Global Commerce in Small Satellites:  
*Trends and New Business Models*

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The views expressed in this paper are those of the authors and do not necessarily represent those of their employers.

**ABSTRACT**

As the conference theme suggests, new business opportunities, rising demand for satellite based services, and particularly emerging nation markets have sparked the imagination of established providers and new space entrepreneurs to capitalize on the unique abilities of small satellites in bringing to market new businesses or government services. Specifically, the emergence of new satellite manufacturers and service providers around the globe has focused attention on the potential benefit of mergers, acquisitions and partnerships to thrive within the space industry. The pan-Asian and Middle-Eastern markets are among the liveliest sectors where demand for small space systems is rising. In reaction to these market forces, ATK Space Systems has undertaken to establish a regional marketing and production collaboration that draws upon the established electronics expertise available from Singapore to better enable our ability to service these markets at a performance level and price point surpassing all of the competition.

The collision of a Silicon Valley business philosophy with the continued miniaturization of space technologies has given birth to a fresh set of *New Space* businesses, some of which have generated significant buzz in the venture capital community. Importantly, many of these new entities plan to rely on constellations of small satellites to produce a capability unachievable from one or two large satellites, and which offer the potential for profit margins far out pacing what can be earned from government contracts. Emerging nations are one of the most rapid growing sectors in the space market where particularly challenging performance targets are desired at price points well below conventional space bus products. Industry trends are leading to cross-market partnerships that enable higher performance small satellites at lower acquisition costs. Coupled with this reality, there is an enduring trend toward improving performance from space platforms that continue to shrink in physical size and mass. What are these trends and how do they affect the commerce of small satellites in the world economy? What must an entrepreneurial space company do to capture market share with superior best-in-class performance at price points consistent with the limited space budgets of smaller nations? This paper will address these questions and the approach ATK and ST Electronics are taking to meet the demand.
1 TWELVE MONTHS OF DRAMATIC CHANGE

The collision of a Silicon Valley business philosophy coupled with the continued miniaturization of space technologies has given birth to a fresh set of ‘New Space’ businesses, some of which have generated significant buzz in the venture capital community. Few if any could have predicted the dramatic change in the state of the small satellite market over the past 12 months – well at least not precisely. How many would have predicted that we would be spelling small satellite this way?

For those having trouble read this word, translated it reads **Google™**, who with their $500M acquisition of Skybox Imaging have started a revolution in space that has been solely enabled by the capabilities of small satellites. As the recent blog post stated, Google did not buy Skybox “just for its satellites.” Google stated “Skybox’s satellites will help keep Google Maps accurate with up-to-date imagery. Over time, we also hope that Skybox’s team and technology will be able to help improve Internet access and disaster relief — areas Google has long been interested in.”

The Google acquisition was itself enabled by another revolution in our industry – the move by certain entrepreneurial New Space companies to create constellations of earth observation small satellites offering unprecedented revisit of every corner of the world. As I stated in 2006, “…small and micro-spacecraft have demonstrated an ability to provide high quality imagery at a cost per square kilometer that rivals (if not improves upon) the cost of imagery from the large imaging systems. Moreover, small satellite systems offer advantages that uniquely set them apart from the large systems.”

No more compelling example of this fact exists than the entrance of Skybox Imaging to the commercial marketplace with the launch of SkySat-1 on November 21, 2013. The image quality of this satellite speaks for itself (Figure 1) and even more importantly, the ability of the Skybox satellites to capture up to 90-second video clips at 30 frames per second is a game-changer in the commercial imagery market. Skybox has contracted to build thirteen more LEO satellites each about 120 kg to

![Figure 1. Nice, France as captured by SkySat-1 on December 7, 2013 (Credit Skybox Imaging, Inc.)](image)
be launched in 2015/2016, with revisit to any point on Earth three times per day.

