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SATELLITE MINIATURIZATION

ARE NEW ENTRANTS ABOUT TO THREATEN EXISTING SPACE INDUSTRY?

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Abstract/Summary

- *Over the past few years, a large number of companies have entered the space sector. Their activities are based on the use of relatively inexpensive small satellites, which enable these companies to provide services equivalent to those of companies that traditionally serve government agencies or public sector industries.*
- *These new entrants have started to conquer significant market shares to the detriment of existing operators, but their definitive position on the space industry market depends largely on the innovative character of their technologies.*
- *It does not seem that small satellites can be considered a disruptive innovation. At least not in terms of the characteristics they currently offer.*
- *On the other hand, the generalized use of small satellites could potentially lead to two equally plausible scenarios: the progressive obsolescence of existing operators' economic models could in time lead to their disappearance and trigger a speculative bubble that could cause more damage than the one observed during the course of the 1990s.*

1. Introduction. Over the past three decades, several new companies have entered the space industry market. Space industry observers generally note the success of the American launch operator *SpaceX*, which threatens *Arianespace*'s near global monopoly, pushing the European operator - and the States that support it - to precipitate finalizing the new Ariane6 launcher. But since the start of the new century, several important operators have been created in the wake of *SpaceX*.

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The main operators are as follows:

- on the American side there are operators *Skybox Imaging*, created in 2009, in which *Google* has just invested; *Planet Labs*, created in 2010 and which was initially known as *Cosmogia Inc.*; *NovaWurks*, highly active since 2012; *OmniEarth* and *UrtheCast,* both created in 2014; *GeoOptics*, *Garvey Spacecraft Corp.* and *Silicon Labs*, created a few years earlier;

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[1] SIRIUS is an academic chair between the University Toulouse1-Capitole and the Toulouse Business School. It is sponsored by CNES, Airbus Defence and Space and Thalès Alenia Space

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- on the European side are operators *NovaNano*; *Clyde Space; Gomspace*; *Deimos Space*; *Dauria Aerospace*; *Virgin Galactic* and *Swiss Space System*, better known under the acronym "S3".

These new operators indicate that the space industry market remains heavily dominated by:

- state monopolies, in terms of their national and international agencies, as well as national and international industries, both from the civil and military sectors;
- publicly financed long-term projects, i.e., highly dependent on political decisions;
- engineers' conservative approach, who remain highly aware of the risk of failure (launch, entry into orbit, breakdowns, de-orbiting) and therefore tend to avoid innovation;
- the generalized extreme confidentiality in terms of program deployment, referring to "defense secret" when it is a question of military programs;
- heavy and highly sophisticated satellites, capable of exceptional performance for a relatively long lifecycle (15 years). However, all~~,~~ or nearly all~~,~~ of the entrant operators listed above are characterized by the use of very light and small satellites with a limited performance.

Small Satellite Class	Mass Range
Mini-satellite	100-500 kg
Microsatellite	10-100 kg
Nanosatellite	1-10 kg
Picosatellite	0.01-1 kg
Femtosatellite	0.001-0.01 kg

Figure 1. Small Satellite Class

These are small and sometimes minuscule satellites that they design, launch into orbit, and use in order to provide their services (Figure 1). However, in spite of their small size, many of these satellites already provide relatively sophisticated services, which point to increasingly significant

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capacities available in the future, thanks to the progress that can be anticipated in the field. They are already sufficient for a number of civil and military uses.

This trend, which began in the early 1990s, seems destined to continue: for *SpaceWorks*, the number of currently operational small satellites grew by 37.2% from 2009 to 2013, and should grow by 23.8% over the course of the next six years (2014 to 2020).

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This expected growth can be predominantly explained by the development of a veritable market of space applications dominated by the "big data" market that is itself a significant factor contributing to the decrease in price for services rendered and therefore overall costs also.

Are these new entrants to the space industry, which is currently experiencing significant transformation, likely to call into question the current hierarchy of existing operators? Can satellite miniaturization be considered a disruptive innovation that is capable of provoking ~~this calling into question~~such possibility? And when it isn't a question of disruptive innovation, can satellite miniaturization have other consequences, such as the obsolescence of current technologies and their economic models, which could push aside existing operators and provoke a speculative phenomenon that could prove as devastating for the sector as the one observed in the 1990s?

This paper responds to these questions, using a methodology founded on a qualitative analysis conducted from April until September 2014.

2. Review of specialized literature and updating a conceptual model. The study required a systematic review of the specialized literature (see the bibliography below), with a view of building a conceptual model, making it possible to answer the questions above.

According to the traditional approach, which is dominated by the *Porter M~~m~~odel* (Figure 2), the level of competition in a given market is the result of four convergent forces:

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- the threat exercised by new entrants;
- the development of substitute products;
- suppliers' negotiation powers;
- customers' negotiation powers.

Figure 2. Porter's Five Forces

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The more an operator dominates its product market (goods or services), and the less prevalent the threat of new entrants or product substitutes, the more the operator exercises market power in relation to its suppliers and clients.

How is it that within a given market that is dominated by companies whose CEOs are intelligent and competent men and women who are highly experienced in management subtleties, who invest in research in order to improve the quality of their products and remain a step ahead of their customers' needs, who supervise their competitors and permanently adapt their strategies to their initiatives, a new entrant operator, often with limited means, can introduce him/herself, displace the current operators, and sometimes even eliminate them from the market in question?

Clayton Christensen[2] has shown that it is a question of what he suggests naming "*the innovator's dilemma*". Existing companies function according to traditional management principles: they improve their product, respond to consumer needs, and monitor their competitors. Their objective is always to conquer more of the market share and therefore to grow *bigger and better*.

In doing so, they neglect what is happening beneath them: current consumers are tiring of their products, or potential consumers are discouraged from being able to afford them. They are therefore highly vulnerable to an entrant who will have perfected a disruptive innovation, who will carry the entire market and progressively marginalize them.

An innovation is considered disruptive when a new technology disrupts the status quo: it makes it possible to create a new market and value network by displacing an existing technology or introducing an entirely new concept, as described in Figure 3.

Disruptive technologies may destroy existing markets and create their own markets; they can be envisaged as a part of the destructive creation process which underpins global economic cycles, according to the economist Joseph Schumpeter's theory.

Disruptive innovations have to be distinguished from *sustaining innovations*, as explained by Christensen. Sustaining technologies are technologies that improve product performance. These are technologies that most large companies are familiar with; technologies that involve improving a product that has an established role in the market. Most large companies are adept at turning sustaining technology challenges into achievements. Christensen claims that large companies have problems dealing with disruptive technologies.

Disruptive technologies, however, eventually surpass sustaining technologies in satisfying market demand with lower costs.

