Revolution in Demand and Supply during Last 10 Years in Small Earth Observation Satellites

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ABSTRACT

While Earth observation applications were dominated by conventional large satellites in the past, rapid advancement in COTS technologies enables relatively smaller satellites to meet certain needs, limited but sufficient to some extent, with reasonably low investment. Ten years ago, the most of small satellites were developed to acquire necessary technologies, or to utilize them as space test beds to verify new technologies or components. However, recently launched small satellites start to draw attention from commercial companies who are considering ~~the~~ small satellites as adequate tools for their businesses.

It is already demonstrated that a small satellite which weighs 200 ~ 300 kg is able to produce quality images with the spatial resolution of approximately 2 meters and soon expected to achieve 1 meter. Considering the unique advantage of satellite constellations in terms of revisit, it is anticipated that small satellite constellations would complement conventional ones in the next few years.

1. CONVENTIONAL EARTH OBSERVATION SATELLITES

Table 1 summarizes conventional Earth observation satellites carrying optical sensors launched recently and to be launched in the near future. It is noted that the most of them are aiming for very high spatial resolution and they are dominated either by commercial programs such as WorldView, GeoEye, and EROS or government programs such as French Pleiades, Korean KOMPSAT, Chinese-Brazilian CBERS and so forth.

The primary direction of users' needs and technology advancement would not be changed from higher spatial resolution during the next decade [1].

Table 1: Conventional Earth Observation Satellites Launched and Planned (Optical)

Country	Satellite	Mass (kg)	Launch Year	Resolution (m)		Swath (km)
				PAN	MS (# of Ch's)	
USA	WorldView-1	2,500	2007	0.45	1.8 (4)	16
Thailand	THEOS	750	2008	2	15 (4)	22 / 90
USA	GeoEye-1	907	2008	0.41	1.64 (4)	15.2
USA	WorldView-2	2,800	2009	0.46	1.8 (8)	16.4
Israel	EROS-C	350	2010	0.7	2.8 (4)	11
China/Brazil	CBERS-3	1,450	2010	5	20 (4)	60
India	ResourceSat-2	1,360	2010	5.8	5.8 (3)	70 / 23.9
France	Pleiades-1	1,000	2010	0.7	2.8 (4)	20

Korea	KOMPSAT-3	800	2011	0.7	2.8 (4)	16.8
France	Pleiades-2	1,000	2011	0.7	2.8 (4)	20
Korea	KOMPSAT-3A	1,000	2012	0.7	2.8 (4)	16.8
Germany	EnMAP-1	780	2013	NA	30 (200)	30
China/Brazil	CBERS-4	1,450	2013	5	20 (4)	60
Turkey	GOKTURK-1	1,000	2013	1	4 (4)	15

2. SMALL EARTH OBSERVATION SATELLITES

While conventional Earth observation satellites are producing very high resolution images even better than 1 meter, small satellites could achieve 10 to 30 meters. However, recently launched small Earth observation satellites demonstrated quality images with fairly high resolution, 2.5 meters in case of RazakSAT and DubaiSat-1 [2]. By the virtue of technology advancement, it is a matter of time to see a small satellite with better than 1 meter resolution.

During the last 10 years, Earth observation satellites developed by emerging countries occupied only 15 % out of total Earth observation satellites (excluding Meteo satellites). However, it is expected to increase to 32 % during the next 10 years and they are mostly developing Earth observation satellite using small satellite platforms. This means that the market demand of small Earth observation satellites will be remarkably increased [3]. The following table summarizes small Earth observation satellites recently launched and soon to be launched.

Table 2: Small Earth Observation Satellites Launched and Planned

Country	Satellite	Mass (kg)	Launch Year	Resolution		Swath (km)
				Pan	MS(# of Chs)	
Germany	RapidEye (5)	150	2008	NA	6.5 (5)	78
Malaysia	RazakSAT	190	2009	2.5	5 (4)	20
UAE	DubaiSat-1	190	2009	2.5	5.0 (4)	20
Spain	Deimos-1	130	2009	NA	22 (3)	600
UK	DMC2-UK	130	2009	NA	22 (3)	600
S. Africa	Sumbandila	80	2009	NA	6.25 (6)	45
Algeria	ALSAT-2A	130	2010	2.5	10 (4)	17.5
Nigeria	NigeriaSat-2	320	2010	2.5	5 (4) / 32 (4)	20 / 600
Singapore	X-SAT	130	2010	NA	10 (3)	50
Turkey	RASAT	130	2010	7.5	15 (3)	30
Chile	SSOT	150	2011	2.5	10 (4)	20
Algeria	ALSAT-2B	130	2011	2.5	10 (4)	17.5
Turkey	GOKTURK-2	500	2012	2.5	5 (4)	20
Vietnam	VNREDSAT-1	150	2012	2.5	10 (4)	20

