down EROS imagery are located in South and East Asia - in India, Singapore, Taiwan, South Korea and Japan - again primarily for "national security" purposes. The close cooperation between Israel and India on certain space imaging projects is very significant and will be discussed in the next section.

II.2 India

The Indian Space Research Organisation (ISRO) has had a most impressive record in space remote sensing. The two earliest satellites - IRS-1A (from 1988) and IRS-1B (from 1991) - generated medium-resolution, multi-spectral imagery with 72.5m and 36m ground pixel sizes respectively. The two follow-on satellites - IRS-1C (from 1995) and IRS-1D (from 1997) - are still operational but with rather little remaining in the way of propellants and other consumables. Their pan imagery has a 6m ground pixel size; their LISS III multi-spectral imagery features a 23.5m ground pixel size and a 142km wide swath; and their WiFS (Wide Field Scanner) imagery has a ground pixel size of 188m and a swath width of 810km. The IRS-1C and -1D pan imagery is just on the edge of being high-resolution in terms of the definition adopted in this article. The imagery has had a fairly wide sale internationally, especially with Space Imaging acting both as a major ground station operator and as the sales outlet for the imagery on the international market.

These two IRS-1C & -1D satellites were followed by the IRS-P3 (launched in 1996), also equipped with a WiFS scanner and IRS-P4 Oceansat (launched in 1999) equipped with a low-resolution optical scanner and a microwave radiometer for ocean monitoring purposes. Next in the series were to be IRS-P5 Cartosat - originally scheduled to be launched in 2000 - and the IRS-P6 Resourcesat. However, before these developments could be fully implemented, came the large-scale incursion of insurgents into the Indian-held part of Kashmir in 1999. Nearly 300 Indian soldiers were killed before the insurgents were forced back into Pakistan after fierce fighting. The Indian military forces had been caught completely unawares and had not anticipated the attack. None of the preparations for the incursion had been seen on the IRS-1C and -1D imagery. This lack of knowledge brought huge public criticism and resulted in the

Figure 3. (a) The main Indian satellite launch centre located on Sriharikotra Island in the Bay of Bengal. (b) The main rocket of the Indian PSLV launch vehicle used to place the IRS and TES satellites into orbit. (c) The launch of the TES high-resolution satellite using the PSLV launcher. (Source: ISRO)

rapid decision by the Indian government to build a reconnaissance satellite that could generate high-resolution imagery with 1m ground pixel size for intelligence gathering purposes. This construction was carried out by ISRO under a crash development programme in less than two years. Thus development of the IRS-P5 and IRS-P6 satellites was placed on a lower priority, while the rather innocuous sounding Technology Experiment Satellite (TES) was built. It was launched in October 2001 from the Indian space launch centre on Sriharikota island, located in the Bay of Bengal, 100km north of the city of Madras (Chennai) on the east coast of India.

TES

The high-resolution (1m) pan images from the TES satellite are only available to Indian national security agencies. While ISRO constructed the TES satellite platform, the solid state recorder, the antenna, etc., Israeli companies helped considerably to implement the rapid development of the TES satellite. In particular, ElOp supplied the two-mirror, on-axis optics and focal plane. Besides which, it also supplied sophisticated electronics components. According to Indian science writers, the TES satellite can be operated synchronously - "..... with a step-and-stare capability to image an area" - apparently in a similar manner to the modes used on the Israeli EROS and Ofeq satellites. TES also has a cross-track (side-pointing) as well as an along-track pointing capability. Both the IRS-P4 satellite and the TES satellite were launched by India's own PSLV launch vehicles. In each case, they were accompanied by two much smaller satellites - Tubsat (German) and Kitsat (S. Korean) with IRS-P4 and Bird (German) and PROBA (ESA) with TES.

Forthcoming Indian Satellites

After the successful construction, launch and operation of TES, ISRO has returned to its original development programme:

(a) IRS-P6 Resourcesat has been launched on 17th October, 2003. Essentially it is a follow-on to the IRS-1C and -1D satellites. It has the same LISS-III imager and a more advanced WiFS imager. However its pan scanner has been replaced by a new LISS-IV multi-spectral scanner with the same ground pixel size (6m) but a narrower swath width (20km). The LISS-IV can also be operated as a monochrome (pan) imager, in which case, it gives the same swath width (70km) as the IRS-1C and -1D pan images.

