High-Resolution Satellite Images: Past, Present and Future

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Abstract

This paper describes some issues on high-resolution satellite images, i.e. commercialisation process, the current status, policy issues and future development.

1 Introduction

In the communities making use of digital images, i.e. photogrammetry, remote sensing, geographical information technology, etc., much attention has recently been paid to the availability of commercial satellite images with high resolution. High resolution normally means a spatial resolution of 4 meters or higher (e.g. 1 meter).

High-resolution images were once controlled solely by the two superpowers (i.e. the United States and the Soviet Union). These images were mainly used for military and intelligence purposes. The collapse of the Soviet Union and advancement in commercial remote sensing have created ripe conditions for selling high-resolution imagery for profit. Since the early 1990s, many countries have launched high-resolution satellite imaging systems and/or are going to launch such systems in the near future. This article aims to examine the development of such systems.

2 The Commercialisation of High-Resolution Satellite Images

It is well recognised that commercial remote sensing started in 1972 when the US launched its first Earth Resources Technology Satellites (ERTS). This satellite system was later officially renamed as Landsat in 1975. The resolution of Landsat images has been improved dramatically from around 80m (from Landsat 1) to about 15m (Landsat 7, which was launched in 1999). The French SPOT system is another major source of satellite images. SPOT-1 was deployed on February 22, 1986. The SPOT-1 offers panchromatic images with 10-meter and multi-spectral images with 20-meter resolution. SPOT images have found wide applications. However, the resolution is still not high enough for applications requiring high geometric accuracy.

The availability of high-resolution images is a recent event in space remote sensing. In the fall of 1987, Russia made the images taken by KFA-1000 commercially available; these were panchromatic (i.e., black and white) and colour images at a spatial resolution of 5-10 meters. In early 1992, Russia allowed the commercial distribution of high-resolution images acquired by the KVR-1000 camera. This panchromatic camera was designed for intelligence applications and is still used by the Russian intelligence community. The resolution of such images is 2m. Russia then became the sole supplier of high-resolution satellite imagery. However, the impact of Russian high-resolution images is very limited because its policy on the sale of high-resolution imagery has not been operationally coherent due to conflicts between intelligence and commerce.

The US government used to set a restriction of 10m spatial resolution for commercial sensors. In order to remain commercially competitive internationally, the US government removed such restrictions in January 1988 after the commercialisation of KFA-1000 images by Russia. In March 1994, after the commercialisation of KVR-1000 images by Russia, the US Government implemented a new policy that encouraged the commercialisation of high-resolution images into the international market. Under this new policy, a number of private companies have obtained licences for the operation of private satellite remote sensing systems. Space Imaging is one of

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them. The company launched the world's first and only 1m resolution commercial imaging satellite, IKONOS, on Sept. 24, 1999. The image products from IKONOS are currently available on the market.

3 The IKONOS One-Meter Resolution Images from Space Imaging

The IKONOS satellite is the world's first commercial satellite to collect images with one-meter resolution. It was launched by Space Imaging on Sept. 24, 1999, aboard a four-stage Lockheed Martin Athena II launch vehicle from Vandenberg Air Force Base in California. The name IKONOS is derived from the Greek word for "image" and is pronounced "Eye-KOH-nos.

The IKONOS satellite system was built by Lockheed Martin Commercial Space Systems (Sunnyvale, Calif.). The communications, image processing and customer service elements were built by the Raytheon Company (Garland, Tex.). The camera was built by Eastman Kodak (Rochester, NY). The complete IKONOS satellite weighs about 1600 pounds. It will orbit the Earth once every 98 minutes at an altitude of approximately 680km. It will be in a sun-synchronous orbit so it will pass a given longitude at about the same local time each day. IKONOS circles the globe on a north-south axis 14 times a day. Its orbit repeats itself exactly every 140 days. However, since the sensor is capable of viewing land surface far from the area directly below the path of the satellite, a site can be imaged almost daily, although not always at one-meter resolution. Indeed, passing over any one region an average of twice a day, with the ability to collect 20,000 square km in a single pass, IKONOS renders the average piece of land visible at one-meter resolution every three days and at two-meter resolution every day (Space Imaging, 2000). Figure 1 shows an example of an IKONOS image.

