

## The Food Chain of the Small Satellites Ecosystem

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### ABSTRACT

*...In a food chain of a biological system, plants (or producers) fix energy from the Sun and use inorganic material to manufacture complex organic substances; consumers (e.g. birds, mammals) use the energy fixed by plants as their nutrients; finally decomposers (e.g. bacteria), break down dead organisms and release nutrients back to the environment for use by the producers...*

The Space Business can be seen as a class of ecosystems, where the producers (equipment suppliers) transform raw materials by using the energy (funds). Consumers (the users) use data and services provided by the satellites to release back the nutrients in form of need of better services and more accurate data: these products generate more funds. This chain creates a stable system. In Small Sat business the cost affects the design approach and the way funds are shared among all the actors. Producers and consumers live in symbiosis to minimize costs and improve their survivability. Design to Cost approach has been already used as design philosophies in small satellite missions, but this does not explain why some Small Satellites experiences give birth to a stable system, while other don't. With some remarkable exceptions, many of the Small Satellites have been one-of-a-kind. Will the Small Sat approach become a self sustained ecosystem with a longer lifetime of products and consumers? The objective is to define a metric to evaluate the stability of a new programme. It also sees the small satellite in a wider perspective to help small satellite to enter other Ecosystems.

### INTRODUCTION

#### *Why this Paper*

This paper has been originated after a consideration that took place at the Symposium on Small Satellites Systems and Services held in Sardinia (Italy) in September 2006<sup>1</sup>. In this symposium, as in many others on the topic of small satellites, a few papers were presented on methods and approaches on how to keep down cost of design, manufacturing, units, and finally of ground operations. The next question is: can the actors in this field make a reasonable profit that will allow staying on the market? The answer isn't evident: pushing down costs means smaller margins, but the technological risks of building small satellites can easily wipe away the profit of a the project. This originated the idea of looking at the small satellite business from a wider perspective to understand if dynamics external to the environment of building a satellite could help to explain and predict the stability of the business. The idea of the analogy to a Food Chain of an Ecosystem came very naturally and has been inspiring the work of this paper.

#### *The Objectives*

The objective of the paper is to define a metric that can help decision makers to evaluate the stability of a new programme or aggressing a new market. Perhaps this goal is too ambitious, but turning our head up and looking at the small satellite environment in a wider perspective, surely gives one more tool for advocating the cause of small satellite in other Ecosystems historically skeptical of the potentialities offered by small satellites.

### THE SMALL SATELLITES ECOSYSTEMS

#### *One of a Kind or a Stable Ecosystem?*

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### *The Nutrients of the Small Satellite Ecosystem*

We have identified a set of nutrients that generated small satellites projects:

1. Understand a phenomenon or measure a physical quantity;
2. Explore;
3. Flight Testing;
4. Exploit Space Infrastructures;
5. Learn.

Table 1 lists the Nutrients that originated small satellite missions and reports in column 2 and 3 the relevant Producers and Consumers. Table 2 assigns to each nutrient risks in term of Economical and Technical Risks. Economical risks are higher for mission operating with commercial terms. In general, missions operating of institutional projects have penalty clauses milder than commercial contract with a firm and fixed price. Technical risks are higher for new challenging missions, typically scientific mission. Operational missions will generally draw on flight proven technologies to convince customers of the reliability of the solution. Figure 1 layout of the variety of the ecosystems, and depicts how the different nutrients may give stable ecosystems.

We can easily see that some of Inorganic Materials have higher chances of generating a stable ecosystem, while other have a high probability to give a “one of a kind” mission. A closer look reveals some interesting features.

#### Understand & Measure

Understand and measure has a high probability to be one of kind: once a parameter is measured or an experiment has been performed there is no need to measure it again. In most of the cases a follow-on will be required to investigate further the phenomenon with a better measurement, but better measurements will require larger or more sophisticated instruments, that could reveal to be unaffordable by the first originator of the

mission. This is the case of Ørsted, a small satellite that mapped the Earth’s magnetic field with unprecedented accuracy proposed and implemented by the Danish Meteorological Institute in cooperation with the Danish Technical University and with Danish industry. The mission has been so successful that a better measurement of the Earth’s magnetic field can only be done with a constellation of satellites. The follow-on mission, called Swarm, is now being implemented by the European Space Agency, breaking the proto ecosystem generated by the Ørsted experience.

