Introduction:

Recent trends in globalization and satellite miniaturization have lowered the cost of satellite manufacturing while expanding the overall market potential tremendously. Availability of commercial off-the-shelf (COTS) microelectronic components built for the terrestrial technology industry, particularly the radiation hardened microprocessor, innovations in thermal systems, attitude and orbit control, and instrument integration have all yielded great dividends. Additionally, globalization driven needs for regional transparency and connectivity (particularly for people living in areas with low terrestrial access lines in service) has placed satellite in a pivotal position of influence.

Small satellite manufacturing and their corresponding applications have increasingly started to look more like a commercial product or service rather than their erstwhile elite high tech art-form. Based on this, the small satellite manufacturers and operators have innovated new business models, carving a niche for themselves in the market. This paper discusses the competitive dynamics resulting from the advent of small inexpensive satellites, and their ability to disrupt\(^1\) the value-chain with simple innovations.

\(^1\) Disruptive business models use innovations that unexpectedly create a new market by applying a different set of values. This allows

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Figure 1: Sustaining versus Disruptive technologies (MIT)

Cost advantage:

One key benefit of small satellite is that in addition to being less costly to produce and launch the value lost in a mission is a lot less than that for a “big bird” in case of a launch failure. Additionally, they can also be used for missions that are not as easily performed by big complex satellites, particularly in complementing large satellites. Small satellites are particularly attractive to countries that are either first-time users with simple needs, or for the countries who have the firm to serve a market segment that does not desire a best-in class premium product, and is often ignored or viewed by the industry incumbents as unprofitable. The theory is based on Clayton Christensen’s book The Innovator’s Dilemma—When New Technologies Cause Great Firms to Fail, Harvard Business School Press, Boston, MA, 1997.
previously not been able to access this technology. In most cases, these customers are part of a market segment deemed either unprofitable or ignored by the traditional satellite manufacturers.

Satellite’s cost generally varies with the mission objective, satellite features, and component design, testing and reviews needed for overall mission success. Additionally, it has been found that the usual large satellite costing models don’t scale well with the decrease in mass, weight, particularly as the design philosophy of large versus small satellites is fundamentally different. While the prior is focused on high-cost mission requiring a risk-averse mindset, small satellites design philosophy embraces a risk management mindset that reduces levels of oversight, independent reviews, paperwork, testing, program management and systems engineering, and the overall development cycle costs (Bearden, 2000-2001). Key cost drivers for the small satellite development remain the choice of attitude control, propulsion, electric power supply, telemetry, tracking, and command,
data handling, structure, and thermal controls.

Harnessing new markets and applications:
Developing countries have increasingly begun adopting small satellites with specific simple payloads for technology demonstration, internet backhaul, and for fulfilling basic earth observation missions. Research institutions in U.S. and Europe are actively trying to use small satellites for testing the efficacy and usefulness of complex payloads and to understand how a constellation of such very small satellites can be used to perform complex tasks, including replicating or complementing an advanced mission objective. Commercial industry (comprising earth observation, navigation, and telecommunication) likewise – after having initially found very little use for small satellites – has significantly warmed up to the idea of developing new business models around this cost-effective capability.

As a result, while the demand for large satellites has fallen from 140 per year to about a 100 in recent years, the demand for small satellite has stayed at about 30 – despite the soft economy of last two years, and the bottlenecks in finding launches for small satellites (Davies, 2010).

Physical constraints and limitations:
One criticism of the small satellites, however, is that they cannot ultimately ever replace large complex satellites simply because the laws of physics don’t permit that. For example, small satellites have a natural limitation in the size, complexity, and mass of the payload that they can carry and the limitations in attitude control and thrust needed for pointing accuracy. In earth observation for instance, while using “push-broom” technology, a large aperture is needed for the charge-coupled device (CCD) image sensors to obtain a high resolution. However, aperture constraints and spacecraft pointing jitter places a practical limitation even after the camera platform is slewed to avoid image smearing for time-delay integration (TDI) by slowing down the apparent motion of the field of view (Matthews, 2004).