In February 2000, Space Imaging announced the introduction of the CARTERRA™ Geo product line. Three distinct products from IKONOS images are available, i.e. CARTERRA Precision, CARTERRA Reference and CARTERRA Geo, offering different levels of mapping accuracy. In May 2000, Space Imaging announced the addition of one-meter resolution colour imagery to its CARTERRA™ product line. This product is a result of fusing 1m resolution panchromatic images with 4m resolution multi-spectral images. In other words, the spatial content of the one-meter resolution black and white data is combined with the colour content of the four-meter multi-spectral (colour) data to form the one-meter colour imagery.

According to the information provided by Space Imaging (2000), these three products from IKONOS have different levels of spatial accuracy and thus distinct applications.

> *"CARTERRA Precision products are suited for applications requiring a high degree of positional accuracy, such as base mapping, cadastral mapping, city planning, geographic information system (GIS) updates, change management, site selection and development. This product is produced using ground control and digital elevation models. It has been claimed to have a 4-meter horizontal accuracy (CE 90%). CARTERRA Reference products are ideally suited for applications where quick delivery and less positional accuracy is crucial, including large-area or regional mapping, GIS backdrops, real estate planning, change monitoring, agricultural monitoring, site evaluation, insurance assessments, natural disaster assessments, and other applications. This product has been claimed to have a horizontal accuracy of 25 meters (CE 90%). CARTERRA Geo products are ideal for projects not requiring a high degree of positional accuracy but which require quick delivery, such as emergency response, agriculture productivity monitoring and media reporting".*

4 The Russian 1-Meter Space Images

In June 2000, the Russian Space Agency, Sovinformsputnik (2000), announced the commercial distribution of Russian one-meter spatial resolution space images. These images were obtained by Russian KOMETA - a satellite system specially designed to produce topographic stereographic photography and high resolution, panoramic photo images for subsequent production of 1:50,000 scale topographic maps. These images are currently unreachable for civil commercial applications.

Figure 1 IKONOS First Images, Beijing, China. (www.spaceimaging.com)

Figure 2 KVR-1000 space image of New York (http://www-com.iasis.svetcorp.net)

The news release (Sovinformsputnik, 2000) states:

> *"Starting many years ago and till today, Russia has accrued the huge and unique archive. There are lots of data on USA, Europe, Middle East and for some parts of South America and Far East. One-meter resolution imagery will be delivered to the customers in digital orthorectified format. Positioning accuracy – 15 meters and 5 meters with Ground Control Points. Satellite images obtained from the previous Kometa mission in 1998 together with a huge archive of topographic data as well as Russian 1m data are* widely used all over the world for a large number of applications".

Figure 2 shows an example of Russian 1-meter resolution images.

On 29th September 2000, the 20th KOMETA mission was successful. On board the Kometa-20 (Figure 3) are the TK-350 and KVR-1000. The former provides a ground resolution of 10m at a typical scale of 1:660,000. The latter provides a resolution of 2m at a typical scale of 1:220 000. The KVR-1000 images are nested within the TK-350 images so as to provide higher resolution than 2m.

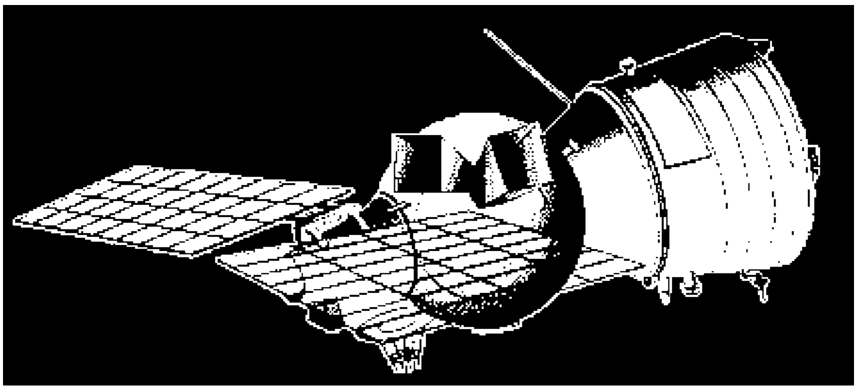

Figure 3 Russian Kometa Satellite system (http://www-com.iasis.svetcorp.net).

