COMMERCIAL SATELLITE-BASED EARTH OBSERVATION INDUSTRY ANALYSIS

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ABSTRACT:
National Space Organization (NSPO), owing and operating the FORMOSAT-2 remote sensing satellite, is one of high resolution image providers in the world. The schedule-to-launch FORMOSAT-5 remote sensing satellite together with current FORMOSAT-2 satellite demonstrates NSPO's determination to compete in the world arena of earth observation (EO) image market. Willing to be a key player of commercial satellite-based EO industry, it is important for NSPO to understand the development and trends of this particular industry. The purpose of this study is to analyze current industrial structures and future trends through conventional industry analysis techniques. The industrial scope defined in the study is the optical satellites-based EO industry. The characteristic of EO industry and EO business model will be characterized for this defined industry scope. Nine major image providers, Digital Globe, GeoEye, Astrium GEO Information Service, RapidEye, Disaster Monitoring Constellation International Imaging (DMC ii), ImageSat International, Antrix, NSPO and Korea Aerospace Research Institute (KARI), are among the subjects of this study and each company/organization profile is briefly described. Based on the image sources and resolutions of image products, the competition positions of these companies/organizations are identified. According to those findings, the companies/organizations with similar competition position are deemed in a strategic group where similar business strategy may be found. From strategic group analysis, the competition intensity of each strategic group is also determined. Furthermore, vertical integration and future trends of optical EO industry are predicted through industrial value chain analysis. These conclusions may lead us to a greater understanding of current status for commercial satellite-based EO imagery industry.

1. MOTIVATION & SCOPE OF STUDY

After the launch of FORMOSAT-2, the first remote sensing satellite of Taiwan, in 2004, NSPO signed an agreement on exclusive distribution of FORMOSAT-2 images, excluding the area of Taiwan and China, with SPOT Image. Thereafter, NSPO formally became a member of global optical satellite-based EO industry. The plan-to-launch FORMOSAT-5 remote sensing satellite will work with current FORMOSAT-2 satellite, a plan shows NSPO' s ambition to compete in the world arena of EO image market. As a new entrant of commercial satellite-based EO industry, it is important for NSPO to understand its current position in this particular industry. The scope of this paper is therefore confined to commercial optical satellite-based EO industry. Conventional industry analysis techniques, such as life cycle analysis, value chain analysis, and strategic group analysis, are considered to analyze of today's industrial structures and future trends. The conclusions of this study may lead us to a better understanding of current status for commercial satellite-based EO industry. The paper is organized in the following manner: The Section 2 describes the characteristics and business models for satellite-based EO industry. In Section 3, commercial EO industry status and structure are collected and then analyzed through industry analysis techniques. Summaries are offered in the last section.

2. EO INDUSTRY CHARACTERISTICS & BUSINESS MODELS

2.1 Characteristics of Satellite-based EO Industry

Characteristics of the satellite-based EO industry are briefly summarized as follows:

Satellite-based EO Industry is a Global Industry
Most of remote sensing satellites are in sun-synchronous orbits with altitude between 400 km to 900 km, which imply that their ground coverage spans from around 80 degree north latitude to 80 degree south latitude globally. A remote sensing satellite can acquire images of most land in the world. Therefore, unlike aerial remote sensing industry, the satellite-based EO industry is a global industry for its global presence of remote sensing satellites.

Satellite-based EO Industry consists of firms with different attributes
The cost and risk to develop and operate successfully a completed remote sensing satellite system, including satellite and ground facility, are high. Therefore, developments of most remote sensing satellite systems in the world still rely on the government investment except very few private firms. For this reason, the satellite-based EO industry consists of firms with different attributes, such as government owned, government supported, and commercial, based on the level of government control and support (O'Connell, 2001). Firms with different attributes may have different operation strategies when they face the competition in EO industry.