#### Explore

This nutrient, of a similar nature of the previous, has higher chances to give a more durable ecosystem, simply because there are several objects that can be explored by using similar technologies for both payload and spacecraft. Differently from all other nutrients, space exploration has a strong appeal on the large public. It is worth to mention Mars Path Finder and Deep Impact, even if they do not follow under the category of small satellites. The web sites of these two missions were visited by an extraordinary large amount of people compared to other space missions. Deep impact had some 8 millions during the first 24 hours setting an absolute record of internet hits. These two missions deployed with a relatively small budget if compared to other NASA exploration missions, show the high potential that space exploration still has to attract the large public. This aspect in combination with prestige that these missions give to the sponsoring organization, the underlying scientific interest, and the variety of possible missions, are elements that if combined together could give birth to a quite stable ecosystem.

#### Flight Test

This is a relatively new nutrient for small satellite. Even if the Sputnik can be considered the first example of a small satellite originated by this nutrient, only recently large institution uses small satellites as “standard platform” for flight testing new technologies. At the European Space Agency a programme called PROBA (Project to test On-board Autonomy) started to test new concepts for on-board autonomy, has now become the name for a long term programme for in-flight demonstration of new technologies. The likelihood of this nutrient to give birth to a stable ecosystem is quite high. The need of flight testing new technologies is coming from the large and expensive mission. Funny enough, the more complex and costly is a space mission, the higher are the chances that critical elements will need to be flight tested before the mission is approved.

**Table 1**

<b>Nutrients</b>	<b>Producers</b>	<b>Consumers</b>
Understand/Measure	- Small Sat suppliers - Research Institutions building the payload	- Research Institutions
Explore	- Small Sat suppliers - Research Institutions building the payload	- Research Institutions - Large Public
Flight Test	- Small sat producers - Space Agencies	- Small satellite producers - Satellite community at large.
Exploit Space Infrastructures	- Small sat suppliers	- Institutions
Gap Filler / Complementary Missions	- Small Sat Suppliers	- Space Agencies - Satellite Data User Community
Learn	- Universities - Research Institutions - Equipment suppliers	- The educational system

**Table 2**

<b>Nutrients</b>	<b>Economical Risks</b>	<b>Technical Risks</b>
Understand/Measure	Low	High
Explore	Low	Very High
Flight Test	Medium	Low
Exploit Space Infrastructure	High	Medium
Gap Filler / Complementary Missions	Medium	Medium
Learn	Very Low	From Very Low to Very High

This is the case of Smart 2 (Small Mission for Advanced Research in Technology ), a small satellite to “pave the way of two for ESA’s ambitious Darwin and LISA missions” to test critical technologies as laser metrology system, the drag-free control system and an ultra-precise micro-propulsion system.

Exploit Space Infrastructures

This is one of the nutrients that all the manufacturers of satellites would like to see generating a stable ecosystem and stable revenues. The life of small satellites in this ecosystem has been very hard, with a few remarkable exceptions: the Amsat, the TAC-Sat programme, and more generally any small satellites developed for responsive space of defense applications.

Gap Fillers / Complementary Mission

This nutrient is similar to the previous, but with the peculiarity of being in symbiosis with the environment of large satellites. Small satellites have proven enough

reliability and performance to complement the space segment of institutional missions. ESA has activities to explore the possibility to complement the large space infrastructure of GMES (the Global Monitoring for Environment and Security) with small satellites designed for Earth Observation, as the SSTL’s Disaster Monitoring Constellation (DMC) and the next generation of Verhaert satellite for Land Observation. Similarly to the Flight Test nutrient, the Gap Fillers and the Complimentary Missions is a Small Satellites ecosystem in symbiosis with the large satellites. Small satellites give and receive nutrients to the ecosystem of large institutional missions.

Learn

Building a small satellite to learn about space engineering and space technologies has been one of the very first nutrients at the beginning of the evolutions of small satellites, and it remains one of the largest generators of nutrient. It’s a renewable form of nutrients: new students come to university every year. What is

peculiar of this nutrient is that most of the satellites built by universities do not generate a stable ecosystem<sup>3</sup>. Only a few universities have stable and long track of small satellites. Remarkably, 19 out of 35 universities only built one satellite, of the remaining only 6 built a second one. Furthermore, in the review presented by Startwout, it is outlined that most of University satellites lack a true payload. Fluctuation of organizational support and lack of continuity of funds are the reasons why most of the universities isn't able to have recurrent program. Furthermore, the development of a satellite lasts longer than the time the student has for his education. The USAF Cadet Programme, one of the examples of small sat programme for education is able to overcome this problem<sup>2</sup>.