5 The Potential Impact of High-Resolution Images

High resolution satellite images have found and will find wide application in a number of markets (Space Imaging, 2000), including state and local government, mapping, agriculture, forestry, emergency response, utilities, telecommunications, real estate, environment, national security, transportation, and insurance and risk management. Large-scale maps of entire countries can be made from satellite images for the first time. Farmers can more precisely monitor the health of crops and estimate yields. Scientists can look at environmentally sensitive areas and predict trends. Government officials can monitor and plan enlightened land use policies. City planners can further the development of new housing communities. New and emerging uses include measuring and mapping damage to properties after natural disasters, planning for emergency response, mapping transportation networks, developing in-vehicle navigation systems, and planning and developing real estate.

The high-resolution images currently available on markets provide the user with sharp details in the scene of interest and with very high temporal resolution. The resolution of such images are said to be comparable with those obtained by KH-7 satellite (1966), and the near real-time capabilities are described as being comparable with those obtained by KH-11 satellite (1976), as shown in Figure 4 (Federation of American Scientists, 2000). As public imagery intelligence, the availability of such high-resolution images will provide non-governmental sectors with unprecedented potential for rapidly presenting compelling and credible evidence to assist in the interpretation of current events and to advance their policy and program agenda. However, with the widespread use of one-meter resolution remote sensing in the US, two key concerns have been raised (Federation of American Scientists, 2000):

a) The possibility that this technology poses a threat to U.S. national security;
b) The possibility of using remote sensing devices to monitor private citizens or property.

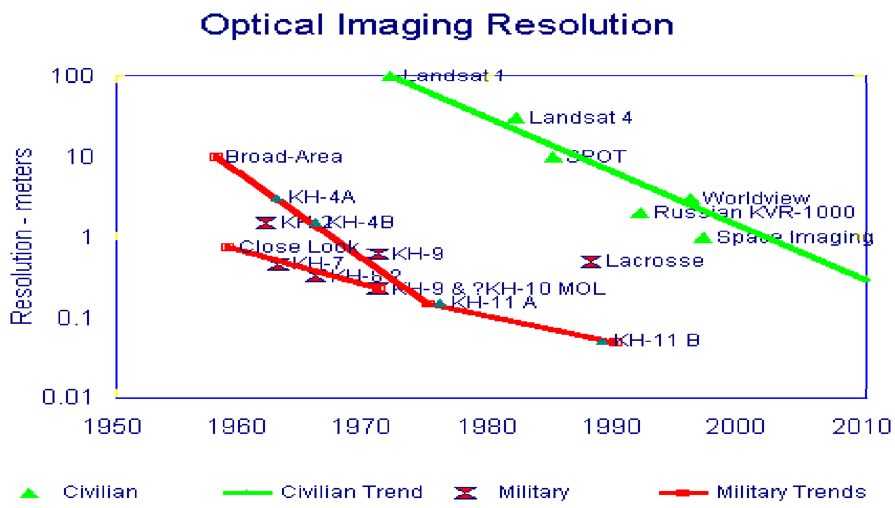

Figure 4 A comparison of spatial resolution of satellite image systems for military and civil usage (http://www.fas.org/eye/imint.htm)

6 Policy Issues on High-Resolution Images

As pointed out by Gupta (1994) in a paper entitled "New Satellite Images For Sale: The Opportunities and Risks Ahead", "while the sale of high-resolution satellite images will open up many opportunities for traditionally Earth-bound states, it will also release a variety of risks from Pandora's Box. And considering how long the United States and Russia have kept high-resolution imaging to themselves, it would be reasonable to deduce that the risks could be as great as the risks associated with proliferation of biological, chemical, and nuclear weaponry. There are numerous potential hazards associated with the horizontal proliferation of high-resolution imagery and many are a function of the specific circumstances that surround the application. In general, the risks depend on how the new remote sensing services will be distributed throughout the political landscape, how belligerent states will use high-resolution images, and how observed states will respond to routine overhead imaging by their neighbours".

Therefore, some policy decisions must be made to restrict some aspects of the commercialisation. In fact, in the same paper, Gupta (1994) recommends:

a) banning sales or leases that give the buyer full control of high-resolution imaging satellites,
b) removing the right of imaged states to have access to commercial high-resolution images of their own territory,
c) discouraging states from obtaining exclusive imaging arrangements for their own territory,
d) prohibiting states from acquiring high-resolution images of areas beyond a 2000-3000-km radius from their ground receiving station, and
e) foreclosing the concept of an International Satellite Monitoring Agency (ISMA), as originally proposed by France in 1978.