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[2] (Christensen, 2006)

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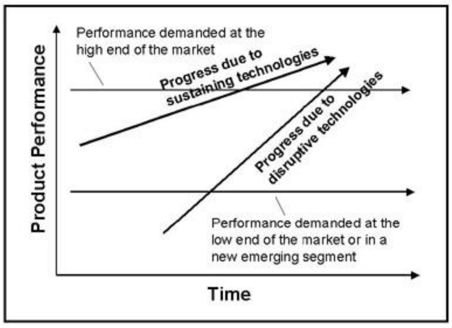

Figure 3. Disruptive Innovation

The first characteristic of a disruptive innovation is that it initially provides inferior performance to existing products available. As a result, it is usually not of much interest to existing users or customers. Disruptive innovations do not meet existing customers’ needs as well as currently available products’ or services’ needs. They may lack certain features or capabilities of the established goods.

The second characteristic of a disruptive innovation is that it is adopted by a market that is currently underserved or not served at all. In other words, it serves a market segment that did not exist before.

The third is that the new product is sold at a very low price compared to the existing product.

The disruptive innovation product starts as a low-quality differentiated product in a low-volume marginal segment of a much larger mature market, which demands attributes that the mainstream market does not, and which is willing to give up some performance attributes. As a result, it is usually not of much interest to existing users or customers. In other words, Christensen’s disruptive technology is initially simpler, cheaper, and less performing.

Several examples can be given in widely differing sectors, whether it is a question of mechanical construction (GM), steelwork (U.S. Steel) or IT (IBM) and telecommunications (France Telecom/Orange).

However, this situation has worsened with the development of financial capitalism (investment funds). Large companies have become excessively focused on the financial and logical rationale. They either fail to innovate sufficiently or do so badly.

To summarize, there are three main phases in the development of a new product (goods or services):

- Phase 1 corresponds to perfecting an invention: (i)~~-~~ this consumes a great deal of capital in terms of research, studies and development; (ii)~~-~~ it creates jobs (iii)~~-~~ it makes it possible to

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put new products or services onto the market that break with existing products and generate strong profitability.

- Phase 2 corresponds to consolidating the invention: (i)~~.~~ capital expenditure is very low; (ii)~~.~~ very weak job creation; (iii)~~.~~ transition from innovation to improvement.
- Phase 3 corresponds to perfecting efficiency, innovation and productivity gains (i)~~.~~ the product is no longer focused on invention, but on the production process; (ii)~~.~~ it's the same product that is proposed to the same consumers, but less expensive; (iii)~~.~~ it destroys jobs, but frees up capital (reduces stock and total payroll).

The big difference that separates innovation financing in the 1980s from what we have observed since the beginning of the current decade is that in the 1980s, the capital freed up in Phase 3 was attributed to financing new research to invent new products or innovations to improve existing products, whereas today, due to the financialization of the economy, financial shareholders (i.e. investment funds) are substituted for industrial shareholders, which leads to the apparition of new ratios (particularly the famous "return on investment"). Capital is most often reinvested in what can generate still more capital for shareholders.

These considerations must finally take into account a product's lifecycle, as described by Anderson and Tushman (Figure 4), where each technology cycle begins~~ning~~ with technology's discontinuity such as a disruptive innovation. This discontinuity is followed by a period of fermentation during which rivalry and competition among variations of the original discontinuity eventually leads to a single dominant design. The dominant design becomes the industry standard. Thereafter it is an era of incremental (evolutionary or 'nuts and bolts') technologies. Once this is over, the cycle begins again with a further technological discontinuity.

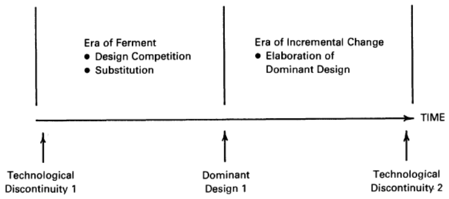

Figure 4. Technology Cycle proposed by Anderson and Rushman (1990)

It is on the basis of the above considerations that we have sought to build an analysis model that enables us to take into account not only all of the information contained in the specialized literature (see the bibliography below), but more particularly that, which is specific to the space industry sector.

3. Analysis model. Our conceptual model identifies six criteria:

- **New entrants must be identified in space industry;**
- **Satellite miniaturization must meet the conditions of a disruptive innovation;**

- **A complementary innovation (‘complementor’) must appear to boost satellite miniaturization as a disruptive innovation;**
- **A path dependency must be observed in the existing firms (Innovator’s Dilemma);**
- **Existing firms must implement open innovations;**
- **New entrants must in turn practice open innovation.**

Some aspects of the conceptual model described above require additional explanation.

The considerations relative to defining a *disruptive innovation* were covered in the above exposition.

On the other hand, it is useful to return to other aspects that make it possible to better define the pertinence of the suggested model.

To begin with, we will address the "*complementor*" concept.

(a)~~.~~ Complementor

Most disruptive innovations do not succeed in isolation and need complementary innovations to attract customers[3]. These complementary products are innovations on the part of other actors, which~~;~~ put the focal firm within an ecosystem of interdependent innovations.

For example: the *Apple*’s *iPod*. *Apple* has created some complementary products for the *iPod* that increase the value of the *iPod*, such as specialized accessories and *iTunes* software. Those specialized accessories are speaker systems, car connectors, *etc*. Apple’s most important complementary asset is the *iTunes* software to encode the content (MP3 from the PC, consumers’ CD collections) for *iPod*’s use.

The focal firm may itself develop the complementary innovations as *Apple* did for the *iPod*. Another solution is to develop various types of relationships with value-chain actors. In the case of the *iPod*, these actors developed the specialized accessories for the *Apple* music player. In their paper, Nalebuff and Brandenburger[4] conceptualize these different types of relationships and call ~~it~~ them the ‘V~~v~~alue N~~n~~et’ (Figure 5). They show how the business game includes customers, suppliers, competitors and … *complementors*. These organizations form part of a *V~~v~~alue N~~n~~et* with integral dependencies.

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[3] (Adner 2006)

[4] (Nalebuff and Brandenburger 1997)

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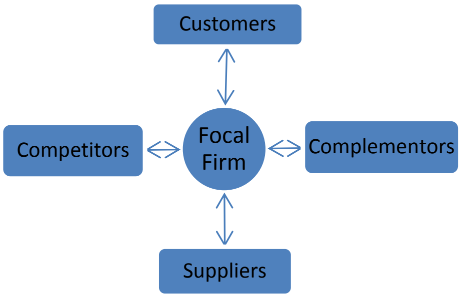

Figure 5. Value Net

(b)~~.~~ Path Dependency

Yu and Hang[5] cite that the entrant firms have a better chance of success in disruptive innovation compared with existing firms because of their smaller sizes, shorter histories and more limited commitments to value networks and current technological paradigms. In other words, existing firms are more hampered in developing a disruptive innovation because they have a longer history and more commitments to the current technology. This is explained by the path dependency theory.