The Young Engineer Satellite Programme (YES) is an interesting initiative started recently at ESA. The YES initiative is going in the direction of providing a more stable platform to overcome the problem of fluctuation of organizational support from Universities. In the YES project there are generally about 30 active team members at any one time, both from ESA Member States and from other countries. Usually, a team member works from his university. A Core Team Member is responsible for a subset of the YES tasks and identifies a suitable task for the team member(s). The team member will receive requirements and due date for delivering the results. The Core Team Member keeps contacts with the team members and offer additional assistance if needed. Experienced team members can be offered an internship at ESA premises as a Core Team Member. The living expenses of the core team members are covered by ESA during the internship.

Figure 1 gives a schematic representation of the different types of ecosystems. The right side of the picture represents stable ecosystems. Two colors are assigned to each type of mission: the color of the box indicates the economic risk: yellow means low risk and red high risk. The color of the box beyond indicates the technical risks. An ecosystem with high chance of survivability will be on the right side of the picture with both colors in yellow.

## THE METRIC

### *Seeing Beyond the Application*

See what's next shall be the very first question to be asked when starting developing a satellite. Find new funding, defining new applications, and laying down cooperation schemes among developers and users of data takes about the same time to develop a small satellite. If the definition of the new mission starts after the launch of the first satellite, in most of the cases the ecosystem will go in starvation: by the time the new mission will have taken a credible shape, the core team will have found new job of research opportunities leaving a only sparse number of persons looking for support.