Various Image products are used and needed in satellite-based EO industry
Figure 1 illustrates the percentage of both image product used and needed with respect to their resolutions (Mondello, 2008). From the figure, it shows that either data used or needed for sub-meter image product accounts for over 50 % of the market. This result clearly reveals the fact that the sub-meter data is the mainstream of EO industry. Since the applications of low resolution image data remains, the market of low resolution image data will not disappear even its needs is relative low.

2.2 EO Business Models

A business model can be understood as the way in which a firm to make profit. In general, the owners of remote sensing satellites provide three different business models to the users through the following categories:

Tasking and standard products: According to orbit characteristics and satellite features, satellite owner can provide variety of tasking services for various applications. With respect to the user's requirements in terms of survey period and area of interest, it offers imaging activities to acquire either large geographic area images or time-series images. All of standard image products should be processing with both radiometric and geometric corrections. Those corrections are based on systematic and periodic calibration activities performed by satellite owner in order to have qualified image products.

Value-added products or services: With the increasing supply of satellite data, the raw image product becomes a commodity today. Therefore, the process to extract useful information from the raw data will be the tendency to enhanced competition in the EO international market. Nowadays, the valued-added products or services include not only digital elevation data, orthorectified images, mosaic images but also services with different applications, such as dynamic change detection, precision farming and emergency response service etc. It is no doubt that the future of EO market relies on the value added products or services. However, it is a great challenge for a satellite image provider to become a service provider due to the wide know-how gap between these two areas.

***Direct downlink services*:** By utilities the space reception infrastructure, the satellite owner provides the image tasking services and download images to the customer directly when satellite flies through a certain geographic area defined by the customer. Within this area, customer has priority to acquire images and download data. Meanwhile, customer also has the authority from satellite owner to manage resource and generate image products.

3. INDUSTRY STRUCTURE ANALYSIS

3.1 Company Profiles

In this paper, nine firms are selected as the subjects of this study. These nine firms have their own optical remote sensing satellites and play the role of an image provider, not a reseller only. These nine firm's profiles, including their attribute, satellite image products, and other products or services may be found in the following paragraphs and summarized in Table 1.

(1) DigitalGlobe (http://www.digitalglobe.com), founded in 1992, is a U.S. commercial image and geospatial solutions provider located in Longmont, Colorado. DigitalGlobe owns and operates the world's most advanced constellation of commercial high-resolution remote sensing satellites including QuickBird, WorldView-1 and WorldView-2.

(2) GeoEye (http://www.geoeye.com) is a U.S. commercial satellite image company based in Herndon, Virginia. In January 2006, Virginia-based OrbImage merged Colorado-based Space Imaging to from a new company, named GeoEye. GeoEye now owns and operates the most high-resolution commercial remote sensing satellite, GeoEye-1, in the world.

(3) Astrium (http://www.astrium.eads.net) is an aerospace subsidiary of the European Aeronautic Defence and Space Company (EADS) which provides civil and defense space systems and services. Astrium integrated SPOT Image and InfoTerra to establish a new business branch, called Astrium GEO Information services, in January 2011.

(4) RapidEye (http://www.rapideye.de) is a Germany-based satellite image and geospatial information provider which focuses on decision-making management through its own EO images and valued-added services. The RapidEye constellation of five identical satellites equipped with 77-km swath image sensor is capable of acquiring over 4 million square km area per day.

(5) DMC ii (http://www.dmcii.com) is a U.K. based commercial satellite image company which provides satellite images from several remote sensing satellites built by Surrey Satellite Technology Ltd, but operated by Algeria, Nigeria, Spain, China and U.K respectively. The DMC provides a unique EO resource that enables daily revisit most of land in the world since their satellites are designed to acquire images with large swath up to 640 km.

(6) ImageSat International (http://www.imagesatintl.com) is a Netherlands Antilles commercial image company. ImageSat International offers high-resolution satellite images collected by its optical remote sensing satellites of EROS-A and EROS-B. The primary customers for ImageSat International are governments and defense sectors who are in the needs of national security and intelligence applications.