(b) IRS-P5 Cartosat is now scheduled for launch in 2004. It quite definitely falls into the high-resolution category. The satellite will feature twin pushbroom scanners operating along-track and generating stereo-images having angles of $+26^\circ$ and -5° with respect to the nadir and a swath width of 30km. Obviously DEMs will be a primary product from this type of stereo-imagery.

(c) Cartosat-2 is currently under development and is scheduled for launch in 2004/5. It will generate pan imagery with a 1m ground pixel size over a 10km swath width. It will also feature flexible pointing, being able to point its imager both along-track and cross-track at angles up to 45°.

(d) RISAT, scheduled for launch in 2006, will feature a C-band SAR with various (ScanSAR, strip and spotlight) imaging modes with ground pixel sizes between 3m and 50m. In fact, looking at its detailed specification, it is quite similar to that of the Canadian Radarsat-2 satellite. One can surmise that the all-weather, day/night capability of the SAR will have a national security dimension.

Summary - Indian High-Resolution Satellites

It is perhaps significant too that, at the beginning of September 2003, India and Israel signed an official agreement for further cooperation on space imaging projects. Besides which, the Indian Shadnagar ground receiving station is now listed as receiving images from the EROS-A1 satellite - (and perhaps also from Ofeq-5?). As with all the other countries that are launching high-resolution satellites, Indian national security considerations lie near the top of the agenda for the acquisition of high-resolution imagery from space. With TES already launched and the two Cartosats under construction, undoubtedly India is going to be a serious player in the field of high-resolution imaging and mapping from space. In this particular context, Space Imaging has just extended its agreement with the Antrix Corp. (the commercial division of ISRO) to cover the sales and marketing of the high-resolution imagery from the Resourcesat (IRS-P6) and Cartosat (IRS-P5) satellites, as well as that from the existing IRS-1C and -1D satellites.

II.3 Taiwan

A long-term plan for the development of a national remote sensing capability by Taiwan began in 1995. Since then, there has been a slow but steady development of the ROCSAT series of satellites with help from various overseas countries and companies.

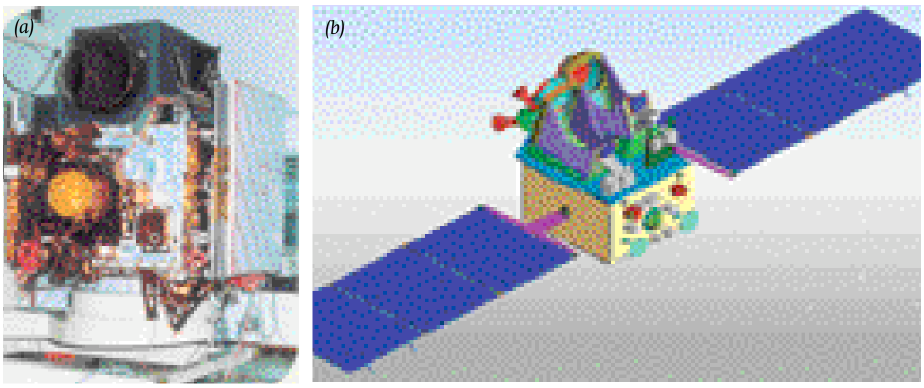

Figure 4. (a) The TES high-resolution satellite undergoing tests prior to its launch. (b) An artist's sketch of the forthcoming Cartosat (IRS-P5) high-resolution satellite. (Source: ISRO)