It is then a very relevant question to ask whether the small satellite players – riding on the backs of the “Moore’s Law”, new methods in integration, increasing commercial success in certain niches, but yet bound by natural physical constraints – will be able to challenge the incumbents and disrupt (Christensen, 2002) the satellite industry value-chain in what is considered core profitable business in satellite industry.

Competitive dynamics and strategic intent:
As a first step it is important to understand what pricing, product development, and R&D strategies these new challengers are likely to use in order to expand their influence within the customer base and other stakeholders. Perhaps the real issue here may not be one of just physics as has been understood but also of technological and conceptual advances occurring in other fields and industries which can be combined with business model innovations to equally influence and meet the overall needs of the small customer. In this regard strategic...
intent\textsuperscript{2} – the belief and confidence in the future direction of the industry and the company’s own goals which can constantly invigorate its vision – is perhaps the biggest motivating factor in determining how technology, capital, and business innovation can be combined to alter the satellite industry landscape.

MicroSat Systems Inc. of Colorado is one such company in micro-satellite development business that is approaching its strategy in the market as an innovative disruptor. MicroSat has developed high-performance 200kg satellites with synthetic aperture radar (SAR) under the TechSat 21 program for Air Force. With an affordable price point and a compressed development cycle, MicroSat believes that its bus can be customized as needed for different mission applications and customer requirements, providing better payload mass fraction, power, data processing, and pointing accuracy than comparably priced satellites.

MicroSat has also adapted its satellite to use the Evolved Expendable Launch Vehicle (EELV) Secondary Payload Adapter Ring (ESPA) as the primary structure of the spacecraft – making ESPA ring a part of the spacecraft – allowing it to provide a 800kg satellite for the price of 180kg bus. The company has also been tinkering with thin-film solar arrays technology and avionics architecture to bring down the cost of currently available technologies.

Based on its success, MicroSat was acquired by Sierra Nevada Corporation in 2008, and remains a poster child of how a company’s strategic intent allowed it to transform the satellite industry value-chain. The company has actively studied and inculcated practices from disruptive innovations of other industries (such as digital cameras and personal computers) into the way that MicroSat approaches its own commercial strategy (Mosher, 2007).

Stakeholders:

In general, large incumbents (due to investor scrutiny and numerically driven market analysis), feel the need to focus on their core franchise of high margin and well paying established customers rather than dabbling their feet in developing a fringe, low-quality product which has an undefined (and seemingly very small) market. Small satellite business for large established players would at best be a distraction, and at worst a costly mistake. And as such it is usually difficult to find an internal sponsor within large corporations for the idea of developing a down-market (low capability) and cheap version of the company’s main product offering, particularly one for an undefined (and invisible) taker of that product. And this is exactly the gap that the small satellite manufacturers and operators have been able to exploit. Motivated by the demand of an un-served market, increasingly small companies have emerged

\textsuperscript{2}The concept of strategic intent was presented by Hamel and Prahalad in their paper \textit{Strategic Intent} in 1989, and highlighted it as the energetic and firm-centric view of the future that sustains a company’s vision – giving the employees and stakeholders a sense of direction, discovery and destiny.
Figure 3: Small versus Large Satellite Competitive Positioning (Mosher, 2007)
out of research labs and garages and established a small satellite value chain parallel to that of the large satellite industry. By making customers of governments with simple payload needs and budget-conscious space agencies that are looking for repetitive, less costly solutions, these emerging and nimble players have established a valuable foothold in a market segment that incumbents such as Boeing, Lockheed Martin, Orbital Science Corp., SES Astra, Eutelsat and Spot Image did not focus on or chose to ignore.