The concept of path dependency suggests that technological change follows an established trajectory of sustaining innovation and evolution~~ary~~. Technological trajectories provide a path whereby firms innovate within a specific technology in an attempt to improve the functional performance of a technology[6]. Furthermore, as Dosi mentioned “[t~~T~~]echnological paradigms have a powerful exclusion effect: the efforts and the technological imagination of engineers and of the organizations~~ they are in~~… are focused in rather precise directions while they are, so to speak, blind with respect to other technological possibilities”. Path dependency’s main argument is that “history matters”; that historic events in the past determine future paths.

Path dependency could imply inefficiencies that may persist for extended periods of time, as explained by several papers in the 1980s (Paul David[7] and Brian Arthur[8]). See, for instance, the demonstration of Paul David on the domination of the QWERTY/AZERTY keyboard layout. The locked-in state can be the most efficient solution for them[9].

Rather than treat the process of lock-in as a random event or historical accident, several papers note the role of entrepreneurs and existing firms in shaping and interacting with their environments. This is explained by the path creation, where the new technologies and production processes that win out in the marketplace reflect the dynamic interplay of producers, consumers, and regulators, and are not guided by efficiency-minded hands, be they visible or invisible. Path creation stories highlight

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[5] (Yu and Hang 2009)

[6] (Dosi 1982)

[7] (P. A. David 1985)

[8] (Arthur 1989)

[9] (Liebowitz and Margolis April 1995)

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the active role of entrepreneurs and existing firms, for it is these actors that help shape the evolution of markets and the rules by which markets operate[10].

For instance,~~:~~ when entrepreneurs favor the emergence of complementary innovations, they also reinforce their own path dependency. There is also plenty of evidence that the technological changes are influenced by national institutional setting[11]. While the cumulative nature of techno-organizational development narrows down the range of potential choices, national paths increase differentiation and diversification as offshoots from the main development path[12].

Inferior technologies have become locked-~~–~~in as industry standards because groups of firms or particular firms have interacted with their buyers, suppliers, and regulators to enable them to standardize what may have been and continues to be a substandard product or technology.

(c)~~.~~ Open innovation

Researchers found that *open innovation* strategy may be applied to managing disruptive innovation[13]. Open innovation can be employed as a way to monitor potentially disruptive technologies that may threaten existing business[14]. If the existing firms do not perform sufficient open innovation, the threat of new entrants is higher.

Open innovation strategy could be employed to accelerate the development of existing products or a new set of products or solutions. Moreover, open innovation can leverage intellectual resources from disruptive technology providers to gain new insights on how these technologies may be applied to meet their goals. The open innovation firms would scan the market thoroughly and develop flexible strategy to exploit new growth opportunity including cooperation or acquisition of disruptive firms. The open innovation firms can also identify and spin-in new technologies and innovation outside of their firms' boundaries, cooperate with suppliers and competitors, involve customers into the innovation process, and drive out-licensing of their own technologies to create new growth opportunities[15].

Henry Chesbrough, in his book "*Open Innovation*", suggests that many innovative firms have shifted to an open innovation model, using a wide range of external actors and sources to help them achieve and sustain innovation. A central part of the innovation process involves the search for new ideas that have commercial potential. Firms often invest considerable amounts of time, money and other resources in searching for new and innovative opportunities. Such investment increases the ability to create, use, and recombine new and existing knowledge.

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[10] (Peteraf and Bergen 2003)
[11] (Johnson, Whittington and Scholes 2011)
[12] (Dosi 1982)
[13] (Yu and Hang 2009)
[14] (Chesbrough and Crowther, Beyond high tech: early adopters of open innovation in other industries 2006)
[15] (Pham-Gia 2011)

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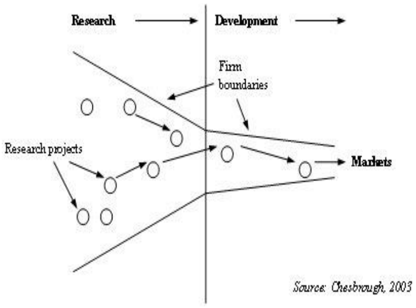
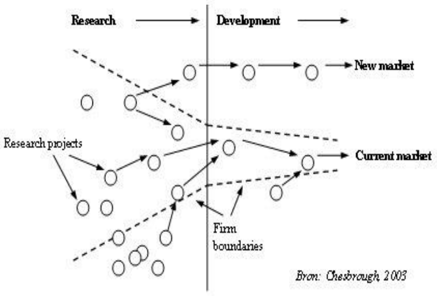
The open innovation strategy is quite a new view as opposed to the closed innovation concept that prevailed during most of the 20th century. In a closed innovation concept, firms attained competitive advantage by funding large research laboratories that developed technologies to produce high margin products that was injected back into research. The view of closed innovation (Figure 6) is that successful innovation requires control. In particular, a firm should control the generation of their own ideas, as well as production, marketing, distribution, servicing, financing and support.



Source: Chesbrough, 2003

Figure 6. Closed Innovation



Bron: Chesbrough, 2003

Figure 7. Open Innovation

Open Innovation (**Erreur ! Source du renvoi introuvable.**~~Figure 2-7~~) is the use of purposive inflows and outflows of knowledge to accelerate innovation. With knowledge now widely distributed, companies cannot rely entirely on their own research, but should acquire inventions or intellectual property from other companies when it advances the business model.

As mentioned by Chesbrough, there are two facets of open innovation. The first and the most common one is called outside-in, where external ideas and technologies are brought into the firm's own innovation process. Some ways to get innovation from outside:

1. Leverage other industries;
2. Acquisition/spin-in: to acquire new technology;
3. Licensing-in: to buy a patent license;
4. Crowd-sourcing/open-sourcing: outsource activity to the crowd;

5. Collaboration with others;
6. Innovation through communities/users: rely on communities/lead users; *e.g.* hosted payload.

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The second facet to innovate is called inside-out where un-utilized and under-utilized ideas and technologies in the firm are allowed to go outside to be incorporated into others' innovation processes, for example:

1. Divestment/spin-out: to pursue outside the technology developed inside;
2. Licensing-out: to grant a patent license.

The open innovation strategy is naturally implemented by new entrants. When new entrants had activities in a previous industry and enter ~~in~~ a new industry, they implement a sort of inside-in strategy ~~when enter in a new industry~~. They need to incorporate the knowledge required to survive in the new industry into their existing knowledge. The strategy of *Apple* in the smartphones industry is an illustration. When new entrants do not exist before their entry, in order to survive they need to get new knowledge by all possible sources, including the external ones. Put differently, new entrants display by nature high absorption capacities required for open innovation strategy.

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Smaller firms are much more entrepreneurial and innovation-driven whereas larger firms are more linear in their behavior, heeding antitrust considerations, established customer relations and industry norms that significantly limit their ability to be proactive and instigate change, unlike their small competitors[16]. ~~;~~ T~~t~~his view was based on research done in the space sector on~~f~~ the role of technological innovation dynamics for small and large firms.

However, that is not always the case with existing firms. Some display high absorption capacities and implement open innovation strategy. However, path dependency mechanisms led other existing firms to display lower absorption capacities. These firms do not implement open innovation strategy and favor a more traditional innovation strategy.