(7) Antrix (http://www.antrix.gov.in) is commercial sector of Indian Space Research Organization (ISRO) controlled by Indian space department. Antrix provides not only image products from IRS-C, IRS-D, Catosat-1 and Catosat-2, but also offers various subsystems for spacecraft.

(8) NSPO (http://www.nspo.org.tw) is the space organization of Taiwan. NSPO involved satellite-based EO industry after the launch of FORMOSAT-2 in 2004. Currently, NSPO is going to build a new remote sensing satellite FORMOSAT-5 which is the follow-on satellite of FORMOSAT-2.

(9) Korea Aerospace Research Institute (KARI) (http://www.kari.re.kr) plays a key role in the area of satellite and launch vehicle development for South Korea. Headquarter located in Daejon, KARI affiliated to KIMM (Korea Institute of Machinery & Materials) was established in 1989. KARI has successfully launched KOMPSAT-1 and KOPMSAT-2 remote sensing satellites in 1999 and 2006, respectively

3.2 Industry Life Cycle

Similar to biological life cycle, an industry life cycle represents the evolution of an industry following a sequence of stages spanned from introduction, growth, maturity to decline. In the introduction and early growth phases, industry development strongly owing to the government investment. The investment from government sector will decrease when industry development is in the maturity and decline phase. For satellite-based EO industry, although some reports indicates that the revenue for EO industry will grow rapidly for the next decade (SpaceRef), most of remote sensing programs for EO industry still heavily rely on government financial support. Therefore, it can be concluded that satellite-based EO industry remains in the early growth stage, as shown in Figure 2.

3.3 Value Chain Analysis

A simplified but typical value chain for satellite-based EO industry is shown in Figure 3. From upstream to downstream, the primary firms include satellite manufacturers, satellite operators, data receiving service providers, image data providers, value-added service (VAS) providers, and users. In general, most of remote sensing satellite firms play both roles of satellite operator and image data provider at the same time. However, two types of downstream vertical integration in the value chain for satellite-based EO industry are observed in this study. The first one is a vertical integration between image data provider and VAS provider, such a integration

trend is common especially for these firms with commercial attribute, i.e., GeoEye, DigitalGlobe, RapidEye etc. They play not only the role of image data providers, but also further extend their business to provide value-added services. As a result, the boundary between image data provider and VAS provider is becoming more blur. The second one is a vertical integration between satellite manufacturer and data provider. For example, Surrey Satellite Technology Ltd has a subsidiary of DMC ii, Antrix is a market sector of ISRO and Astrium integrates SPOT Image and InfoTerra into a new business branch.

3.4 Strategic Group Analysis

Based on the image data sources and resolution of image products, the competition positions of nine image firms with different attributes could be identified. Figure 4 demonstrates that the competition positions of nine companies of satellite-based EO industry. The vertical axis is the percentage of satellite owned by a company while horizontal axis is the image data resolution. Different color represents different attributes, i.e., commercial / government owned or supported. In general, a firm with low percentage of satellite ownership has lower risks from manufacture and/or launch failures but has to make effort to coordinate image tasking activities from different organizations. From Figure 4, it is observed that seven firms with commercial attribute can be grouped into four groups. It shows that only one commercial company DMC ii focuses on the market of low resolution images (resolution > 30 m), and RapidEye is the only one company in the medium resolution images (resolution between 4 m and 30 m) market that owns all its satellites. Astrium forms a group by itself since it has medium satellite ownership rate and focuses the markets ranged from high to medium resolution images. The market of ultra high resolution images (resolution < 1m) is very competitive since GeoEye, DigitalGlobe and ImageSat International are in the same group and Astrium will move into this group with the inauguration of Pleiades 1, 2 and SPOT-6, -7 satellites.

4. FUTURE TRENDS

In this section, some trends from a perspective view of image data source are observed and described as follows.