State of the economy:

One of the key drivers of space industry in is the interest and wherewithal of a nation (and all its various constituents, including the commercial entities) in accessing and using space for useful applications. The financial crisis of 2008 has adversely impacted the developed space-vested nations (Peeters, 2010), and this will automatically constrain the discretionary spending in satellites.

Small satellites, however, having grown in capabilities are likely to be beneficiaries of this crisis as countries tend to focus on cutting down spending where possible, instead using small satellites as a bridge until the economy has improved. Hence, the small satellites industry should be a net beneficiary of the adverse economic conditions.

However, a dearth of debt and equity financing available in the market is bound to hurt the small satellite manufacturers and operators who are more entrepreneurial in nature and would need bank and private equity (or institutional) support in order to weather cash flow cyclicality. In this, the small satellite manufacturers with elements of public-private partnership and with larger corporate sponsors would have a better chance of surviving and thriving.

Case study 1: Surrey Satellite Technologies Ltd. (SSTL)

Key characteristic of the small satellite manufacturers and operators strategy has been to find a market for an inferior product (which the small satellites were considered to be until recently) and to tap into a whole new class of customers that previously didn’t exist. Governments of developing countries weren’t active existing developers of satellite, although in some instances satellite based products and services were used for commercial and governmental purposes.

Among the new companies that have steadily emerged from within the university or research segments are Surrey Satellite (SSTL) of England (just acquired by EADS Astrium) and MicroSat Systems Inc. of U.S. (now owned by Sierra Nevada). These companies are pursuing opportunities in the small satellite manufacturing market. And while both have been acquired by large satellite manufacturers, it is fascinating to note in particular SSTL’s evolution over the last 20 years and the path forward.

While traditionally SSTL has competed for earth observation and navigation related markets for European and American science and navigation satellites, their mainstay has been the developing country government contracts (such as for governments of
Nigeria and Vietnam). In November 2009, SSTL (a few months after it was acquired by the European defense and Aerospace company EADS Astrium) announced a strategic migration towards the high-end of the market by winning an order from the Sri Lankan government to build a 3KW end-of-life geostationary telecommunication satellite (Selding, 2009). This win essentially represents an extension of SSTL’s product suite from SSTL’s core platform – that has generally weighed between 100-300kg range for earth observation and 600kg for navigation – with an ability to carry optical or remote sensing payload in tens- to hundreds- of Kilograms. SSTL’s telecom satellite (whose final configuration is not yet determined) could weigh in the +1000kg range (up to 3,000 kg launch mass) and would additionally give Sri Lanka access to images from SSTL’s DMC-2 (Disaster Management Constellation -2), including an earth station on ground in the country, and advice from SSTL on the creation of a Sri Lankan space agency. And while it is a curious service for a satellite manufacturer to advise a government of a developing South Asian country on its space policy, yet again this may be a trend that the larger satellite manufacturers may perhaps be overlooking.

The Sri Lankan deal is reported to be in the $150 million range (SLNF, 2009), and through this SSTL has effectively (and clearly) stepped into a market segment at the bottom-end of the communications satellite manufacturing, that had traditionally belonged to the likes of U.S. based Orbital Science Corporation (OSC) and the Italian satellite manufacturer Thales Alenia (Taverna, 2009). SSTL’s strategy – cost leadership, reliance on COTS components, and capitalizing on a market opportunity borne of trends in globalization – has clearly paid off.

What is more interesting is that EADS Astrium, having reportedly acquired 85% of SSTL in the vicinity of £40-50 million in April 2008 (BBC News, 2008) (approx. $80-100 million, based on the April 7th 2008 exchange rate of 1.9855/GBP), has decided to keep SSTL an autonomous running business as opposed to fully integrating it within its core organizational structure – a clear sign that it is aware of the potential of SSTL’s stand-alone business model and growth potential. It is however a matter of significant interest in the satellite industry to assess how the SSTL acquisition will affect EADS Astrium’s own legacy small satellite development initiative, and more importantly the broader implications of SSTL’s manufacturing and integration methodology on its mid- and large-size satellite business, particularly as SSTL migrates towards higher end of the satellite capabilities spectrum, as evidenced by its Sri Lankan deal.