4. Discussion.

(a)~~.~~ Are there new entrants in space industry?

The response is evidently positive, as the ~~below table~~Figure 8 below shows.

Firms	Location/HQ	Year Founded	Main Product	Main Application
SSTL	UK	1985	Small satellite	EO, Navigation, Telecom-munication, Research
Satrec Initiative	Korea	1999	Small satellite	Earth Observation

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[16] (Carayannis and Roy 2000)

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Deimos Space	Spain	2001	Small satellite	Earth Observation
GeoOptics	California (USA)	2006	24 small satellite constellation	Environmental, Weather Monitoring
Gomspace	Denmark	2007	Nano and cube satellite	Research, Low-Cost Science
Clyde Space	Scotland	2008	Nano and cube satellite	Research
Skybox Imaging	California (USA)	2009	24-satellite constellation	Earth Observation
NovaNano	France	2009	Nano satellite	Earth Observation
Planet Labs	California (USA)	2010	100 cubesat constellations	Earth Observation
TyvakNano Satellite System	California (USA)	2011	Nano and cube satellites	Scientific Mission
Novawurks	California (USA)	2011	Hyper-integrated satellite	Space Exploration
Dauria Aerospace	German, Russia	2011	Small satellite	EO, Communication, Navigation
PlanetiQ	Maryland (USA)	2012	12-24 small satellite constel-lation	Weather Monitoring
Omni-Earth	Virginia (USA)	2013	18-small satellite	Earth Observation

Figure 8. List of entrants in the space sector since 1985

(b)~~.~~ Are small satellites a disruptive innovation?

As stated in the literature review, new entrants can pose a threat to the existing firms if they could produce a disruptive innovation. As the common product of the new entrants in space industry is a small satellite, our next task is to analyze if the small satellite could be disruptive.

Small satellites show another way of thinking about doing business in space. Small satellite firms, especially new entrants, start from nothing or from a new concept that has not previously been used by existing firms. The small satellite community has shown that highly-reliable parts for short duration mission are not necessary. Other industries, such as cellphone and computer industries, are producing micro technologies that can be useful for small satellites.

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Small satellites represent a new technology in the space industry. Compared with traditional spacecraft, small satellites are from one to two orders of magnitude smaller and less massive, as well as simpler and faster in their construction or design. They can be designed, manufactured and launched in ~~under~~ less than two years and with total mission costs of a few hundred thousand Euros. Small satellites are also more modular than large satellites. Modularity is achieved by accepted and utilized standards; ~~or~~ in other words, there is standardization in small satellites. Small satellites can be developed and deployed quickly, and this is the key competitive advantage compared with traditional large satellites.

Small satellites, with their miniaturized components, make it possible to reduce costs and enhance the capabilities of certain space missions. Though the capabilities of small satellites are traditionally more limited than those of larger counterparts, the relatively light mass of small satellites allow for drastically reduced launch costs; reduced development times for small satellites also result in the use of more modern technology, which can enhance capabilities and mitigate some of the compromises made to reduce the system mass.

One characteristic of a disruptive ~~technology~~ innovation is the initial inferior performance of existing products. Small satellites are currently ~~are~~ less reliable and with a shorter lifetime. Micro or small satellites have lifetime of 5 years, compared to 15 years of traditional large satellites. Nano and cube satellites even have shorter lifetime, ranging from several months to one year.

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The *second characteristic* of a disruptive innovation is that it is adopted by a market that is currently underserved or not served at all. In other words, it serves a market segment that did not exist before. The small satellite missions address a different, under-served, still marginal market which is much simpler, cheaper and non-competitive in the traditional space market parameters. New markets are developing countries, research institutions which~~to~~ test complex payloads, and commercial industry. Developing countries begin using small satellites with specific simple payloads for technology demonstration, internet backhaul, and for fulfilling basic earth observation missions. Research institutions need 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 starts to see the small satellite potential to revolutionize commercial market in the earth imagery, internet access, and telecommunications. There is a transition of the market from an institutional domain to more commercial domain. Recently *Google* has acquired *Skybox Imaging* as they use lots of satellite images in their commercial applications. They also believe that satellite imagery in the future can be an integral part of decision-making for people on a~~the~~ daily basis.

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Small satellites are much cheaper than large, traditional satellites; and this fulfills the third characteristic of a disruptive innovation.

Existing space firms currently ignore these markets due to very low profit margins, which means that new entrants can take the business with their unusual business models in the space field, such as standardized space-qualified spacecraft components *via* an online shop to individual customers.

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Small satellite business for existing firms would be just a distraction and it is usually difficult to find an internal sponsor within large firms for the idea of developing a low capability and cheap version of the firm’s main product offering. And this is exactly the gap that new entrants and operators are able to exploit.

Taking the above signs into account, recent small satellite activities seem to show most of the main characteristics of a potentially disruptive innovation for the space sector: inferior performance, under-served market, lower price. Therefore, it is possible to accept the following necessary condition “t~~T~~here is **a disruptive innovation** in the industry”.

(c)~~.~~ Does a ‘complementor’ exist for small satellites?

Most breakthrough innovations do not succeed in isolation and they need complementary innovations or a *complementor*. In the case of satellites, the very important *complementor* is the launcher as a way to put ~~the~~ a satellite into space. Only ten countries in the world have launch capability; but only seven of them have operational launchers[17]. Putting and launching satellites in orbit is still a major and expensive endeavor.

Even though the technology seems ready for small satellites for increasingly challenging mission, this industry is still in nascent phase with one important missing piece, which is dedicated small launcher. The effective use of small satellites to fulfill their mission needs depends on the availability and costs of launch vehicles. As satellites become smaller and less expensive, so must launch vehicles; or launch costs will become disproportionately large. For years, small-satellite developers were eager to obtain any ride into space even if that meant traveling as a secondary payload to orbits that were far from ideal. As small satellites become more capable and sophisticated, however, their orbital requirements and schedule demands grow. Secondary payload leads to important drawback, as it does not provide the specificity required for many small satellites which have unique orbital and launch-timing requirements, because they have to adapt to the launch calendar of the primary payload. More efficient launch vehicle propulsion engines could provide a competitive advantage for small payload delivery, therefore enabling the reduction of costs in Low Earth Orbit (the “LEO”) satellites deployment by orders of magnitude. Under this scenario, the industry would be more competitive than it is today, with lower barriers to entry. All these innovations together would most likely bring in a more open, innovative, and competitive space industry than we know today.