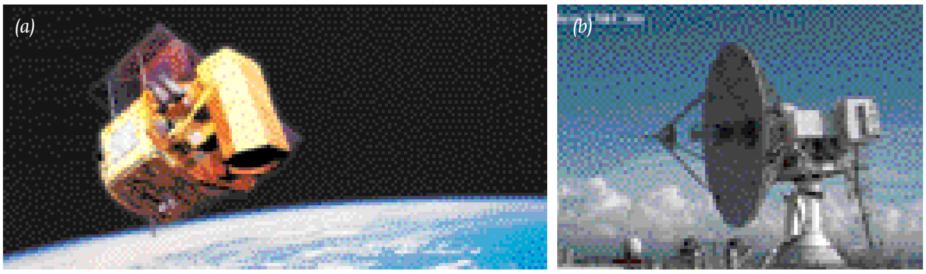

Figure 5. (a) An artist's impression of the soon-to-be-launched ROCSAT-2 high-resolution satellite in its near-polar orbit. (Source: NSPO, Taiwan), (b) The Tracking, Telemetry & Command (TT&C) station for the ROCSAT-2 satellite located in Northern Taiwan. (Source: Allied Signal)

ROCSAT-1

First of all, ROCSAT-1 was built for Taiwan's National Space Program Office (NSPO) by the American TRW company and launched using a Lockheed-Martin Athena rocket in 1999. It featured a low-resolution ocean monitoring imager, which is no longer functioning - although the other non-imaging (comms and scientific) instruments on ROCSAT-1 are still operational. The national plan was for ROCSAT-1 to be followed by a high-resolution satellite (ROCSAT-2) and a constellation of small weather satellites (ROCSAT-3).

ROCSAT-2 Satellite

The story of ROCSAT-2, the high-resolution satellite, has become quite a saga! In particular, its construction and launch have been subjected to continuous interference by outside countries, mainly on political grounds. First of all, in February 1999, Dornier was awarded an $83 million contract to build the ROCSAT-2 satellite. However the German government received strong protests from China about this contract on the grounds that ROCSAT-2 would be used for spying!! As a result of these representations, the German government refused to issue DASA/Dornier with an export licence and the deposit made for the construction of the satellite was returned to Taiwan. Then, in December 1999, a new contract was made with Matra-Marconi Space for the construction of ROCSAT-2. The French government ignored the resulting protests from China and issued the necessary licences to Matra-Marconi to go ahead with the construction of the satellite. The irony of all this is, of course, that both DASA/Dornier and Matra-Marconi are now two of the major partners in the Astrium company, part of the giant pan-European EADS aerospace corporation.

ROCSAT-2 is a fairly large and heavy (760kg) satellite. It has been constructed on the basis of Matra-Marconi's Leostar 500 platform design with quite a number of the components being built in Taiwan. Originally the ground resolution was to be limited to 5m ground pixel for the pan imagery and 20m for the multi-spectral imagery. However, it has since been revealed that the imager will, in fact, produce pan images with a 2m ground pixel and multi-spectral images with an 8m ground pixel size. To achieve this, the ROCSAT-2 will utilize a telescope with very advanced mirror optics employing silicon-carbide material for its structure, built by the French company, Boostec Industries, based in south-western France.

ROCSAT-2 Launcher

The supply of the launcher for the ROCSAT-2 satellite has also been an interesting story. Originally ROCSAT-2 was to be launched using the Indian PSLV launcher. However the contract was cancelled after heavy pressure on the Taiwanese government from the United States - which cited the UN embargo that was then in place on the supply of high-tech parts to India. So ROCSAT-2 was to be launched instead using Lockheed Martin's Athena launcher. However, finally the contract for the launch was awarded to the Orbital Sciences Corporation. The company will use its Taurus rocket to launch ROCSAT-2 from the Vandenberg Air Force Base in California. Also the contracts for the supply of the tracking and ground stations were awarded to another American company, Allied Signal, while those for the command and control software went to Integral Systems. The image processing software has been developed in Taiwan.

Currently the ROCSAT-2 satellite and the Taurus launcher have both been completed and are undergoing their final tests. The launch of ROCSAT-2 was scheduled originally for 25th November, 2003, but the date has since been changed to 27th February, 2004. The imagery is supposed to be available to civilian users, but there is little doubt that Taiwan's national security and intelligence agencies will be the prime users of the imagery. Already these agencies are major users of the images acquired by the EROS-A1 satellite through Taiwan's SOP (Satellite Operating Partner) contract with ImageSat International which allows the direct reception of EROS-A1 imagery by a Taiwanese ground station. This will help to balance the reported purchase of IKONOS imagery of Taiwan by China that has been made through a South Korean company!