**Case study 2: O3b**

Emergence of small satellite has also had a profound impact on the price gap between terrestrial fiber and satellite-based capacity in niche markets, particularly in countries with low (and hence expensive) fiber connectivity. Where previously fiber cable could comfortably compete with geo-based large telecom satellite transponder capacity (and not only in characteristic signal latency
since signal to and back from geostationary orbit takes 500-600ms where fiber-based transmission has virtually none), that advantage has been narrowed or overturned by small MEO-based satellites. In this, small satellites have uncannily become a go-between the expensive and sophisticated geo-based satellites and the countries that don’t have the capability or the capital to afford them. Additionally, it is likely that they will also begin to create a strategic shift in the market for transponder capacity in the geostationary orbit – managed by the International Telecommunication Union (ITU).

In November 2009, SES, the premier global communication satellite operator invested $75 million in Channel-island based O3b (“Other 3 billion” – a commercial play on the growing developing market without access to good telecommunication products) and promised it other in-kind services for a 30% stake in the company (Selding, SES Takes a stake in O3b, 2009). O3b, which was created in 2008, had a goal of launching a constellation of small telecommunications satellites (700kg each) to 8,000km in the Mid Earth Orbit (MEO) to service the developing countries, particularly Africa and Middle East. Other partners in the venture include U.S. based Google and Liberty Media, Allen & Co., and HSBC Principal Investments; Thales Alenia has been chosen for construction of the first eight (of the total design constellation of sixteen) satellites.

With its business model of providing low-latency fiber-quality (up to 10Gb) IP-trunk and mobile backhaul services in a region that has a serious dearth of bandwidth, O3b has already signed firm five-year customer contracts with local wireless and internet providers in Africa and Mideast for +$600 million. With each MEO satellite costing approx. $22 million, the O3b’s entire constellation will cost as much as a full GEO satellite – however not being in GEO, the latency effect will be much lower and the power requirements on-board each satellite (for the 12 steerable antennas) are greatly reduced. From a cost standpoint, O3b is expected to provide a per-Mbit cost of 3G backhaul that is much better than that for a GEO satellite (O3b Networks, 2009).

SES however is approaching the O3b acquisition very differently from EADS Astrium’s acquisition of SSTL. While O3b has invested $75 million for a 30% stake, it has also retained full sales exclusivity for the transponder capacity brought online by the O3b constellation. Additionally, SES’ vision is to ultimately fully own O3b integrating within its core business platform – in essence, again, clearly signaling the true potential of the MEO-based telecom constellation play. SES also announced that its CFO will leave SES to lead O3b in March 2010.

In addition to being a technological diversification for SES (which has 41 operational satellites in GEO), it also allows the company to interface directly with customers in Middle East, Africa, and South Asia who were wholly dependent either on cable fiber or GEO-based products, offering them wireless backhaul at $800/Mbit per month as opposed to $1,000/Mbit being charged by cable providers. Additionally, the 840 GEO transponder-equivalent
capacity (Ka-band, steerable spot beams) brought online by O3b will boost SES’ current 1100 transponder capacity by almost 80%. The satellites are designed for a lifetime of 10 years and each has a 4.8GHz spectrum – almost 77GHz for the total constellation. It however remains to be seen if the MEO-based O3b constellation will actually enable SES to realize some capital efficiency in its GEO-based capital expenditure plan beyond what is expected to be scaled down, since SES investment in GEO-based transponder capacity peaks in the 2008-11 period (Euro700-800 million each year), and then decreases to two-thirds in 2012 (approx Euro500 million), tapering off to Euro365 million in 2013 (SES, 2009).