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[17] (OECD 22 July 2011)

Launch Vehicles	Company (Country)	Capacity to Low Earth Orbit
Taurus	OSC (US)	860-945 kg
Pegasus	OSC (US)	450 kg
Minotaur	OSC (US)	1700 kg
PSLV	ISRO (India)	1300 kg
Shavit	IAI (Israel)	340 kg
Dnepr	Yushnoye (Ukraine)	3600 kg
Epsilon *(not yet operational)*	JAXA (Japan)	1200 kg
Cyclone *(not yet operational)*	Yushnoye (Ukraine)	4000 kg

Figure 9. Launch Vehicles available for Small Satellites

Figure 9 above shows the list of launch vehicles available for small satellites to go to the L~~l~~ow -E~~e~~arth O~~o~~rbit. There are not many to begin with and some of them are not available for a commercial market. The launch vehicles from Orbital Sciences Corporation (the "OSC") are mainly used by~~for~~ the U.S. G~~g~~overnment~~s~~ and institutional satellites. Polar Satellite Launch Vehicle (the "PSLV") from India ~~are~~ is also prioritized for Indian domestic use and leave almost no capacity for export to commercial market. *Dnepr* from Ukraine, a launcher based on missile conversion, is~~are~~ nearly retired since the missiles SS-18 are out of production for around 25 years. This view is shared also by some interviewees; one says: *"If today there is a micro launcher, that is not expensive and available, therefore it* [the small satellite] *is disruptive".* He emphasizes that the two attributes are important: cheap and available (for commercial market). On top of that, looking at the payload capacity of those launchers, we can see that there is a clear oversupply of payload capacity for small satellites.

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Hence the small satellites need to sacrifice other attributes, such as orbit selection and launch date, to get into orbit.

Current launch providers seem to be ignoring this trend, even the most entrepreneurial one, ***SpaceX***. They have discarded the development of Falcon-1 that could have been suited for small satellite launcher. There isn't any commercially available solution especially designed for small satellites and there isn't any public project from established launchers to serve this segment with a dedicated launcher. The structural costs of these players make them perceive this market as unattractive but it makes them vulnerable to new entrants willing to disrupt the market[18]. This opportunity has inspired some new entrants to pursue the development of a small satellite launcher. ***Garvey Spacecraft Corp***, founded in 2000 in California, U.S., currently is focused on developing a dedicated launch vehicle for nano satellites that is designed to deliver 10 kg payloads to the LEO~~low Earth orbit~~. ***Virgin Galactic***, a British commercial spaceflight company, is developing *LauncherOne* to launch up to 200 kg small satellite to the L~~l~~ow ~~-~~E~~e~~arth O~~o~~rbit. Another new entrant, created in 2012 in Switzerland, ***Swiss Space System*** **(S3)** plans to provide orbital launches of small satellites up to 250 kg. There may be some other firms not mentioned here.

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This leads us to reject the necessary condition of having a complementary product to increase the perceived value of a~~the~~ disruptive innovation for potential adopters**.**

(d)~~.~~ Is "path dependency" observed in the existing firms?

Existing space firms are mainly bearing the stamp of a conservative industry that is heavily implicated by path dependency. The next part shows the research result on the question whether~~if~~ existing firms are implicated by the innovation barrier of path dependency.

Technology innovation is path dependent, with roots in the past that the firms have continued ever since. History matters, and space industry is heavily influenced by its history. It began with *Sputnik*, in the early years of the Cold War, when the atmosphere was influenced by political tension between the Soviet Union and the United States. For instance, Bruggeman's paper[19] described that there was a persistent, path dependent concern that the National Aeronautics and Space Administration (the "NASA") could not survive politically unless it emphasized human space flight. Political victories (perhaps necessarily) were given priority over long-term presence in space. Organizations become more rigid and less flexible as they grow and it is often forced by larger political system and through formalization of procedures. An additional consequence of bureaucratization was the increased risk aversion. For an agency where innovation and risk are never far apart, aversion to risk suppresses creativity and lowers confidence. NASA became more conservative and less willing to take risks. The people who stayed learned to do the same; those who did not or could not learn the new path left.

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[18] (Serra, Ars and Solanilla 2013)

[19] (Bruggeman 2002)

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The United States' space governmental budget was US$43 billion in 2009[20]. NASA's budget historically represents around 40% of the total space budget (or about US$18 billion), ~~.~~c~~C~~ompared ~~this~~ with ESA budget of €3.6 billion in 2009 and €3.74 billion in 2010. U.S. is~~are~~ the leading country in the space industry, not only in terms of the budget spent, but also it is one of the first countries with space activities. Hence it is fair to say that NASA prints the path to be followed, perhaps unconsciously, by other agencies in the world.

The space industry continues to be largely dominated by governmental programs and decisions. Until now, it has been obvious that the space industry does not have a market structure based on full competitive free markets dominated by private firms; instead it is largely influenced by governments following their investments, objectives, and priorities. This is confirmed by interviews when discussing the budget for R&D: *"The money needs to come from somewhere, and that's from a government".* This situation induces a lack of some innovation--stimulating effects.

Space activities are naturally high-risk endeavors and they are also high-risk adverse due to the mindset that offers practically no opportunities for error corrections after launch, as confirmed by the interview: *"By default insurers are conservative. So final customers also tend to be conservative and they put high pressure on the industry to be conservative as well"*. This has left little freedom for innovation not strictly needed for mission success and leads to technically conservative space engineers and project managers. While this behavior favors incremental changes at subsystem level and thus for sustaining or incremental innovation, it acts as a strong inhibitor against fundamentally new approaches related to radical or disruptive innovation.

Are large existing firms experiencing the innovator's dilemma? The small satellite market presents some key characteristics of a potentially disruptive innovation: they come from and address a different, still marginal market; they are much simpler, cheaper and non-competitive in the traditional space market parameters. Nevertheless, traditional space firms are by large ignoring the market due to very low profit margins. One large existing firm ga~~i~~ve~~s~~ this comment when asked about the small satellite business development~~ in his firm~~: "[s~~S~~mall satellites for developing countries] *it is not a mature market. There is no added value for a big company like us to go on so small a product with low added value. We do not consider that this is a market for us"*. Another fact: only 5 of the almost 200 registered participants at the Second European Cubesat Workshop organized by the European Space Agency (the "ESA") in January 2009 came from the traditional European space industry[21].

Large firms adopt a skeptical attitude of "wait and see". They decide to wait before taking any action because they doubt that this new technology would prevail; for example, this comment: *"I am still waiting to see the business of nano satellites, today I would say it modestly I haven't yet seen* [the business plan of nano satellites in terms of capex and ROI]. *This nano sat is still an experiment".*

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[20] (OECD 22 July 2011)
[21] (Summerer 2011)

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Large firms believe that small satellites have inferior performance and are not currently reliable; for example, *Dove* satellites from *Planet Labs* only lasts several months in space and from 28 satellites launched in February 2014, only 9 survived. Then it is complemented by this remark: *"Space is a hostile environment where the entry barrier is very high. Planet Labs, Skybox, Google don't know how to build satellites with 10 years of lifetime".*

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The large firms also believe that this time around it could be another bubble in the space industry, as one says the following *"Right now it is obvious there is a bubble in the space industry, for the satellites and also for access to space".* The new entrants' explosion happened before in the 1990s, however all finally experienced commercial failure. ***Teledesic***, created in 1990s with early funding from Bill Gates (*Microsoft*), was designed for commercial broadband satellite constellation and went into Chapter 11 in 2002. ***Iridium*** with back-up from *Motorola* was founded in 1991 to operate 66 satellite constellations for communication but went bankrupt in 1999. ***Globalstar*** (with *Loral* and *Qualcomm*) and ***Orbcomm*** (*Orbital Sciences*) were founded in 1991 for satellite phones, but they went bankrupt in 2002 and 2000 respectively.