II.4 South Korea

In many ways, South Korea's progress towards high-resolution satellites and imagery parallels that of Taiwan. Both countries have neighbours making threats against them. Both have made long-term plans to enter space in a serious way via communication and meteorological satellites as well as high-resolution remote sensing satellites. Both have enlisted help from foreign countries in their efforts to achieve space remote sensing capabilities. South Korea's earliest efforts were concentrated on micro-satellites - Kitsat-1, built with the help of SSTL in the UK, and Kitsat-2. These were launched in 1992 and 1993 respectively. Since then, South Korea has moved on to the development of larger and more capable satellites.

KOMPSAT-1

As with Taiwan's ROCSAT-1, the first of these South Korean satellites, called KOMPSAT-1, was built partly by TRW in the U.S.A. and partly in South Korea by the

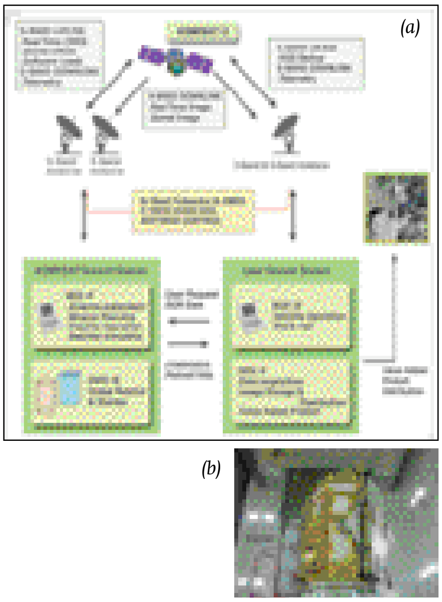

Figure 6. (a) Diagram giving an overview of the ground facilities supporting the operation of the KOMPSAT-2 high-resolution satellite scheduled to be launched in November 2004. (b) The KOMPSAT-2 satellite during its construction and testing in South Korea. (Source: KARI)

Figure 7. (a) An H-IIA launcher lifting off from the main Japanese launch site at Tanegashima Space Center. (b) The ALOS satellite undergoing tests. (c) An artist's impression of the ALOS satellite in its polar orbit transmitting data via a DRTS communications relay satellite (operating in a geostationary orbit) onwards to a ground receiving station in Japan. (Source: JAXA)

Korean Aerospace Research Institute (KARI). The satellite was launched in December 1999 using an Orbital Sciences Taurus rocket. KOMPSAT-1's pushbroom scanner was also supplied by the TRW company, which built it with the assistance of Litton Itek Optical Systems. It generated images with a 7m ground pixel size giving a 17km swath width. A second low-resolution imager was also mounted on KOMPSAT-1 for ocean monitoring.

KOMPSAT-2 Launcher

With the development of its KOMPAT-2 satellite, South Korea is moving into the high-resolution imaging field. Again this development has become a rather tangled story through the involvement of international partners who are subject to interference from foreign governments on political grounds. In the case of the launcher, originally KOMPSAT-2 was to be launched by a Chinese Long March 2C (CZC-2) rocket from Xichang in April 2004. Again international politics intervened in the matter. Now the KOMPSAT-2 satellite is scheduled to be launched by Eurockot GmbH – which is a German Astrium and Russian Khrunichev joint venture - from the Russian space center at Pletesk in North Russia in November 2004 using an SS-19 rocket.

KOMPSAT-2 Satellite

As for the satellite itself, the platform or bus is being developed and built by KARI with the help of technical advice and a certain amount of hardware procurement from Astrium. The optical imager, called a Multi Spectral Camera (MSC), is in fact a pushbroom scanner that will generate 1m panchromatic and 4m multispectral images over a 15km swath width. This imager has been purchased from ElOp in Israel. Under a sub-contract from ElOp, the German company, OHB-System, based in Bremen, is providing the data storage and downlink system for KOMPSAT-2.