In fact, some countries have already set their policies. For example, according to the Federation of American Scientists (2000) in a paper entitled "Public Imagery Intelligence", Israel continues to restrict the use of 1-meter resolution images. In 1996, the US Congress passed the Kyl-Bingaman Amendment to the Defense Appropriations Act. That law says that the US government may not license an American remote sensing company to collect or disseminate imagery of Israel at a better resolution than what is generally available from remote sensing companies in other countries, i.e. 2 meters. Therefore, companies was notified of this decision in 1998 (Federation of American Scientists, 2000).

Some other policies adopted by US government have also been pointed by the same paper (Federation of American Scientists, 2000):

> *"Under US Presidential Decision Directive 23 [PDD-23] of March 1994, during periods when national security or international obligations and/or foreign policies may be compromised, as defined by the Secretary of Defense or the Secretary of State, respectively, the Secretary of Commerce may, after consultation with the appropriate agency(ies), require the licensee to limit data collection and/or distribution by the system to the extent necessitated by the given situation".*

> *"The National Oceanic and Atmospheric Administration (NOAA) issued an Interim Final Rule on July 31, 2000, revising the agency's minimum requirements for the licensing, monitoring and compliance of operators of private Earth remote sensing space systems under Title II of the Land Remote Sensing Policy Act of 1992 (the Act). These regulations implement the provisions of the 1992 Act, as amended by the 1998 Commercial Space Act, and the Presidential Policy announced March 10, 1994 (hereinafter PDD 23). …… This new rule is effective August 30, 2000.".*

7 High resolution satellite in the near future

In the near future, high-resolution satellite images will be used widely. Apart from USA and Russia, many countries, such as Brazil, China, Canada, Germany, India and Japan, will also launch such systems, either for military or civil usage. Table 1 lists a number of such systems to be launched in the next few years, which is extracted from ITC web site (2000).

It should also be noted that one-half meter resolution imagery is expected soon. As reported by Gildea (2000), a decision on the sale of one-half meter resolution is to be made soon. In the US, an inter-agency group has discussed whether commercial companies should be permitted to sell one-half meter resolution satellite imagery. The inter-agency group is comprised of representatives from the Department of Defense (DoD), the Commerce Department and the State

Department. If the one-half meter resolution is approved, there are also questions on whether to add some sort of restriction.

Table 1 High Resolution Earth Observation Satellite Launch Timetable (http://www.itc.nl/~bakker/launch-table.html /)

Date	Spacecraft	Country/Remarks	Best Resolution
July 2001	TES	India/defense	1m
31 Mar 2001	OrbView-4	USA/commercial	1 m
Q3 2001	OrbView-3	USA/commercial	1 m
Q3 2001	IRS-P5	India, Cartosat-1	2.5 m
2003	Radarsat 2	Canada	3 m radar
2002	CBERS-3 & 4	China/Brasil	3 m
Q3 2003	ALOS	Japan	2.5 m
2003	IRS-2A	India, Cartosat-	1m
2004	TerraSAR	DLR, Radar	1 m

The report (Gildea, 2000) also states: "The commercial satellite imagery industry has been pushing for the ruling so that they can make the imagery available before other nations do so. Industry officials also argue it will take close to five years to build the satellites able to collect that data, and they need a policy in place to move forward from a business standpoint. …… While military and intelligence officials are beginning to acknowledge such imagery is becoming increasingly available around the globe, they are still reluctant to give a full endorsement to companies for taking the lead on the sales of high-resolution images". But these officials also recognise that "it is not a matter of if the US will move to one-half meter resolution, it's a matter of when and what is the proper time for implementing this decision." Of course they want to move slowly and keep their secrets as long as they can. However, it is certain that one-half meter resolution will become available in the near future, possibly in five years or so.

8 Conclusions

High-resolution images were fully controlled by the military and intelligence agencies in the past. However, satellite images with resolution as high as 1m are now available in the commercial markets. High-resolution images will have impacts on national security and basic human rights. In spite of these great concerns with the widespread use of high-resolution images, the commercialisation of satellite images with one-half meter resolution is also expected to come in the near future. These images will be a major source of geospatial information in the 21st century and will affect every sector in geospatial engineering.

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