Joining Skybox Imaging in the pursuit of New Space markets are many other firms looking to capitalize on the demand in established markets or unique niche markets for commercially generated space-based data. Notable among these new starts-ups are:

1. *Planet Labs* of San Francisco, California, whose principal focus is to create an earth imaging satellite network built on CubeSats launched off the International Space Station and in their short lifetime has raised an estimated $65M in venture capital. In all (as of this writing) Planet Labs has launched 43 satellites (called “doves”) as of June 19th in its first “Flock 1” and has plans to launch more than 100 satellites over the next 12 months.

2. *GeoOptics* of Pasadena, CA and *PlanetiQ*, based in Boulder, CO, which are both seeking to be first to market with constellations of GPS/GNSS radio occultation (GPS-RO) satellites that can provide data to improve the accuracy and timeliness of weather forecast models, as well as contribute to climate modeling and space weather prediction. PlanetiQ expects to collect over 5.5 million global observations per day. Both are still building their first satellites and raising capital.

3. *Dauria Aerospace* in Skolkovo, Russia and NASA Ames Research Center, CA is pursuing a new generation of low cost, small satellites and is planning to deploy constellations of earth observation and communications satellites to “bring to commercial markets the capability of providing imagery of the entire arable surface of the Earth”\(^3\) for precision farming, traffic management, dynamic urban management and polar broadband services. Dauria recently established a distribution partnership with Elecnor Deimos of Spain.

And beyond these, there is evidence that Facebook is also looking to leverage the capabilities and capacity of small satellites in a global effort to make affordable basic internet services available to everyone in the world.

2  THE EXPANDING WORLD SPACE COMMUNITY

Beyond this explosion of activity in small satellites domestically, the number of space-faring nations continues to grow at an increasing pace. In all some 54 nations currently operate satellites, but less than 10 of these possess a launch capability. 24 other countries have established space agencies, but not yet entered the community of satellite operators. Among the newest agencies established in this decade are the UK’s new executive space agency (UKSA), the South African National Space Agency (SANSA), Belarus Space Agency (BSA), Mexican Space Agency (AEM), National Aerospace Development Administration (North Korea), and Turkmenistan National Space Agency (TNSA) (Figure 3). Many more were established in the first decade of this millennium in Chile, Algeria, Iran, and Bolivia. Regional agencies are under discussion

![Figure 2. (Left to right) Planet Labs "Doves"; GeoOptics "Cicero"; Dauria Aerospace "Auriga" & "Perseus".](image-url)
in certain world regions. “Space-faring nations [and non-space-faring nations] worldwide are increasingly acknowledging the essential role, and benefits, of space-based services to their citizens, national economy, security and commercial competitiveness.”

In the second decade of this century, small satellites are poised to become the predominant core of numerous Earth Observation (EO) systems and a significant source of global imagery. Satellite imagery is commonly available through two means – state-owned and operated systems, or from commercial data providers, e.g., DigitalGlobe, SPOT, Skybox, or BlackBridge (formerly RapidEye), with systems that generate this imagery generally divided into two classes:

- Exquisite, large “national“ or global systems, which only a very few countries or major commercial operators can afford to procure and operate, and
- Smaller, regionally focused systems or small constellations of systems typically built on platforms of ≤500 kg in mass.

Multiple sources of data indicate more than 275 government-owned earth observation satellites are under contract, in development, or projected to be developed for launch in the period from 2013 through 2022. Euroconsult’s latest research report indicates “the number of Earth observation (EO) satellites launched by civil government and commercial entities is expected to more than double over the next decade to 360 satellites, translating into $35.8 billion in manufacturing revenues over 2013 to 2022, an 88% increase over the previous decade.” This significant growth in both government and commercial earth observation systems is, in part, fuelled by projected Compounded Annual Growth Rates (CAGR) between 15% and 25% in the earth imagery market over the next five years. Depending upon the source, the growth in satellite-based earth observation products through commercial vertical markets, i.e., information, data products and value added processing, is projected to double, if not triple, from approximately $2B today to as much as $6B by 2022. Thus by every rea-
reasonable metric, significant growth in EO satellite systems and services is clearly evidenced. But what does this imply for the small satellite market?