Over the last decade, the improvement in key technologies enabled remarkable changes in the performance of small Earth observation satellites. The most of small satellites launched until early 2000 were gravity-gradient stabilized and carried frame-type cameras, which could perform very limited operation [4]. However, from KITSAT-3 which was launched by KAIST (Korea Advanced Institute of Science and Technology) in 1999, the most of small Earth observation satellites employed 3-axis stabilized control, pushbroom type cameras and high speed image downlink using higher frequency band.

The following figure shows the comparison of two images taken by KITSAT-3 (110 kg) launched in 1999 and DubaiSat-1 (190 kg) in 2009. These two satellites show great difference in performance made in 10 years. The mass has been increased by 2 times, however spatial resolution has been improved nearly by 5 times (15 meters to 2.5 meters) [5].

Apart from the spatial resolution, nowadays the small satellite platform presents higher agility for off-nadir imaging, multiple target imaging and along-track stereo imaging and very high speed image downlink for more

frequent imaging (100 Mbps or even higher), which could not be imagined 10 years ago.

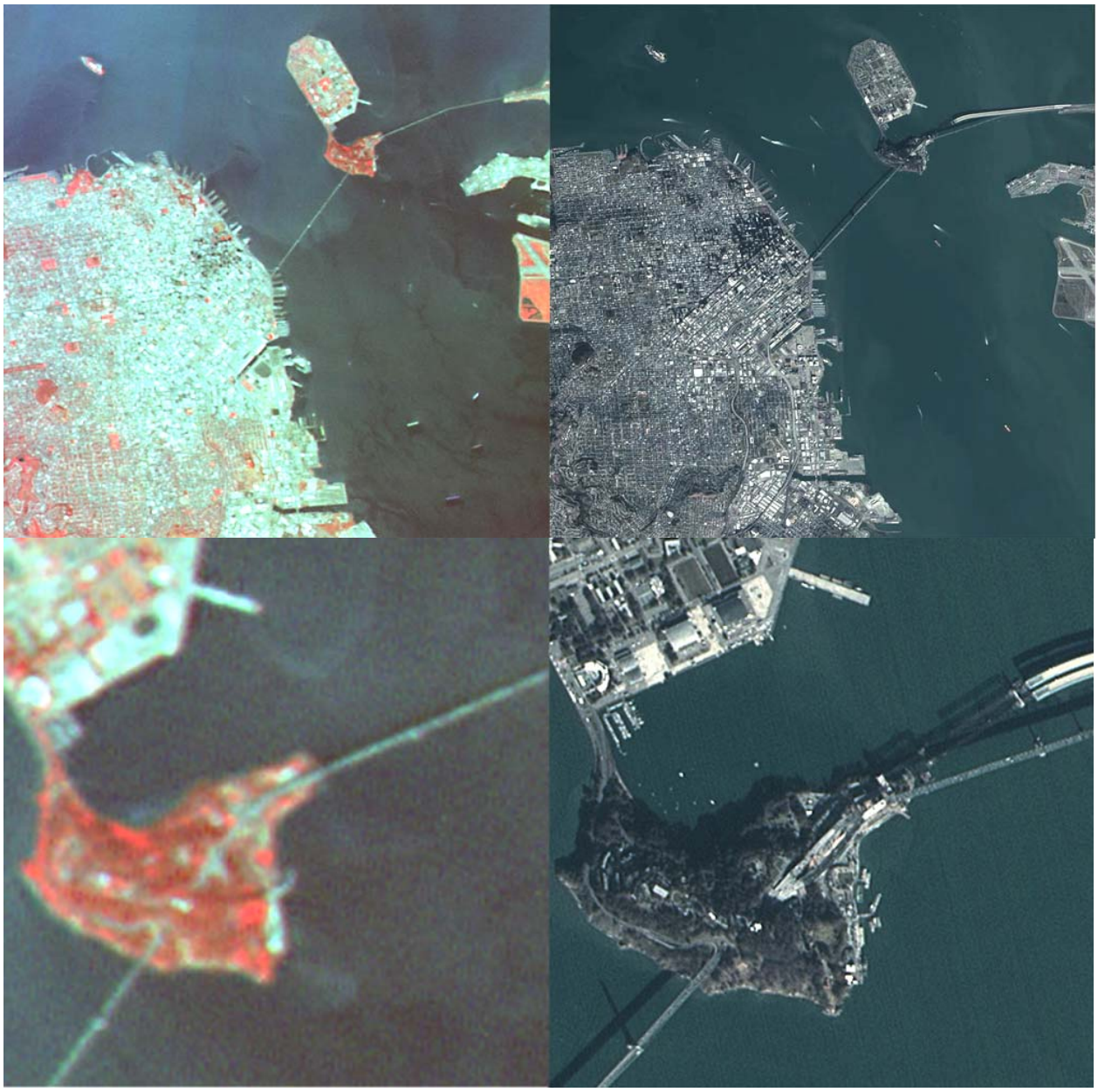

Figure 1: Bay Area taken by KITSAT-3 (left) and DubaiSat-1 (right) (courtesy of KAIST & EIAST)

3. CHANGE IN DEMAND AND SUPPLY CHAIN

During the early period of the small satellite era, the most of customers were looking for small satellites as tools for technology acquisition [4] or new technologies' space qualification. However, there are new demands requiring satellite images for remote sensing, although limited but sufficient for certain applications. In addition to that, from mid-2000, newly established companies have been commercializing spaceborn images using small Earth observation satellites such as RapidEye [6] and Deimos [7].

Another notable change is the vertical integration of the Earth observation business. A couple of satellite manufacturers started to sell satellite images and provide value-added services, while application service providers developed or owned their own satellites.

Table 3 shows the comparison between the Earth observation missions realized during 1999 ~ 2008 and those planned for 2009 ~ 2018 [3]. As can be seen in the Table, during the next decade, two times more Earth observation satellites are expected to be launched and ten more countries are joining to this market.

Although the overall market size of the Earth observation satellite manufacturing is growing almost at the same rate with other space sector, the average satellite mass and cost are forecasted to be reduced significantly. It is not clear whether such a change is driven by supply or demand, however it is sufficient to tell that this indicates that small satellites start to play a more important role in the Earth observation business in the coming years.

Table 3: Earth Observation Market Summary: 10 Years Past and Future

	Realized EO missions (1999-2008)	Future EO missions (2009-2018)
Number of satellites	101	206