EKOSAT

There is a proposal by the same three partners - ElOp + KARI + OHB (= EKO-SAT) - for a follow-on satellite, utilizing the spare test model from the earlier KOMPSAT-1 mission. This would use the so-called MSRS (Multi Spectral high-Resolution System) scanner to produce imagery in 12 bands (i.e. superspectral) with a 5m ground pixel size over a 26km swath width. This would be supplemented by the Hot Spot Recognition system that is already being used by DLR on the German BIRD micro-satellite. It is suggested that, since much of the hardware has already been developed, the EKOSAT could be prepared comparatively quickly for launch in 2005.

More KOMPSAT Satellites + MACSAT

Two more high-resolution satellites, KOMPSAT-3 and -4, are currently in the planning and development stage, based on the country's experience with KOMPSAT-1 and -2. Their launches are scheduled from 2005 onwards. However another intriguing project is the MACSAT programme involving a South Korean company, SaTReC Initiative, and an agency of the Malaysian government, Astronautic Technology. Development of MAPSAT started in 2001. It is a mini-satellite weighing 200kg that is planned for launch into a near-equatorial orbit with an orbital inclination of 8° in 2004. It will feature a pushbroom scanner generating pan imagery with a 2.5m ground pixel and multi-spectral imagery with a 5m ground pixel over a 20km swath width.

II.5 Japan

Rather like India, Japan has had a very active and successful programme of constructing, launching and operating imaging satellites for many years. In particular, several geostationary meteorological satellites have been operated from 1977 onwards. Later, two oceanographic satellites, MOS-1a and -1b, were operated between 1987 till the mid-1990s. These were followed by the JERS-1 satellite with its optical and SAR imagers both delivering images with an 18m ground pixel size between 1992 and 1998. Finally there was the ADEOS (Advanced Earth Observation Satellite) launched in August 1996, but which failed in June 1997. After which, the Japanese NASDA agency planned to launch ADEOS-II in 2000 and ALOS (Advanced Land Observation Satellite) in 2002.

Intelligence Gathering Satellites (IGS)

However, in August 1998, North Korea launched a Taepo Dong ballistic missile that flew over Honshu, the main island of Japan, and landed in the North Pacific. Apparently there was little or no warning of this event from Japan's ally, the U.S.A. - which had placed certain restrictions on the sharing of imagery and intelligence with Japan. This had a huge impact on the Japanese government and public. After this experience, the government decided that it wanted to have its own independent intelligence capacity and no longer be dependent on U.S. imagery and intelligence sources. Within two months, the Japanese government had approved a plan to build four high-resolution satellites. Early in 1999, Mitsubishi received a formal contract for their design and construction. This project was to be given the highest priority. As a result, the development of the civilian ADEOS-II and ALOS satellites were placed much further down the priority scale.

On 28th March 2003, the first two of these IGS satellites were launched together using Japan's powerful H-IIA rocket - which had also been developed to replace the earlier H-II launcher which had a poor record of failures. Both IGS satellites are quite large and heavy - IGS-1a carries an optical imager and weighs 850kg; IGS-1b has a SAR imager and weighs 1,200kg. They deliver high-resolution images having 1m (optical) and 3m (SAR) ground pixel sizes. The main customer is Japan's recently formed Cabinet Satellite Intelligence Center (CSIC) - although it is said that some data may be released for "disaster monitoring" and "scientific research". The attempt to place the second pair of high-resolution satellites - IGS-2a and IGS-2b - into orbit took place on 29th November 2003. Unfortunately this was unsuccessful due to the failure of one of the booster rockets to detach from the main H-IIA launcher. A new generation of IGS satellites giving images with 0.5m ground pixel size is now being developed with launches planned for 2008.

ADEOS-II
More attention is now being paid to NASDA's (now re-named JAXA) civilian ADEOS-II and ALOS satellites, whose development and launch had slipped by two years. ADEOS-II was finally launched in December 2002. Its two imagers - AMSR (Advanced Microwave Scanning Radiometer) and GLI (Global Land Imager) produce low-resolution (250m ground pixel) images. Unfortunately the latest news, (issued on 25th October 2003) is that the satellite has stopped sending data to its ground receiving station after only 10 months operation.