Key technical challenges to the O3b constellation will come from the high levels of radiation in MEO and the ground station architecture and antenna network needed to ensure that communication continues during satellite pass and the hand-offs. Assuming the O3b business model is able to launch and operate successfully, it is expected to bring significant value to SES, as already evidenced by a 25% rise in stock price since the deal was announced in November 2009.

Case study 3: RapidEye

Sharp decrease in the cost of large satellites by an order of magnitude combined with a rapid build-to-launch cycle has also allowed for a transformation in remote sensing and earth observation business. The value of remote sensing increases with the resolution at which a satellite can observe, the number of spectra in which this observation can be carried out (such as multispectral and hyperspectral images), the revisit time of the satellite, and its lifetime and ability to carry out targeted imaging of regions of interest. While small satellites cannot carry as many instruments as the large ones, constellations of satellites carrying similar payload in a coordinated orbit can be very useful to increase the revisit time – effectively reducing the impact of clouds. Sharply falling cost of manufacturing small satellites has made the earth observation data affordable by most commercial and non-governmental agencies, allowing them to become a regular user of this information for strategic planning.

The German company, RapidEye AG, a public-private partnership (PPP), is a constellation of five mini satellites built by SSTL (contracted via MDA) to provide high-resolution multispectral imagery along with Geographic Information System service on a commercial basis (Yong Xue, Guang, Zhang, & Guo, 2008). The sensor images five optical bands in the 400-850nm range and provides 6.5m pixel size at Nadir, and can be used for crop monitoring and mapping, yield prediction, field maps to help insurers assess insurance claims, cartography, and disaster assessment and visualization including Digital Elevation Model (DEM) generation. The constellation is designed to provide a daily revisit (using body pointing techniques), and will be placed at 630km in sun-synchronous orbit to ensure consistent imaging.

Canadian space company, MDA, was contracted by RapidEye to provide the turnkey delivery of the five satellites in-orbit, including launch, insurance, and ground station for C$170 million (MDA,
2009) (approx. US$140 million at the exchange rate of US$0.82/C$ on Dec 31, 2008). SSTL, the manufacturer of the satellite, received £19.5 million (BNSC, 2006) for the satellites – approx. $28 million (at the Dec 31, 2008 exchange rate of $1.4619/£).

RapidEye, however, is a unique business case within the remote sensing and earth observation business. The industry, dominated by the American LandSat until 1980’s, was heavily regulated (Shaida Johnston, 2003). However, after perestroika, a systematic deregulation initiative was formed to start sharing the images and data relevant to governmental and commercial organizations. French jumped in to the business with SPOT, which was able to provide a better resolution than LandSat and at a lower price. This began the cycle of innovation and competition within the industry that continues to this day, with an exception that the innovators of yesterday, for example SPOT, are now ready for being challenged by the likes of RapidEye.

Like SSTL and O3b, RapidEye’s advantage lies in marrying the COTS platform pioneered by SSTL to a market for geospatial intelligence that can only now be satisfied at a cost-point acceptable by the commercial users. RapidEye, like its larger legacy competitors (such as LandSat and SPOT) is focused on medium-resolution (6.5m at nadir-pointing) images that can also be orthorectified, however its competitive advantage lies in its ability to provide this with a higher-frequency (daily revisits) allowing the users of this information to weave this intelligence within its base-load work-flow and everyday decision-making process.

Essentially, RapidEye’s offering takes out earth observation from within the military and governmental markets, and creates a whole new class of customers who can now make intelligent decisions about their supply chain through a continuous use and mining of earth observation images. Their target market is not only the government, as has traditionally been the case with LandSat and SPOT, but agri-producers, insurance companies, commodity brokers, non-governmental organizations, and commercial/civil organizations in need of cartography solutions (Krischke, 2000).