3 EMERGING MARKETS AND APPLICATIONS

In the coming decade, over 40 countries will order, build and/or launch an EO satellite — most of them small. Earth observation remains the number one small-satellite-based application worldwide. EO missions from emerging nations will contribute to staggering growth in the number of satellite launches in the coming decade. Thus, when it comes to small satellites, the sheer number of spacecraft to be built and the projected manufacturing revenues make it evident that small satellites have become big business in space. This is welcome news to small satellite manufacturers in the current environment of diminishing domestic space budgets. While much of the activity in earth observation continues to focus on visible and near-infrared imaging from space, three applications appear to be emerging and show potential for commercial space expansion.

Agricultural Monitoring and Management: Over the past three years, multiple New Space entrants have proposed building small constellations of satellites with a chief focus on enhancing the ability of farmers to monitor and increase the yield of their crops. Much has been written about the spectral signatures of various crops and what they can tell an observer about the health, growing conditions, and yield prospects as a result. Rice is one of the more notable crops where the application of Hyperspectral Imagery (HSI) offers unique information to aid the grower in increasing yield and managing against disease pressure. And, given the importance of rice in the diets of much of the world’s population, an ability to better manage rice crops suggests a potential information market that might support the cost of a space system to collect data on this crop alone.

Synthetic Aperture Radar: In portions of the world, most notably the Asia-Pacific region, the ability to collect electro-optical imagery is severely limited by seasonal changes in atmospheric circulation and precipitation commonly known as monsoons. The Asian monsoon season has its first onset over the southern Bay of Bengal in late April, moving over the Indo-Chinese peninsula and south India in early May, and then progressing north northwest into the continent reaching Japan by late June to July. Rising rainfall over the South China Sea (SCS) and adjacent countries is well known for creating significant flooding in Thailand, the Philippines, Vietnam and other countries in the region. Adding insult to injury, at precisely the time when these regions could most benefit from imagery to manage the resultant disasters, electro-optical satellites are unable to collect imagery due to the omnipresent cloud cover. This creates an obvious demand for synthetic aperture radar (SAR) satellites, but the power demand and size of SAR payloads have proven difficult to package on microsatellites. “Satellites equipped with synthetic aperture radar (SAR) will ... be increasingly used by governments worldwide."5

Weather: In addition to the regional weather impacts caused by seasonal monsoons, global weather is a prospective area of commercial space market growth. As government budgets continue to experience downward pressure, advancements in sensing technologies and the capabilities of industrial companies to build affordable small satellite systems that can host these payloads is a future area of enhanced commercialization in space. GPS-RO has already been mentioned above and has demonstrated its efficacy in weather prediction on the COSMIC-1 mission jointly fund-
ed by Taiwan and NOAA back in 2001. Beyond terrestrial weather, space weather is also an area of increasing concern and NOAA recently took the first steps toward the acquisition of data that can forewarn us of solar storms caused by the Sun's coronal mass ejections. In three to five years, it is anticipated that the first commercial weather satellites will be launched and placed in service.

4 Capturing Market Share in an Entrepreneurially Charged Market

When resources are tight, new and creative strategies can provide opportunities to grow the business in new ways and still complete the mission. Current market conditions have proven conducive to traditional competitors joining forces to pursue the business of space hardware manufacturing, countries and agencies agreeing to a greater exchange of imaging data, and even imaging providers agreeing to share their distribution channels, each getting a share of the business. Examples are numerous:

Thailand and Japan share a common interest in the successful production of rice in their two countries. Thus, while they are competitors on the world rice market, Thailand’s Geo-Informatics and Space Technology Development Agency (GISTDA) and the Japanese Aerospace Exploration Agency (JAXA), Japan, have co-organized a series of workshops focused on rice crop monitoring through the eyes of their respective imaging systems – the Thaiichote or THEOS-1 EO satellite and the Japanese Advanced Land Observing Satellite (ALOS). This is but one example of significant Asia-Pacific regional cooperation in earth observation.