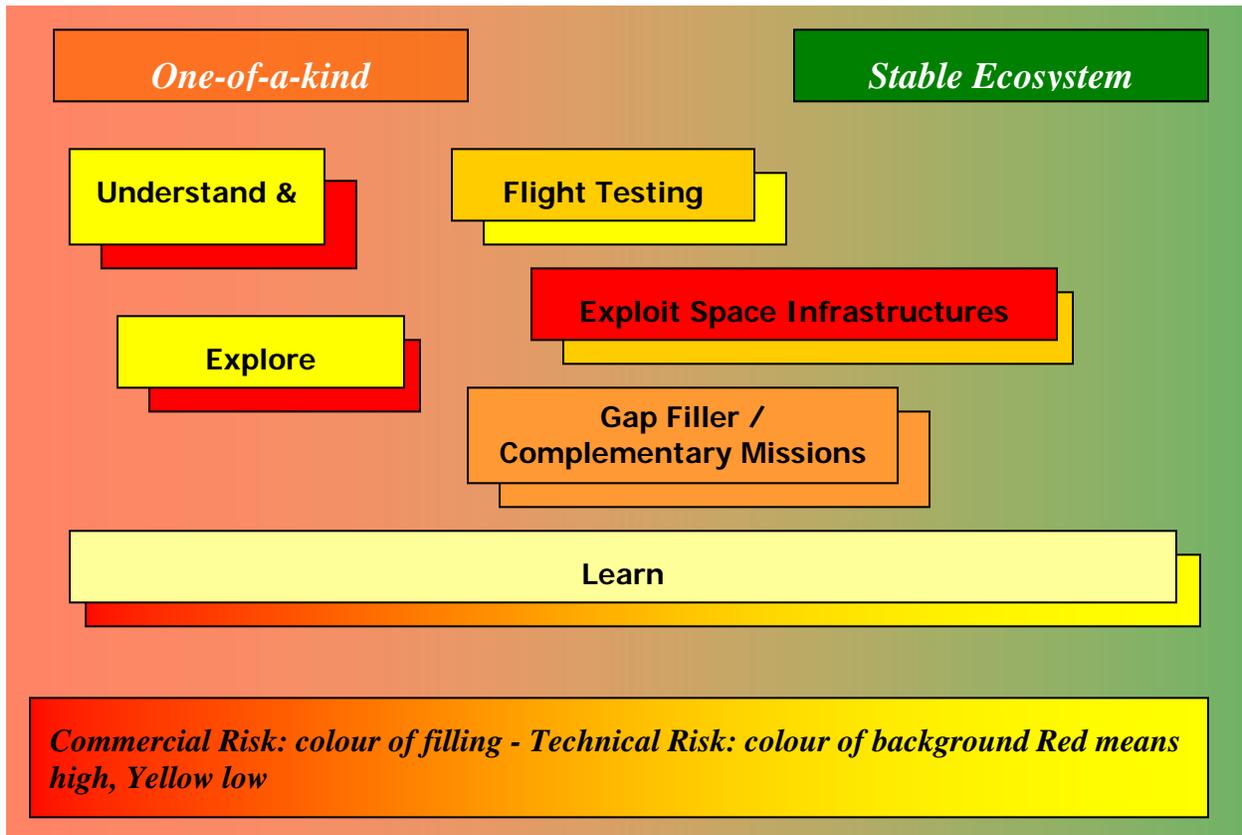
### *Close and Open Ecosystems*

The close control of development and cost, user of data and developers belonging to the same institution pushes toward small satellites developed in a close environment. This has the advantage of reducing interface and therefore reducing documentation and management cost, but at the same time the probability of survivability is practically zero if the institution doesn't have long term internal resources to support small satellite missions.

An open system, where needs, developers and users are scattered among different institutions has more chances to establish synergies that will increase the probability of initiating an ecosystem. The flip side of the coin is that the more are the interdependencies, the weaker can be the ecosystem. The Stability of the symbiosis among the institutions plays the most important role to ensure a long lasting small satellite programme.

Among the cases analyzed the DMC is one of the most interesting example where SSTL had the capability to establish a cooperation among Nigeria, Algeria, asasa, and UK for building and operating satellites for DMC. This is example shows that establishing a common base of interests is highly rewarding and sparse resources can initiate a new ecosystem.

It will be interesting to see in a few years if the ESA's YES programme will be able to generate a similar type of ecosystem .



### *Disruptive Innovations, Nonconsumers and New Ecosystems*

Disruptive innovations that successfully open new markets follow two patterns<sup>4</sup>:

1. They introduce a relatively simple, affordable service that increases customer competitiveness who historically lacked money to get important job done
2. They help customers to do more effectively what they already do.

Using a small satellite platform to flight test new concepts or new technology may generating a new ecosystem following the first path. To complement space segments of operation systems with small satellites is one example of the second path.

Differently from a commercial market, space is largely dominated by institutional funds. In Europe, the customers that could be addressed are decision makers scattered in large institutions both at National and

International level. Europe has 6 National Space Agencies, 3 National have space technology offices.

Furthermore the European Space Agency, Eumetsat and the European Union are sovranational institutions that purchase or operate satellites for multinational purposes. They are composes of 17, 19, 27 Nations respectively. In this case, the challenge to create a stable ecosystem consist in generating a consensus among the various partners to build a common program. This is very difficult for companies operating in the sector of small satellites that generally address only their National institution.

### **CONCLUSIONS**

There examples of stable ecosystem of small satellites. Most of the them, if not all of them, are in close relation with university or they have an educational role in broader sense. The educational role remains the underlying nutrient of small satellites. Ecosystems can be generated when Universities team-up with private companies of conversely when private companies use

low cost satellites to provide affordable platform to research institutions.

The reliability demonstrated by small satellites in recent years start to generate more thrust in old customers and this is the first form of nutrient for having large institution using small satellites as test platform or to complement existing services. Two new ecosystems are on the horizon: small satellites as a technology platform and small satellite as complement to operational satellites.

## **ACKNOWLEDGMENTS**

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## **REFERENCES**

1. R. Meurer: Key Challenges and Opportunities after 20 Year History of Promoting Small Satellites, Proceedings of the 4S Symposium: Small Satellites, Systems and Services, 25-29 September 2006, Chia Laguna – Italy. ESA SP-625.
2. M. France et Al, The FalconSat-2 Research Program, Proceedings of the 4S Symposium: Small Satellites, Systems and Services, 25-29 September 2006, Chia Laguna – Italy. ESA SP-625.
3. M. Swartwout: Twenty(Plus) Years of University Class Satellites, Proceeding of 20<sup>th</sup> Annual AIAA/USU Conference on Small Satellites.
4. C. Christensen, S. Anthony, and E. Roth: Seeing What's Next, HBS Press, Boston, 2004