RapidEye’s customer-centric vision is a departure from the history of earth observation industry, where users in need of data often had to often make-do with low quality information that was available at irregular intervals at best – and often the image providers did not really understand the true needs of the end-user. RapidEye, in contrast, is building a domain-specific model for each industry vertical that it wishes to serve. The vision for RapidEye’s continuous offering was conceived by a group of private investors with a vision to “commercialize satellite based earth observation”. These corporate entrepreneurs were then able to harness funding and resources from European Union and other institutions to execute on this vision in the form of a public-private partnership (PPP).
RapidEye’s offering is another prime example of how lowering of barriers to entry through a low-capital solution can bring flexibility and business model innovation even though it does not use the most advanced technology.

A moderate solution (that is mid-resolution) combined with frequent revisits to create a whole new class of untapped customer demand – otherwise left unsatisfied given the solutions available in the market. Importantly, the solution being created for this market is independent of the needs of the more sophisticated customers who require high-resolution imagery. While it would be speculative at this point to forecast the synergies that RapidEye could bring to SPOT or another large earth observation player, the future of an entity that can grab on to the market share and hold on to it seems ripe with possibilities.

Case study 4: Space exploration and science demonstration

Last ten years have seen a surge in the use of small satellites for space exploration and science demonstrations. The primary target, like in the space commercial applications market, are the countries interested in budgeted approach to space exploration and university and governmental labs looking for quick results for sponsored research. A prominent example of this is NASA’s 4kg NanoSail-D – designed to prove the efficacy of using solar-sail for propulsion – which however didn’t succeed due to the launch failure of SpaceX Falcon1 rocket over Pacific. The cost of two NanoSail-D spacecrafts (at $2.3 million each, with a six month development cycle) however showed the value of designing small, inexpensive spacecrafts, particularly where the launch technology is not yet stable.

Another such program is the Naval Research Laboratory’s TacSats program, with the goal of providing ground forces with real-time satellite imagery and reliable communications. This program is also geared towards standardizing the size, shape, and equipment of small satellites. It is hoped that through standardization, companies would be able to manufacture such systems in bulk, further reducing cost and time to build small satellites for science and military missions. TacSats aims to develop and launch satellite in a matter of days after being commissioned.

Various other initiatives are underway in using small satellites for exploration, including the Canadian Space Agency’s $12 million surveillance satellite to study asteroids, comets, and meteoroids, orbiting in near-Earth vicinity. The satellite in this case has a 6-inch telescope and the entire satellite is only 70kg (National Geographic, 2008).

NASA has recently also commissioned Fast Affordable Science and Technology Satellite (FASTSAT) for $4 million, which Dynetics and Von Braun Center for Science and Innovation (VSCI) is expected to complete in 10-1/2 months. FASTSAT is 39.5 inches in length, hexagonally shaped, and weighs 90kg – with an ability to accommodate a 50 kg of payload.
Impact on the launcher industry:

Creation of a viable small satellite commercial market has also created interesting dynamics for the commercial launcher industry. First, it has allowed innovative new launchers (such as SpaceX) to cater to a market that is non-traditional in nature, but nonetheless profitable, and can help new entrants in the launch business amortize research and development costs.

Second, it has created a viable secondary- and shared-payload market that allows for multiple payloads (including clusters of small satellites) to be delivered using established traditional rockets. This for example was how the RapidEye’s constellation of five satellites (150kg each) were launched on DNEPR-1 from Baikonour in Kazakhstan.

In both cases, the launch industry is a significant beneficiary of customers wanting to launch inexpensive, low volume, low mass payloads – particularly since such customers have a relatively higher threshold for risk (purely on the basis of the payload cost) than the owners/operators of large commercial telecom and earth observation satellites that may run into hundreds of millions of dollars. For latter, the sheer value-at-risk perpetuates a conservative mindset in all aspects of decision making (Sweet, 2008).

ESA’s Vega solid-fueled rocket is designed to launch satellites in the 300-2000 kg range, while ISRO’s PSLV-CA (“Core Alone”) model – without its six strap-on boosters in the conventional model – is also being used for demonstrating the capability to launch multiple spacecrafts from a single rocket, and is capable of launching up to 1,200 kg in 650km sun-synchronous orbit (SatMagazine, 2010).