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The interview result above allows us to accept the necessary condition that the large existing firms are implicated by the path dependency.

(e). Do existing firms employ open innovation?

Traditionally, conducting space technology development and launching space missions required massive infrastructure investments, long lead times and large teams of experts. Furthermore, since its creation after the Second World War, the space industry has been dominated by government or institutions that resulted in a monopsony market. As a consequence, the space sector is a fairly closed sector, with few natural exchanges outside of aerospace and defense[22].

Characteristics of open innovation that can be done in space industry:

- Outside-in:
    - Leverage other industries: agile aerospace (to be done like in the software industry: release early and often), analytical platform for big data (from the Internet), use smartphone flash memory, simplify testing (not typically done in traditional space industry);
    - Using COTS: not space-proven components or ready-to-buy components (without specific contracts or specification);
    - Acquisition/spin-in: acquire new technology;
    - Licensing-in: buy a patent license;
    - Crowd-sourcing/open-sourcing: outsource activity to the crowd;
    - Collaboration with others;
    - Innovation through communities/users: rely on communities/lead users; e.g. hosted payload.

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[22] (Summerer 2011)

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- Inside-out:
    - Divestment/spin-out: pursue externally the technology developed internally;
    - Licensing-out: grant a patent license.

Large, existing firms in the industry state that they perform collaborative innovation and look out for ideas from universities/engineering schools, new entrants, competitors, conferences, suppliers, or subcontractors. One comment: *"We are looking for any sources to monitor trends which will allow us to match better the market evolution and competition"*. One interviewee explained how their company approached other company outside of space industry to collaborate. *Boostec*, ceramics specialist based in Tarbes, is a manufacturer of the terrestrial industry application. In the 1990s it was contacted by *Airbus Defense and Space* (then *Astrium/Matra Marconi Space*) that said that their silicon carbide held promise for space optics. Their decades-long collaboration led to a production of a state-of-the-art reflector that is currently flying on the *Herschel* and *Gaia* satellites. One large firm also confirms *"I think both commercially and technically we are innovative, maybe it is fast enough* [to follow market evolution]*"*.

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They agree that COTS components will be used more and more in the future, mostly for LEO~~low earth orbit~~ satellites: *"In the future we will have more and more COTS on board. We have Samsung flash memory in our LEO satellite now"*. It is difficult to use COTS components for geostationary telecommunication satellites because the telecommunication market is more competitive and sensitive to reliability (1-minute loss of broadcast is a disaster, especially if it is during very important event). In a way, ~~low earth orbit~~LEO satellites are more adapted to innovation because the application is less demanding (they can lose 5-minute of coverage without significant impact) and also because their customers are less experienced. One existing firm mentioned that they employ COTS components in their *Iridium* satellites. This is feasible because *Iridium* is a constellation and the reliability in a constellation is measured by the whole system and not by individual satellite.

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Looking at the characteristics above and the interview result, we reject the following necessary condition: the existing firms do not implement **open innovation.**

(f)~~.~~ Do new entrants practice open innovation?

New entrants fundamentally work in a different way compared to existing firms. Smaller teams, significant use of commercial off~~-~~-the~~-~~-shelf technologies, crowdfunding, a more aggressive approach to managing risk and a great motivation to leverage intellectual property or other industries are just some of the defining characteristics of open innovation.

The interviews with small/medium firms (though not all of them are new entrants) support the idea of these firms implementing open innovation. All of them look for outside ideas and technologies and collaborate with other firms, even with firms outside of the space industry. There is one firm that was not originally involved in space (they was started their business in TV broadcast), so this firm naturally is already open to innovation because they leverage other industry for the space component they produce. Also, there is one technology research firm whose business is to do technology research in different fields (energy & environment, defense & security, information technology, ergonomics, and aerospace & transport).

Regarding the COTS usage, the small firms interviewed stated that they always try to use COTS components as much as possible; however often they are prevented to use it because the mission and main customers' requirement ask for high reliable components, so therefore COTS cannot be optimally used. This confirms the fact of monopsony market makes the space industry less innovative.

We therefore accept the following necessary condition: new entrants implement **open innovation**.

5. Results.

Our assumption is as follows: there is a threat of new entrants to existing space industry firms if the following necessary conditions display a high level of probability.

The levels obtained are summarized in the Figure below:

No	Necessary Conditions	Status
i	There are new entrants	Accepted
ii	Small satellite is a disruptive innovation in space industry	Accepted
iii	There is a complementary product to complete the disruptive innovation	Rejected
iv	The existing firms are implicated with path dependency	Accepted
v	The existing firms do not implement open innovation	Rejected
vi	The new entrants implement open innovation.	Accepted

Based on our results it seems too early to tell if these new entrants will be successful and small satellites will disrupt the space industry. Our results prevent giving one single answer to our research question because all of these developments are still happening now. We propose two possible scenarios that could take place in the future.

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The **first scenario** is the ‘***Kodak Scenario***[23]’ for the existing firms. This scenario is considered because the following necessary conditions prevail:

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(i) There are new entrants;~~.~~
~~(ii)~~ Small satellite is a disruptive innovation in space industry;~~.~~
~~(iii)~~
~~(iv)~~(ii)
~~(v)~~(iii) Existing firms are implicated with path dependency;~~.~~
~~(vi)~~(iv) New entrants implement open innovation.

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New entrants are showing up recently, out of the need to fill a market-need in a segment that was either overlooked or ignored by existing firms. Furthermore, these small satellite providers are beginning to propose their new business models to win business that ~~would~~ traditionally have been considered the domain of large, well-capitalized players.

The small satellites have boosted their performance and sustained their innovation to a high level. Taking all the ~~symptoms~~indicators into account (simpler and lower performance, under-served market, and cheaper), recent small satellite activities seem to show most of the main characteristics of a potentially disruptive, radical innovation for the space sector.

The result has also shown ~~that~~ the path dependency and the innovator’s dilemma behaviors observed in the existing firms. For example,~~:~~ the “wait ~~-~~and ~~-~~see” attitude for the small satellites; the comment that small satellite is not a mature market and therefore it is not a market for them; and also the comment that what is happening now ~~for sure~~certainly is a bubble.

Under the assumption that the mechanisms observed and studied in fully competitive free markets are applicable to the space industry, traditional existing firms might need to take these developments seriously and deploy proactive strategies to include these fully into their planning and future business scenarios.

