



Small Satellites – Evolving Innovation for the Entire Market

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Topics

- “Traditional” and Small Satellite Domains
- SmallSats as a Laboratory
- Migration Between Domains
- Future Trends & Symbiosis
- Conclusion

“Traditional” and Small Satellite Domains

- The satellite industry can be divided into two domains – each with a set of manufacturers, customers, component vendors, support services
- Each domain has unique role and capabilities they bring to industry

Traditional Satellite Domain

- Larger, more complex vehicles and systems
- System costs are much greater and can be secondary driver for requirements and design
- Risk averse customers and stakeholders
- Decades of heritage in technology, operations, and processes
- Change is slow paced and evolutionary



Small Satellite (SmallSat) Domain

- Smaller and simpler vehicles and systems
- Far more cost conscious and price is always a primary driver in requirements and design
- Much higher risk tolerance
- Willing to invent or import new technology, operations, and processes wholesale
- Change is rapid and can be non-linear

“Traditional” and Small Satellite Domains

- SmallSat domain is a “Disruptive Innovation” for the satellite industry
 - The SmallSat domain will not replace the Traditional Satellite Domain
 - The mission requirements & complexity rule that out
- SmallSats started with Sputnik⁽²⁾, but now reaching a critical mass
- Migration between the two domains is accelerating
- Kratos can offer insights on the symbiosis between the domains

Disruptive Innovation

- Products that redefine “trajectory”
- Not as good as currently available
- Simpler, more convenient, less expensive
- Appeal to new or less demanding customers

Ref: Christensen, see Note 1

Kratos and the Two Domains

- Long history of working with all the major companies and organizations within the Traditional Domain
- Strong background in SmallSat domain with numerous customers
- SmallSat focused, cross discipline team inside Kratos for new products & customers
- Has developed line of SmallSat oriented products for command and control, modems, front end processors

SmallSats as a Laboratory

- As a Disruptive Innovation, the SmallSat domain is a “laboratory”
- One analogy is the Bullets and Cannonball case from *Good to Great* ⁽³⁾
 - Bullets are smaller attempts to zero in on a target – Lower risk; verify aim
 - Cannonballs are large attempts – Use all resources to hit and “sink” the target
 - The mantra they advise → Bullets **then** Cannonballs
- A Cannonball for a SmallSat company is a Bullet on the SmallSat Domain or Satellite Industry scale

Do the SmallSat Domain Efforts Qualify as “Bullets” for the Satellite Industry?

- **A Bullet is Low Cost:** Compared to the cost of a typical traditional satellite, the cost is far lower for a SmallSat domain innovation
- **A Bullet is Low Risk:** There are little to no consequences to the Traditional Satellite Domain from failures in the SmallSat domain
- **A Bullet is Low Distraction:** SmallSat efforts have not stopped missions or technology for the Traditional Satellite domain from continuing

Ref: Collins and Hansen, see Note 3

SmallSats as a Laboratory

- Many examples of technical innovation from the SmallSat domain, but four trends are noteworthy
 - Use of COTS products & standards from outside the space industry
 - Not just at piece part level, but component / element level
 - PhoneSat,⁽⁴⁾ ArduSat,⁽⁵⁾ Cameras, Batteries, Processors,
 - Software – More open source, more commercial tools, more APIs
 - CAN Bus (for road vehicles) used by SSTL⁽⁶⁾ - Others now using
 - “Data center” ops is the model desired for C2 operations
 - Highly automated, VMs, Cloud Infrastructure, HTML5 User Interface
 - Modularity – “designing in” modularity and planning to use modular parts and standards
 - CubeSat and P-POD standards
 - Standards helped grow vendor “ecosystem”

SmallSats as a Laboratory

- The “laboratory” is also producing business trends
 - Focus more on consumer vs space technology efforts
 - OneWeb and SpaceX broadband constellations⁽⁷⁾
 - Planet Labs’ data “transparency” objective⁽⁸⁾
 - On-line shops for credit card users to purchase spacecraft kits⁽⁹⁾
 - New efforts not predicated on winning corporate IRAD
 - Kickstarter used to finance projects – ArduSat⁽¹⁰⁾
 - Company to company funding → Millennium Space Systems' Bootstrap program as an investor and developer⁽¹¹⁾
 - Venture Capital funding for new companies⁽¹²⁾

(Partial Portfolio as an example)



Major investors are helping push new startups and fuel innovation



Specialized services and products are now available for VC, investors, and analysts