Number of countries operating Earth observation satellite	24	34
Average Launch Mass	1,268 kg	694 kg
Estimated total manufacturing revenue	$16.7 billion	$19.3 billion
Average satellite cost	$165 million	$93.7 million

4. FUTURE PERSPECTIVES

During the next decade, it is foreseen that more small Earth observation satellites will be launched and their performance will be dramatically enhanced. Constellations of small Earth observation satellites will become very usual. However a constellation of small satellites cannot become a killer option, since it has a different market segment from that of higher performance larger satellites. Rather, it will be a complementary option providing more frequent imaging to conventional systems and market.

The fast turn-around time of small satellite manufacturing will enable to accommodate new technologies and new demands rapidly. Small satellites employ newly developed COTS technologies more aggressively, which give rapid response to new technical needs in a more cost effective way.

More and more new emerging countries are expected to enter this business and sooner or later they are considered to become key players in supplying small Earth observation satellites and images.

It is still premature to forecast that SAR, hyperspectral, and IR imaging small satellites would appear to this market in the near future, but apparently there are strong needs and they will drive satellite manufacturers to implement such systems in the future.

5. SATREC INITIATIVE (SI)

Based in Daejeon, Korea, Satrec Initiative Co., Ltd. (SI), a private company listed in KOSDAQ, is the world's leading company for high performance Earth observation small satellite solutions. SI was founded in 1999 by the engineers who had developed the first Korean satellite and a series of advanced small satellites in KAIST, for 10 years, and has successfully commercialized the space technology. SI has had successful international and domestic programs with over 20 overseas customers from Middle East, Asia and Europe. The company currently has more than 130 employees.

Over these years, SI has focused on customers' needs with innovative space technology and the company has provided the customers optimized high quality satellite solutions: integrated turnkey satellite systems, satellite components, platforms, electro-optical instruments, ground stations, satellite operations, image processing and remote sensing applications.

SI has recently launched two Earth observation small satellites, Malaysia's RazakSAT and UAE's DubaiSat-1 on July 14 and July 29, 2009, respectively. Both satellites generate high quality Earth images with the ground resolution of 2.5 m in panchromatic and 5 m in multispectral. The company has developed these high performance satellites with international partners while providing both theoretical and on-the-job training for a fraction of budget and timeframe normally associated with typical satellite programs. SI is currently developing electro-optical satellites with better performance and planning to expand its capabilities to radar imaging.

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