Very high resolution sensors: From a public resource, it is reported that the resolution for U.S. military reconnaissance satellite, such as KH-11, has been achieved to 10 cm (Dunay, 2004). GeoEye-2 and Worldview-3, expected to launch in 2012 and 2017, are reported to have resolutions of 25 cm and 31 cm, respectively. However, only satellite image products above 50 cm resolution are available in the current EO commercial market due to regulations enforced by U.S. government. Nevertheless, it is a trend for a commercial remote sensing satellite to produce higher and higher resolution images. Whether the quarter-meter or better image products become available in satellite-based EO market in the near future depends on the resolution of U.S. national security policy rather than a technical issue.

Remote sensing satellite constellations: High revisit frequency and global coverage are goals for today's satellite-based EO industry. Since a single remote sensing satellite can not provide daily revisit and global coverage simultaneously, the only goal solution is form a satellite constellation. The RapidEye satellite constellation, launched in Aug 29, 2008, consists of five satellites which can achieve daily revisit and global coverage. GeoEye plans to deploy a GeoEye satellite constellation, including GeoEye-1, GeoEye-2 launched in 2012, and GeoEye-3 launched in 2017. Another example is DigitalGlobal, DigitalGlobe will integrate QuickBird, Worldview-1, Worldview-2 and oncoming-launched Worldview-3 satellites to form the world largest sub-meter remote sensing satellite constellation. Clearly, the trend driving commercial EO satellites to form a constellation is irreversible in today's satellite-based EO industry.

Multi-resolution & multi-spectral sensors: Images with single spatial, spectral or temporal resolution have different applications. However, from the perspective of image analysis, multi-resolution & multi-spectral images promise more accuracy analysis results. For example, one can utilize optical images to detect the changes on the ground before and after operation activities for the application of post military operation assessment analysis. Furthermore, for similar assessment but aiming at underground destruction, one may turn to SAR images. On the other hand, users do feel convenient to purchase different image products once image provider can offer one-stop-shop solution for multi-sensors images. Therefore, today's satellite-based EO companies, such as DigitalGlobe, GeoEye, Astrium etc. provide not only optical image products with different resolutions but also SAR or aerial image products.

5. SUMMARY

In this paper, current status and industrial structure for satellite-based EO industry are studied. Although the satellite-based EO industry is still in the early growth phase, the market for high resolution images, especially for sub-meter resolution images, is extremely competitive: DigitalGlobe, GeoEye and ImageSat International already complete each other in this market and Astrium will enter this market after the deployment of Pleiades/SPOT satellites. Since the primary task for NSPO is satellites development, in near term, it will be of lower risk to team up with marketing channel such as Astrium GEO Information Service. In the long run, NSPO still has to consider the vertical integration approaches, i.e., SSTL-DMCii model or ISRO-Antrix model, to enhance its competitiveness.

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Table 1: Company Profile

Firm	Attribute	Satellite Products	Best Resolution (m)	Aerial / SAR Products	DDS	VAS	Satellite Owned Percentage
DigitalGlobe	Commercial	QuickBird Worldview-1 Worldview-2	0.65 0.50 0.46	Aerial	Yes	Yes	100 %
GeoEye	Commercial	GeoEye-1 Ikonos-2	0.41 0.82	Aerial	Yes	Yes	100 %
Astrium	Commercial	SPOT-4 SPOT-5 FORMOSAT-2 Deimos-1 KOMPSAT-2	10 2.5 2.0 22 1	SAR	Yes	Yes	40%
RapidEye	Commercial	RapidEye-1~5	6.5	No	N.A	Yes	100%
DMC ii	Commercial	Alsat-1 Beijing-1 NigeriaSat-1 Deimos-1 UK-DMC /2	32 4 (Pan) 32 22 22	No	Yes	No	33%
ImageSat International	Commercial	EROS-A EROS-B	1.9 0.7	No	Yes	Yes	100 %
Antrix	Government owned	IRS-C IRS-D ResourceSat Catosat-1 Catosat-2	5.8 5.8 5.8 2.5 0.8	No	Yes	No	100%
NSPO	Government supported	FORMOSAT-2	2.0	No	Yes	No	100%
KARI	Government owned	KOMPSAT-1 KOMPSAT-2	6.6 1.0	N.A	N.A	N.A	100%