More recently, on April 15th, 2014, DigitalGlobe, Inc. announced they would cooperate with MDA in Canada to offer combined optical and synthetic aperture radar satellite data solutions to their respective defense and intelligence customers globally. The announced joint capability was created to provide their customers with an ability to “task and collect with DigitalGlobe’s constellation of high-resolution earth imaging satellites, along with ability to receive and process near real-time data from the RADARSAT-2 synthetic aperture radar satellite” under a common architecture. Two existing competitors of image data saw the opportunity to merge their capabilities thus creating an “improved ability to regularly monitor large regions” for purposes of change detection linked to human activity or natural events.

In February 2014, two independent suppliers of small and micro-satellites – ATK Space Systems Inc. and ST Electronics (Satcom & Sensor Systems) Pte. Ltd. entered into an agreement to jointly develop, manufacture and supply microsatellites and integration services to the world market. Together, our two companies created a unique partnership to deliver cost-effective, turnkey space mission services with STEE-SatComS leading marketing efforts and promotion of the products in the Asia-Pacific region and ATK leading marketing efforts in the Americas, Europe and Middle East regions. Drawing on their mutual systems heritage, space experience and resources, ATK and STEE-SatComS have introduced the A150S/SS-150 microsatellite to the market as a platform that is optimized to respond to the global market demand discussed earlier for earth observation, scientific exploration and research, and technology maturation and validation missions.

4.1 ST Electronics’ Emerging Space Business

ST Electronics (STEE) started in the satellite communications (satcom) business in 1991 selling RF modules in the Asia Pacific region. Some twenty years on, the company has added new businesses with iDirect operational
hubs in Singapore and the U.S. Today, they lead the market in satcom ground infrastructure. Leveraging their capabilities in design and production of satcom and sensor modules, they advanced into the space business as a next growth area.

Nanyang Technological University (NTU) and DSO National Laboratories (DSO) successfully launched their eXperimental SATellite (X-SAT) on 20 Apr 11. X-SAT recently celebrated its third year anniversary on April 21, 2014. Riding upon the success of X-SAT microsatellite with a mass of 100 kg based on the SS-100 bus, STEE has since embarked on small satellite manufacturing through its STEE - Satellite Systems, a joint venture company formed on May 31, 2011 comprising STEE - Satcom & Sensor Systems (SatComS), NTU and DSO, set up to design, develop and deploy advanced earth observation satellite systems, and to exploit and commercialize indigenous satellite engineering capabilities.

STEE is currently developing its indigenous TeLEOS-1, the first commercial satellite planned to be launched in a Near Equatorial Orbit (NEqO) for launch in Q4 2015 on the Indian PSLV. TeLEOS-1 differentiates itself from the world players of Earth Observation satellites in sun synchronous orbits and yet complements them by providing high responsiveness and high availability data (mean revisit time of 12 to 16 hours) by nature of its low inclined orbit at 10° to 15°. This is achieved by foregoing global coverage for equatorial belt coverage. The equatorial belt covers many major shipping routes and natural disaster prone regions. With a satellite mass of 400 kg, TeLEOS-1 and its electro-optical payload providing a panchromatic resolution of 1m (at nadir) is based on STEE’s own S-400 bus. Building on this experience coupled with the extensive experience of ATK’s Space Systems Division, STEE & ATK have introduced the new SS-150/A150S bus through a partnership bringing new innovation in microsatellites of less than 200 kg mass.