Small selection of other companies funded or about to be funded

SmallSats as a Laboratory

- As a corollary to the Bullets and Cannonballs suggested by Collins and Hansen in *Good to Great*.
 - ***In a given time, more Bullets can be “fired” than Cannonballs***
 - *“How quick can they be reloaded?”*
- A “laboratory” or petri dish environment has rapid generations of prototyping and evolution
- On a company level, the Planet Labs approach to rapid spacecraft evolution embodies this
 - “Release Early, Release Often” – Like commercial software⁽¹³⁾
- From a domain perspective, the use of 3D printing highlights this pace
 - Initially some Cubesats (KySat-2⁽¹⁴⁾, PrintSat⁽¹⁵⁾, RAMPART⁽¹⁶⁾)
 - Now a 27U bus from Millennium Space Systems (ALTAIR)⁽¹⁷⁾

Migration Between Domains

- Technical Trends

- 3D Printing (Additive Manufacturing)

- 3D printing of aerospace parts has increased in recent years
 - 3D printing in SmallSat Domain has reduced risk
 - Modernization of Lockheed Martin A2100 features significant use of 3D Printing for cost and efficiency reasons⁽¹⁸⁾

- Modularity

- Reuse of flight proven systems is not necessarily modular, each reuse may require significant rework to fit new application
 - Designing in modularity from the start increases initial costs and long term flexibility; Decreasing costs of later systems
 - Boeing 502 Phoenix Satellite product line highlights flexibility due to modularity⁽¹⁹⁾

Migration Between Domains

- Technical Trend Migration (con't.)
 - Commercial Data Center like CONOPS for Command and Control (C2) is just starting to be considered in Traditional satellite domain
 - Data Center CONOPS: Combined use of Virtual Machines, Cloud Infrastructure, Web Based User Interface, and Lights Out automation
 - Sunk costs for existing systems may be preventing broader adoption
 - Already a high level of automation (albeit not lights out), so additional cost for last portion may not be worth ROI
 - Potential adopters will closely monitor SmallSat efforts for a Data Center CONOPS, especially for large fleets, for risk reduction

Migration Between Domains

- A technical **and** business trend is the development of SmallSat expertise in house within Traditional Satellite domain companies
 - Change to structure and approach highlights how seriously the Traditional domain considers the changes from SmallSats
 - Seen as an opportunity to build expertise and then crossflow new technology and processes to mainline programs
 - Seen as a business need to participate in SmallSat domain
 - Some centers are being built through acquisition, as with EADS Airbus and their purchase of SSTL in 2009⁽²⁰⁾
 - Others are using “skunkworks” type approaches, such as Boeing did when it developed the Phantom Phoenix line of SmallSats⁽²¹⁾
 - Another option is partnering outside the company, such as Northrop did with Sierra Nevada for a line of SmallSats⁽²²⁾

Migration Between Domains

- Business deal structure is another trend where SmallSats have influenced the Traditional Satellite domain
- The Traditional satellite domain has seen more Joint Ventures (JV), where the satellite manufacturer shares initial risk and long term profit
 - Different than the usual “cash and carry” contract
 - ViViSat, which is selling on orbit stationkeeping services not spacecraft, is a JV between US Space LLC and Orbital-ATK⁽²³⁾
 - The companies competing to form a JV with OneWeb for their satellite production highlights the impact
 - The potential partners – Lockheed Martin, Space Systems/Loral, OHB, Airbus, Thales Alenia – are all in the traditional space domain⁽²⁴⁾
- Other new partnership approaches are being used
 - As part of the contract to build the next 13 Skybox satellites, Space Systems/Loral gained licensed use of the Skybox design⁽²⁵⁾

Future Trends

- A larger focus on the data and less on the space segment
 - New systems will be seen – even by the spacecraft developers – as “data systems that use space” versus “space systems that generate data”
- Emphasis on use of COTS and standards along with modular design approaches
 - Standards and COTS will propagate directly from the SmallSat domain as they are proven in orbit
 - Increase will make modular design easier and more prevalent
- Commodity computing with cloud based systems and data center like operations
 - Efforts underway now (Small and Traditional) will drive this

Future Trends

- Blurred line between “large” SmallSats and small Traditional satellites
 - Technology and processes developed newly built up in house expertise will shape next generations of satellites
- Partnerships between Traditional domain companies and SmallSat companies will turn into acquisitions
 - As the SmallSat company’s IP becomes more critical for market viability and profitability, they will become attractive to purchase
- Personnel crossflow between the domains will become a torrent, with significant benefits to each domain
 - Rapid size increase of SmallSat domain increases talent pool size
 - More opportunities for students to be hands-on prior to starting career also increases level of skills for the talent pool
 - SmallSat growth offers opportunities for Traditional domain talent

Conclusion

- The SmallSat domain is a “Disruptive Innovation” for the satellite industry
 - Laboratory for new ideas and ideas and processes that serve as “bullets” for overall industry progression
- The “Traditional” satellite domain will not be replaced by the SmallSat domain, but it will be influenced by it
 - The migration of ideas – technical and business – has begun
- The trends seen to date are indicators of future change for the Traditional satellite domain
 - Not a crystal ball, but valuable to examine
- The symbiosis between the two domains is still in an early stage, but the benefits will be good for both

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