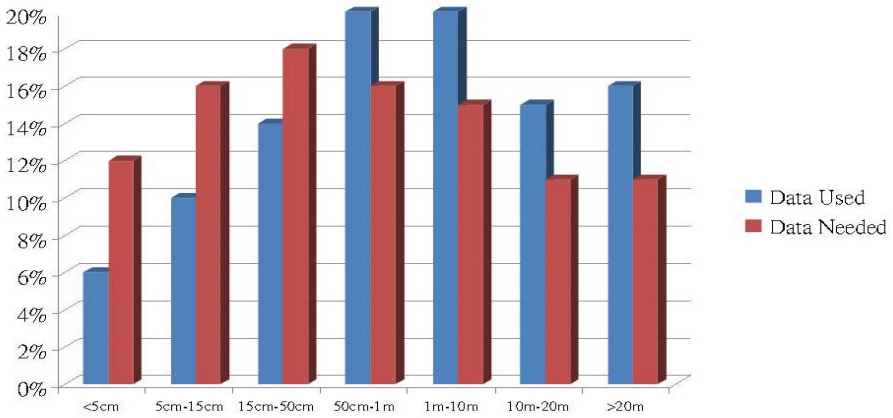

Figure 1 Percentage of data used and needed vs. data resolution

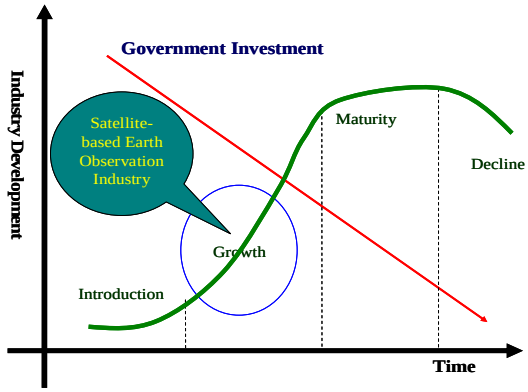

Figure 2: Life Cycle for Satellite-Based Earth Observation Industry

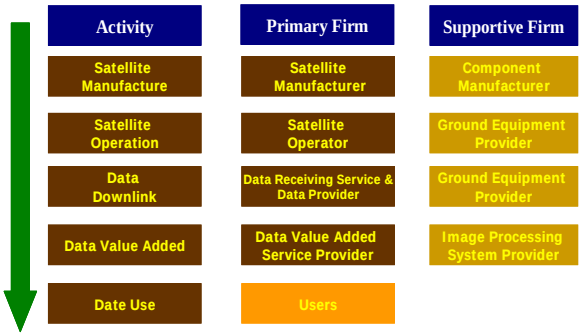

Figure 3: Satellite-Based EO Industry Value Chain

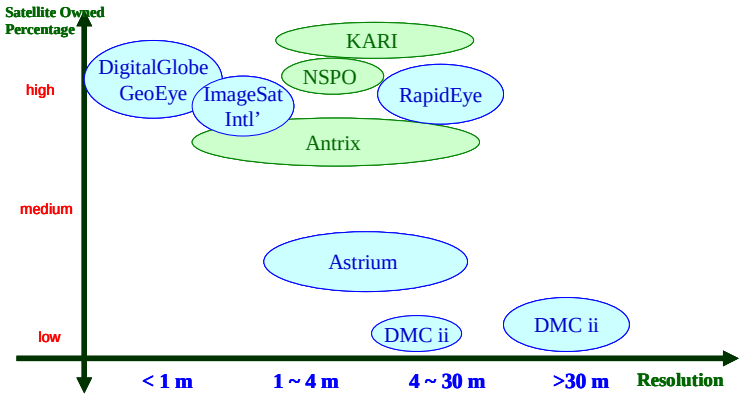

Figure 4 : Strategic Groups for Satellite-Based EO Industry