ALOS
Much more relevant to this discussion on high-resolution imagery is ALOS. This is a very large and heavy satellite equipped with multiple imagers that will weigh 4,000kg (4 tons). Currently it is scheduled to be launched by an H-IIA rocket in the summer of 2004. However this may be delayed following the failed launch of the IGS-2 satellites. On board the ALOS satellite will be three imagers - AVNIR, PRISM and PALSAR. The AVNIR-2 (Advanced Visible & Near Infra-red Radiometer-2) is a four-channel optical imager producing images with a 10m ground pixel intended for global mapping. It is an improved version of the AVNIR scanner that was mounted on board ADEOS. The PRISM imager is a three-line pushbroom scanner with forward, nadir and backward pointing linear arrays with a configuration very much in the style of the German MOMS-02 scanner. However, in contrast to MOMS-02, its stereo-imagery will have a ground pixel size of 2.5m; a base:height ratio of 1.0; and a swath width of 35km. Supplementing the PRISM imager, ALOS will also have three star trackers for accurate altitude determination and a dual-frequency GPS for precise positional determination. Through the use of this combination of auxiliary instruments, it is hoped that DEMs can be created with a minimum need for ground control points. Finally PALSAR is an L-band SAR that is designed to produce imagery with a 10m ground pixel size when operated in its high-resolution mode, but much less (100m) when operated in its ScanSAR mode. Given the huge data load that will be generated by the three imagers, Japan plans to use two of its DRTS (Data Relay Technology Satellites) to transmit the data to its ground stations.

Asia is an area where currently there is a huge activity in terms of building and launching satellites with a high-resolution imaging capability.

Summary - Asian High-Resolution Satellites
The rapid development of satellites with high-resolution imaging capabilities in Asia has been quite astonishing. It is of course largely the result of concerns about national security amid threats from neighbours. Both India and Japan already had substantial civil space programmes and had developed powerful launchers. So it was very much easier for them to implement crash programmes to develop high-resolution imaging satellites without political interference from outside countries. Israel has a much less powerful launcher derived from its medium-range Jericho ballistic missile, so it has developed small, lightweight and very agile satellites. Taiwan and South Korea have had to use foreign launchers and get help from abroad to build and launch their high-resolution satellites. So their programmes to acquire their own independent high-resolution space imaging capabilities have been subjected to political interference from abroad. Besides building their own satellites, all of these Asian countries have been large-scale consumers of high-resolution imagery for intelligence gathering and mapping. Thus chains of ground receiving stations have been established both in the Middle East and in South and East Asia to take down commercial high-resolution imagery from EROS (in Japan, South Korea, Taiwan, Singapore and India, as well as Israel); IKONOS (in Japan, Singapore, U.A.E. and Turkey) and OrbView-3 (in Japan).

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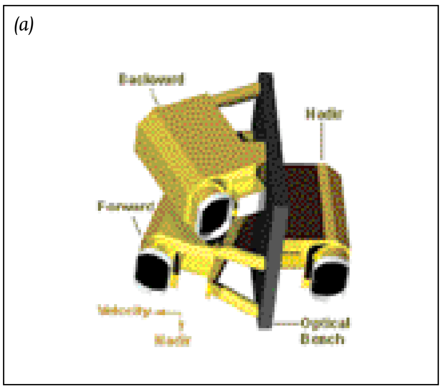

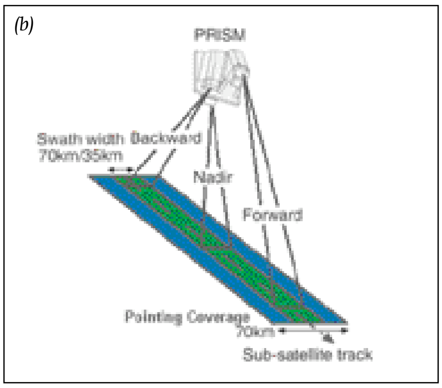

Figure 8. (a) A drawing of the PRISM three-line pushbroom scanner that will be mounted on the ALOS satellite. (b) A diagram showing the operation of the PRISM three-line scanner from the ALOS satellite with forward, nadir and backward pointing linear arrays acquiring overlapping stereo-coverage of the terrain for DEM generation. (Source: JAXA)