During the discussion at 18th Annual Conference on Small Satellites sponsored by *AIAA* in August 2004, while agreeing that microsatellites were certainly disruptive, Martin Sweeting from *SSTL* stated that if the concept of disruptive means totally wiping away everything that went previously and replacing it with something new, it was probably going a bit far for small satellites. The analysis shows that while small satellites do enable valuable missions, they represent only a small part of the overall space market. It would be interesting ~~though~~ however to see his opinion now, ten years later, because the small satellites seem to claw their existence deeper in the industry.

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Yu and Hang[24] mention that disruptive innovation does not always imply that entrants or emerging business will replace the existing firms or traditional business. In fact, an incumbent business with

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[23] Kodak, a market leader in the film business in the 20th century failed to respond to changes in technology, choosing not to move into digital photography and consequently, letting others dominate the digital photography field

[24] (Yu and Hang 2009)

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existing high-end technologies can still survive by concentrating on how to satisfy its most demanding but least price-sensitive customers.

The second scenario ('bubble scenario') is that we may be heading for another **'space bubble~~-~~'**. Bubble, or it is known as well as boom-and-bust cycle, is a reference to a severe business cycle; a time period where business activity increases very rapidly (for example, a lot of new entrants show up) followed by sharp and rapid contraction. In the 1990s, the satellite industry went through a 'space bubble' when investors projected that phones connected *via* constellations of satellites would be the immediate future of mobile communications. But the growth of terrestrial cellular networks left few customers for satellite phones, and several years later the market collapsed. However, *Iridium* case study shows that their main flaw is the escalating commitment from the top management who kept pushing *Iridium* forward in spite of deeply flawed business plan. Moreover, at that time, the technology needed was not mature at all, whereas currently in its second time around, it seems they have matured the technology and *Iridium*'s business case is more robust.

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This scenario is considered because the following necessary conditions ~~are~~ have prevailed:

(iii) There is no complementary product to complete the disruptive innovation;
(iv) Existing firms implement open innovation.

It has been acknowledged that the lack of affordable and timely access to orbit is the most prominent barrier to small satellite adoption. It could be easily implied that cost-effective development in launching technologies, which will enable dedicated launches for small satellites with the use of small rockets, would greatly increase the adoption of small satellites for the purpose they serve today. This breakthrough could potentially reduce launch costs in a very significant way to increase launch opportunities, reduce the need for safety and increase the rate of innovation in the satellite industry. A dedicated launcher for small satellites would tackle these problems enhancing the mission capabilities of small satellites. Without it, the small satellite would not be a disruptive innovation in the space industry.

Existing firms employ an open innovation strategy. They monitor the market systematically to identify the new technology in the industry. They also collaborate with new entrants, other companies, *etc*. This open innovation effort would reduce the threat posed by new entrants.

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Problematic and persistent behavior in the space industry of thinking of engineering first and of the customers second could be a reason for another bubble. This industry is a 'technology push' and is known to push the solution onto a market that does not quite yet exist. Furthermore, it is often observed that small satellites cannot ultimately replace large complex satellites, simply because the laws of physics do not permit that. They have a natural limitation in the size, complexity, and mass of the payload that they can carry.

Nevertheless, this bubble may be regarded as the start of a new technology cycle in the space industry. A new cycle starts with a discontinuous innovation and is followed by 'nuts-and-bolts' innovations. Most of these innovations fail (for example, the 'bubble' in the 1990s); however progressively a variation of the first discontinuous innovation has emerged that will become the standard in the future. This process may last several years, or several decades. Put differently, we may say that the time for small satellites will come one day; we just do not know when. Lastly, should this prove to be a bubble, the existing state of affairs will dictate the future.

Bibliography

"2014 Nano/MicroSatellite Market Assessment." *SpaceWorks.* 2014. http://www.sei.aero/eng/papers/uploads/archive/SpaceWorks_Nano_Microsatellite_Market_Assessment_January_2014.pdf (accessed Jul 9, 2014).

Adner, Ron. "Match your innovation strategy to your innovation ecosystem." *Harvard Business Review 84 no. 4*, 2006: 98.

Anderson, Philip, and Michael L. Tushman. "Technological discontinuities, dominant designs: a cyclical model of technological change." *Administrative Science Quarterly* , 1990: 604-633.

Anthony, Sebastian. *The history of Kodak: Pioneer of film and digital photography.* Oct 12, 2011. http://www.extremetech.com/extreme/99281-the-illustrious-history-of-kodak-inventor-of-the-snapshot-digital-cameras-oled-and-more/10 (accessed Jul 16, 2014).

Arthur, W. Brian. "Competing Technologies, Increasing Returns, and Lock-In by Historical Events." *The Economic Journal Vol. 99*, 1989: 116-131.

Assink, Marnix. "Inhibitors of disruptive innovation capability: a conceptual model." *European Journal of Innovation Management* 9, no. 2 (2006): 215 - 233.

Beesemyer, J. Clark, Adam M. Ross, and Donna H. Rhodes. "Case Studies of Historical Epoch Shifts: Impacts on Space Systems and their Responses." *AIAA Space 2012 Conference.* American Institute of Aeronautics and Astronautics, 2012.

Bower, Joseph L., and Clayton M. Christensen. "Disruptive Technologies: Catching the Wave." *Harvard Business Review*, 1995: 43-53.

Bradshaw, Tim. *US start-up to launch record number of satellites.* Nov 26, 2013. http://www.ft.com/intl/cms/s/0/a8b611c0-5661-11e3-ab12-00144feabdc0.html#axzz31mLznuR8 (accessed May 30, 2014).

Bruggeman, David. "NASA: a Path Dependent Organization." *Technology in Society 24*, 2002: 415-431.

Carayannis, Elias G, and Robie I Samanta Roy. "Davids vs Goliaths in the Small Satellite Industry: the Role of Technological Innovation Dynamic in FIrm Competitiveness." *Technovation 20*, 2000: 287-297.

Chandy, Rajesh K, and Gerard J Tellis. "Organizing for Radical Product Innovation: The Overlooked Role of Willingness to Cannibalize." *Journal of Marketing Research*, November 1998: p474-487.

Chapman, Lizette. *Private Space Co. Dauria Aerospace Will Use Smartphone Tech To Launch Russian Satellites.* Oct 21, 2013. http://blogs.wsj.com/venturecapital/2013/10/21/private-space-co-dauria-aerospace-will-use-smartphone-tech-to-launch-russian-satellites/ (accessed May 30, 2014).

Mis en forme : Centré

Chesbrough, Henry. *Open Innovation: The New Imperative for Creating and Profiting from Technology.* Boston, MA, USA: Harvard Business School Press, 2003.

Chesbrough, Henry, and Adrienne Kardon Crowther. "Beyond high tech: early adopters of open innovation in other industries." *R&D Management*, 2006: 229-236.

Christensen, Clayton M. *The Innovator's Dilemma.* New York, USA: Collins Business Essentials, 2006.

David, Leonard. *Big Promises from Small Satellites.* Aug 23, 2004. http://www.space.com/274-big-promises-small-satellites.html (accessed Aug 2, 2014).