4.2 STRATEGIC COLLABORATIONS WITH PARTNERS

Believing that additional market strength and presence would result from working together, ATK and STEE sought collaboration for a new venture into the space business. At the Global Space and Technology Convention 2014, it was announced that STEE-SatComS and ATK’s Space Systems Division had entered into a strategic marketing and manufacturing agreement to jointly develop, manufacture and supply the A150S/SS-150 microsatellites and integration services to the world market. The partnership leverages on the respective and unique strengths of both companies in satellite design and production for cost competitiveness. The A150S (Figure 4) will be produced at ATK’s Space Systems Division facility in Beltsville, MD. Future versions of the SS-150 will be produced at SatComS in its fully equipped state-of-the-art satellite production and AI&T facility in Singapore. Table 1 below reflects the A150S/SS150 target performance metrics.

Under their agreement, SatComS will contribute avionics and electronics modules and subsystems solutions which are developed in-house e.g. on-board computers, on-board da-
ta recorders, power control and distribution modules as well as ground stations systems integration. ATK will contribute flight-proven hardware and technical expertise in satellite components and subsystems, integrated small satellite bus systems; thermal control systems, multidisciplinary engineering and design services as well as launch services.

This strategy also enables STEE to grow a vibrant and sustainable space industry in Singapore through subcontracting of space manufacturing jobs to small and medium enterprises in the aerospace industry. Moreover, the two companies can establish parallel production lines to increase responsiveness for constellations striving to be first to market.

Besides satellite manufacturing, STEE is active in satellite imaging services. STEE will continue to expand and establish its global network of data delivery and value-added geospatial services. Similarly, ATK brings its strengths in rocket propulsion and launch systems to the ATK-STEE relationship. Both are able to benefit from STEE’s close collaboration with Singapore’s Centre for Remote Imaging and Signal Processing (CRISP) where the TeLEOS-1 ground control station will be located. STEE and CRISP will also collaborate in value-added image exploitation works.

4.3 FORMING CONJUNCTION CLUBS

In the current global financial situation of tight budgets, emerging space nations can collaborate in higher temporal resolution access to constellations brokered by satellite manufacturers or operators. One business model is for customer to procure and contribute a satellite to an evolving constellation becoming a member of that ‘club’. Another model is for the operator to build a constellation and provide shared capacity contracts to anchor customer(s). Variations on these themes, e.g., access to constellation without satellite contribution or partial ownership agreements with monthly access time quota, are similarly possible.

STEE and ATK envision the potential of delivering TeLEOS-1 class mini-satellites and A150/SS-150 class micro-satellites for customers to form a NEqO constellation with shared access and increased temporal resolutions for countries in the equatorial belt. These satellites could accommodate a mix of imaging modalities to account for the range of application interests by emerging space nations. The A150S/SS-150 is especially suited for experimental space program for new space nations, packaged with space capability build-up where required. The synergy also extends to launch services as NEqO satellites could ride on the same launch vehicle instead.