SSTL is currently promoting the concept that encourages the use of Virgin Glactic’s White knight, designed for suborbital space tourism, to be used as a launcher. This could bring down the cost of a launch from $5 million to $1 million (Hambling, 2009).

Military uses and future commercialization of sensitive technologies:

Current military research in small satellite area is focused on assessing the viability and potential designs of the next generation constellations of near identical (or self coordinating multi-functional) satellites that can enhance existing space based capabilities (Kenneth G. Carpenter, 2010). It is felt that small satellites, despite having made great strides over the last few decades, have not truly been deployed within the mainline military satellite systems – nor have individual small satellites proved particularly useful for military mission.

Key areas of focus in this regard are networking, computing, high bandwidth communications, integration, micro-miniaturization of electronics and satellite components, high-power, light-weight energy storage, efficient electric propulsion, advanced radiation resistant solar cells, and on-orbit servicing via robotics.

In particular, military is interested in dramatically cheaper solutions and/or new capabilities that can be deployed quickly compared to space systems available today.
Swarms of nano- or small-satellites flying in formation enabling distributed apertures with advanced propulsion technologies and satellites that physically connect or self-assemble on-orbit (without the need for extensive command from the ground station) to deliver arbitrarily large apertures are of significant interest.

Applications in high bandwidth communications, high resolution radar, and selectable optical resolution strategic imagery allow the military to extend its vision of an Operationally Responsive Space (ORS). Through networking in particular, satellite data can be beamed back via sister-satellites instantly as opposed to waiting for the main payload carrying satellite to appear over the horizon in view of a ground station. NASA and DOD are also looking at sparse aperture and interferometric missions using small satellites that can increase angular resolution by two orders of magnitude (Hambling, 2009).

While the technologies within this area remain restricted under the International Traffic in Arms Regulation (ITAR), which controls export and import of defense-related materials, the solicitation by DARPA clearly asks for commercial applications of the technologies that the bidder is interested in providing, and the likely transition paths.

Successful commercialization of advanced technologies, among other things, depends on where these were originally created in a university, at a research lab or in the industry. Ones born out of industry, having been strengthened and integrated within a new platform for military use – must be de-rated for non-aggressive civilian use. Large companies in general are better suited to create a formal process needed to assure the integrity of this technology transfer. This may yet be another rationale that favors small satellite manufacturers and operators as part of a larger robust corporation.

Other key factors that influence this diffusion process are the versatility of the technology in its application to different products and industries, and its integration within potentially similar industries and product concepts.

Finally, space technology commercialization is also heavily influenced by the cost-point, reliability, and performance of the technology, and the level of commercial acceptance the technology (or technology-embedded product) is likely to have at a certain cost-point (Giorgio Petroni, 2009).

In December 2009, DARPA awarded a $74.6 million contract to the Orbital Sciences Corporation for the phase 2 design work on “System F6” (Future, Fast, Flexible, Fractionated, Free-Flying Spacecraft). A fractionated system splits subsystems into different spacecrafts to be developed and deployed a lot more flexibly while allowing for selective replacement of damaged or obsolete elements. IBM and NASA’s Jet Propulsion Laboratory are Orbital’s partners, and the unique thing about “System F6” is that it is open-source, and will allow third parties with access to the source code, operating system and standards for designing modules compatible with the existing spacecraft network – laying foundations for a space Internet (Defense Industry Daily, 2009).
Competitive imperative:

Based on the four case studies and a variety of vignettes presented in the paper, it is clear that the market seems to be fast favoring intelligent content providers and business model innovators using small, low-cost, easily deployable satellites. This trend is expected to only accelerate given the financial woes stemming from 2008 market meltdown and the ability of small satellites to be used as a “bridge” until economy has substantially improved.