David, Paul A. "Clio and the Economics of QWERTY." *The American Economic Review Vol. 75*, 1985: 332-337.

de Selding, Peter. *Surrey Founder Credits Consumer Electronics for Fomenting Small-satellite Revolution.* Mar 28, 2014. http://www.spacenews.com/article/features/40019surrey-founder-credits-consumer-electronics-for-fomenting-small-satellite (accessed May 30, 2014).

Dosi, Giovanni. "Technological paradigms and technological trajectories: a suggested interpretation of the determinants and directions of technical change." *Reserach Policy 11 no.3*, 1982: 147-162.

Dyer, Jonny. *Building the World's Most Capable Microsatellites, Part 2.* Mar 19, 2014. http://www.skybox.com/blog/microsatellites-pt-2 (accessed May 30, 2014).

Finkelstein, Sydney, and Shade H. Sanford. "Learning from Corporate Mistakes: The Rise and Fall of Iridium." *Organizational Dynamics 29 No. 2*, 2000: 138-148.

Fischer, Bill. *There Are No 'Kodak Moments'.* Jul 04, 2014. http://www.forbes.com/sites/billfischer/2014/07/04/there-are-no-kodak-moments/ (accessed Jul 16, 2014).

Foust, Jeff. *Smallsat constellations: the killer app?* Jul 1, 2013. http://www.thespacereview.com/article/2322/1 (accessed May 30, 2014).

Freedman, Andrew. *The Space Race Is On for Climate, Weather Privatization.* Jul 15, 2013. http://www.climatecentral.org/news/the-space-race-is-on-for-climate-weather-privatization-16243 (accessed May 30, 2014).

Henderson, Rebecca. "Underinvestment and Incompetence as Responses to Radical Innovation." *RAND Journal of Economics*, 1993: 248-70.

Johnson, Gerry, Richard Whittington, and Kevan Scholes. *Exploring Strategy (9th Edition).* Essex, England: Financial Times Prentice Hall, 2011.

Keith, Adam. *Satellite-Based Earth Observation, Market Prospects to 2021.* Market Analysis, Paris: Euroconsult, October 2012.

Krasny, Jill. "Skybox: The Bold Startup Indexing Every Inch of Planet Earth." *Inc.* Apr 23, 2014. http://www.inc.com/audacious-companies/jill-krasny/skybox-imaging.html (accessed Aug 5, 2014).

Mis en forme : Centré

Liebowitz, Stan J., and Stephen E. Margolis. "Path Dependence, Lock-In, and History." *Journal of Law, Economics and Organization*, April 1995: 205-226.

Meyer, Robinson. *Silicon Valley's New Spy Satellites.* Jan 7, 2014. http://www.theatlantic.com/technology/archive/2014/01/silicon-valleys-new-spy-satellites/282580/ (accessed May 30, 2014).

Mortara, Letizia, and Tim Minshall. "How Do Large Multinational Companies Implement Open Innovation?" *Technovation* 31 (2011): 10-11.

Nalebuff, B. J., and A. M. Brandenburger. "Co-opetition: Competitive and Cooperative Business Strategies for the Digital Economy." *Strategy & Leadership 25(6)*, 1997: 28-35.

"NovaNano: Le rêve spatial low cost." *Nova Mag no. 18.* Jun 2011. http://www.novacite.com/IMG/pdf/novamag_18.pdf?PHPSESSID=7a4990ea6c517574ea23b2f2b6241027 (accessed May 30, 2014).

OECD. *The Space Economy at a Glance 2011.* OECD Publishing, 22 July 2011.

Pedersen, Soren. "Air Traffic Control from Space using Nano-Satellites." *Cubesat Developers' Workshop.* April 23-25, 2014. http://mstl.atl.calpoly.edu/~bklofas/Presentations/DevelopersWorkshop2014/Pedersen_Air_Traffic_Control_from_Space.pdf (accessed May 2014, 2014).

Peteraf, Margaret A., and Mark E. Bergen. "Scanning Dynamic Competitive Landscapes: A Market-Based and Resource-Based Framework." *Strategic Management Journal Vol. 24*, 2003: 1027–1041.

Petroni, Giorgio, and Stefano Santini. "Innovation and Change? The Evolution of Europe's Small Satellite Manufacturers." *Space Policy* 28 (2012): 25-32.

Pham-Gia, Khanh. *Radical Innovation and Open Innovation: Creating New Growth Opportunities for Business.* Hamburg, Germany: Diplomica Verlag GmbH, 2011.

"Satellite Industry Association Press Release." *SIA Report Shows Higher Satellite Industry Growth in 2012.* Washington, D.C., USA, June 17, 2013.

Serra, Lluc Palerm, Jordi Barrera Ars, and Jorge Salas Solanilla. "Microsatellites and Microlaunchers: The Tandem That Will Disrupt The Satellite Industry." *64th International Astronautical Congress.* Beijing China: International Astronautical Federation, 2013.

Sharma, Rakesh. *Forbes Tech.* Feb 26, 2014. http://www.forbes.com/sites/rakeshsharma/2014/02/26/all-set-for-take-off-silicon-valley-startups-redefine-space-imaging-market/2/ (accessed Jul 9, 2014).

Stanislaw Ostoja-Starzewski, 29 years old, created mini-satellites in order to provide accessible and universal access to the Internet. 2014. http://www.tr35france.com/stanislaw-ostoja-starzewski/ (accessed May 30, 2014).

State of the Satellite Industry Report. Washington, D.C.: Satellite Industry Association, 2013.

Sull, Donald N. "Why Good Companies Go Bad." *Harvard Business Review*, Jul-Aug 1999: 1-10.

Summerer, Leopold. "Signs of Potentially Innovation in the Space Sector." *International Journal of Innovation Science Vol. 3 No. 3*, 2011: 127-140.

Thrane, Sof, Steen Blaabjerg, and Rasmus Hannemann Møller. "Innovative path dependence: Making sense of product and service innovation in path dependent innovation processes." *Research Policy 39*, 2010: 932-944.

Voyer, John J. *Kodak and the Innovator's Dilemma.* Feb 06, 2012. http://usmschoolofbusiness.wordpress.com/2012/02/06/kodak-and-the-innovators-dilemma/ (accessed Jul 16, 2014).

Werner, Debra. *Dauria, Elecnor To Offer New Earth Imagery Provider Constellation.* May 19, 2014. http://www.spacenews.com/article/civil-space/40611dauria-elecnor-to-offer-new-earth-imagery-provider-constellation (accessed May 30, 2014).

Wireless is way forward for Internet. April 28, 2014. http://www.japantimes.co.jp/news/2014/04/28/business/tech/wireless-is-way-forward-for-internet/#.U4hSZ3KSySp (accessed May 30, 2014).

Yoffie, D. B., and M. Kwak. "With friends like these." *Harvard Business Review 84(9)*, 2006: 88-98.

Yu, Dan, and Chang Chieh Hang. "A reflective review of Disruptive Innovation Theory." *International Journal of Management Reviews*, 2009.

Mis en forme : Centré