### Table 1. The A150S/SS150 offers market competitive performance with a focus on enhanced payload support.

<table>
<thead>
<tr>
<th>Spacecraft Bus Attributes</th>
<th>Performance Metric</th>
<th>Payload Accommodation</th>
<th>Performance Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mission Class/Design Life (Years)</td>
<td>Class B/C/D; 3 Design; 5 Goal</td>
<td>Nominal Mass (kg)</td>
<td>Up to 75</td>
</tr>
<tr>
<td>Redundancy</td>
<td>Single String to Selective</td>
<td>Nominal Volume (cm)</td>
<td>51 x 46 x 20</td>
</tr>
<tr>
<td>Bus Volume (Nominal, cm)</td>
<td>61 x 71 x 91</td>
<td>Payload Power (W-OA)</td>
<td>75</td>
</tr>
<tr>
<td>Attitude Knowledge (*)</td>
<td>0.008</td>
<td>Peak Power (W)</td>
<td>125</td>
</tr>
<tr>
<td>Attitude Control (*)</td>
<td>0.05</td>
<td>Voltage (V)</td>
<td>28 ±6</td>
</tr>
<tr>
<td>T&amp;C Uplink (Band; kbit/s)</td>
<td>S; 2-32</td>
<td>Aperture Size (Typical, Ø cm)</td>
<td>46</td>
</tr>
<tr>
<td>T&amp;C Downlink (Band; kbit/s)</td>
<td>S; 16-2000</td>
<td>FOV (sr)</td>
<td>2π</td>
</tr>
<tr>
<td>Battery Chemistry; Size (Ah)</td>
<td>Lilon; 22.5</td>
<td>Payload Data Storage (GBytes)</td>
<td>16</td>
</tr>
<tr>
<td>Propulsion (ΔV, m/sec)</td>
<td>150</td>
<td>Data Downlink (Band; Mbps)</td>
<td>X; 300</td>
</tr>
<tr>
<td>Launch Vehicle Compatibility</td>
<td>ESPA, Athena, Dnepr, Falcon 9</td>
<td>The modular, scalable design of the A150 enables multiple payloads to be accommodated with available FOVs on several faces of the bus.</td>
<td>Vega, LauncherOne, and others</td>
</tr>
</tbody>
</table>
of as piggy-back payloads waiting on the schedule of a compatible prime spacecraft.

Importantly, not every application requires sub-meter resolution, especially in commercial sectors. Budget conscious, customers will find the A150S/SS150 microsatellites well positioned for the niche 80/20 rule applications; \( \approx 80\% \) performance of a high end satellite at \( \approx 20\% \) of their price. Furthermore microsatellite delivery time can be shorter, within 18 to 24 months with a choice of electro-optical, weather, scientific and or navigation payloads, e.g., Automatic Identification System.

4.4 Value-Added Data Services

Besides satellite manufacturing and bus integration services, SatComS’ business also includes value-added remote sensing data services, including the ground segment hardware and image processing system. Because of its high data availability and high responsiveness in NEqO, TeLEOS-1 imagery is especially applicable for maritime security and safety, a business application which many service providers are offering in conjunction with Automatic Identification System (AIS) correlation for vessels. SatComS aims to be a commercial service provider in value-added geospatial services using multiple satellite imagery sources together with TeLEOS-1 in the mix for effective surveillance and classification and identification of vessels over global coverage through fusion with AIS, Long Range Identification & Tracking (LRIT) as well as information vessel traffic management & information system (with its on-site maritime radar, pan-tilt-zoom surveillance cameras and radio direction finders) for a near real time recognized maritime situation picture. This solution could be offered as an application package to customers of TeLEOS-1 Direct Receive Station (DRS) on the equatorial belt.

5 Inferences for the Future of the Small Satellite Market

The inferences for the future are clear – The small satellite market is expanding at a healthy rate with many new consumers of this technology, especially for commercial earth observation or national needs of emerging space-faring nations.

Small satellites are an enabling technology within reach of even small nations with very modest technology budgets. Whether to satisfy a critical national information need for remotely sensed data, provide for educational or technological advancement, or simply to fulfill a national pride objective, small satellites (or the data they produce) are poised to be an essential part of an expanding space manufacturing and information market serving all corners of the globe.

Meeting this market demand requires both technical and business agility by platform suppliers and operators. Technological advancements, many of them terrestrial-based, in an insatiable information age are enabling New Space entrepreneurs to envision and pursue new businesses that only a few years ago were deemed unthinkable. The spatial, spectral, and temporal resolution of even the smallest systems is rapidly improving, placing ever higher demands on the processing abilities and communications links necessary to receive and interpret massive amounts of data. The mass vs. performance curves of small satellites continue to trend in seemingly unachievable directions; and then along comes Skybox with a Silicon Valley mindset to further expand the realm of the possible.

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2. “Key Challenges and Opportunities After a 20 Year History of Promoting Small Satellites,” Robert H.
Meurer, The 4S Symposium, Chia Laguna, Sardenia; September 25, 2006.