It further appears that enough operational and financial history has been built with regards to space industry innovators successfully engaging in market development activities, where large strategic players are comfortable in acquiring these pioneers – presumably in recognition of the market opportunity and desire to buy-out potential future competition to themselves.

Third, the bar for small satellite manufacturers and operators is being raised as new technologies for miniaturization and payload integration emerge. The key imperative for small satellite players is to find and exploit a market niche, and gain dominance in that niche before expanding into areas being served by the larger incumbents – in many cases challenging the viability and efficacy of other divisions within the same company.

Fourth, the most successful small satellite manufacturers (SSTL) and the operators (RapidEye and O3B) have found it more attractive, even when profitable – as SSTL was – to merge within a larger corporate structure than to go solo forever. This may be because of the efficiency of corporate fundraising and governance, plus instant access to credibility that an entity achieves by being part of a larger corporate entity – both from a market and regulatory perspective. Also, going solo, particularly in the current economic and jittery market circumstances, could be considered more risky when compared to the alternative of a negotiated acquisition agreement.

Fifth, small satellites have the potential to replenish or augment capacity – particularly in the form of constellations for both navigation and earth observation – at a fraction of the cost of what large satellites can deliver. Similarly, for science missions, such as to study the impact of micro-gravity, small satellites can be used at a cost-point far below what it would cost to study the same on the International Space Station.

Sixth, small satellite industry will continue to need to harness talent from colleges and universities (as SSTL perfected) in order to train a workforce that is both able to perform satellite design and development and integrate breakthroughs in materials and component performance. Strong relationships within a research laboratory is key in ensuring that the company continues to look at the satellite development process with a fresh eye. SSTL is expected to continue its liaison with Surrey to ensure the continuity in its ability to source talent pool, ideas, and technologies.

Finally, based on their own success, small satellite industry will encourage development of an ecosystem of component and launch providers who will uniquely be suited to service the small satellite market.
This base of component and technology providers will further entrench small satellite business model as a parallel value chain to the current established satellite operators and providers arises.

Conclusion:

The small satellite industry is fast becoming an emergent ecosystem of component providers, technology firms, integrators, and launch providers – all working together in a generally entrepreneurial competitive marketplace. Most of these companies were borne out of the need to fill a market-need in a segment that was either overlooked or ignored by an incumbent. Increasingly now, after having gained a foothold in a market niche, these small satellite providers are beginning to tinker with their business models to win business that would traditionally have been considered the domain of large, well-capitalized players.

The emerging competitive dynamics has led to most of the successful small satellite manufacturers to get acquired by large industry veterans. While too early to tell, this could be mutually advantageous as small companies lack the capital, governance, and the branding to fully exploit the market opportunity.

At the same time, while the large incumbents can incubate an in-house small satellite initiative, the philosophical and cultural roots of embracing the risk management in design and solving for the mass, power, performance problem in a constrained budget may be difficult – or impossible for large firms to emulate. In that, acquiring a well-run small satellite manufacturer or operator may be the best path forward.

Innovation in the small satellite industry is likely to transform the ability of small spacecrafts to perform tasks that today are the domain of complex, expensive satellites. Constellation-flying, on-orbit assembly, and high-bandwidth telecommunication capabilities all hold promising opportunities to further increase the capacity of small satellites – and bring advanced functionalities to a commercial client.

For small satellite manufacturers and operators to be successful, they must continue to innovate and find market niches that allow them to exploit their cost and time-to-market advantage – rather than immediately stepping into the fray with a large, well-capitalized competitor. Approaching the market opportunity with an economic mindset is likely to allow them to attract additional capital to grow and invest in the business. This will additionally have a spillover effect of allowing component providers and micro-launch service industry to attract capital.

Overall, a market-driven approach is likely to enable small satellite companies to build a model that can ultimately either challenge the incumbents on their own turf – causing a market disruption in the cost-performance matrix – or alternatively become a value-accretive part of the larger, well-capitalized competitor through acquisition.

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