The 99$ Satellite

Luca Maresi
European Space Agency
Keplerlaan 1 2200 AG Noordwijk – The Netherlands; +31 71 565 4968
Luca.maresi@esa.int

ABSTRACT

The rule of the game is called 'shared economy'. Some of the most successful companies in the world don't own the assets they sell. Uber, the largest taxi company in the world, does not own taxis. Airbnb doesn't own the houses they rent. This was already the case in the past. For example, tour operators didn't own the hotels in their portfolio. The difference, with respect to Airbnb and Uber, is that in these cases the assets are privately owned and shared with customers. The big revolution of the shared economy is happening thanks to the Internet. The users can check and score the quality of the service, the owners, the honesty and their reliability.

How does this relate to small sats? In the case of space assets, privately owned satellites can't be rented through a 'Spacebnb'. Not yet, at least. With the proliferation of cubesat and picosats, the question is when and how it will happen, rather than if it will happen. The following question is: how will this affect the design and operations of the next generation picosatellites, the space business and the companies currently operating in the sector?

Very often when talking about technology innovation we use words like evolution or revolution. In case of the shared economy, it's more appropriate to talk about transformation. This paper evaluates and discusses new types of business schemes and possible design evolution of small sats that will transform the space business. In a future that might be closer than we think, we may able to rent a satellite, and use it for our own purposes, for just 99$ per application.

INTRODUCTION

Over the years, we heard several times the terms "technology innovation", "technology disruption", and "technology breakthrough". Engineers and companies have been striving to stay on the cutting edge of technology, remain competitive, and keep the right balance between cost and performance of manufactured goods.

More recently, the word 'transformation' started to be used by CEOs to explain companies' strategic actions to move away from their core business to avoid being wiped out by a fast changing economy. On February 4th, 2019 Ikea announced a business *transformation*: from the model of megastores selling furniture and home appliances, to a furniture rental model. Why? Torbjorn Lööf, the chief executive of Inter Ikea, explains that furniture rental is more environmentally friendly, and thus moving Ikea into the circular economy, i.e. from make, use, and dispose to make, use, reuse, and recycle.

With this *transformation,* Ikea is making its products more affordable and more appealing to young generations, especially those on short term work assignments, or those opting for solutions that are more sustainable.

The transformation of the business from use and dispose to a sustainable business does not come for free and requires significant investments, logistic and organizational change. In order to make its transformation, Ikea is rethinking their traditional out of town big-box outlets. Instead, they will place small shops in city centers more readily accessible to clients, and use virtual reality tools to help customers configure the furniture in their homes. As a consequence, Ikea employees will need to be trained for a job that is quite different from what they are currently doing.

BMW, the car company, has estimated that the car sharing scheme will reduce the market of city cars by a factor 30 within 10 years. There is no technology innovation, either disruptive or breakthrough, that will make any car company sustain the current level of sales. BMW and other manufactures have to *transform* themselves into companies handling a fleet of city cars used as daily rentals. BMW is implementing short rentals of 'free-floating vehicles'. After driving the car, users don't need to return it to the pickup spot. Instead, they can park it in any public parking within the company's business area.

Going one step further, multimodality apps like ReachNow are a sort of jack-of-all-trades of mobility planning. Instead of switching between several apps and payment methods, users get everything from a single source. For example, a person might use a vehicle from a car sharing provider to get to a business meeting and travel from there by a shared e-bike to their next

appointment, before using public transport to get home. Bookings and payments are made via a single app. In this scheme, the profit is generated by all the available mobility services. The city cars, once generating a large percentage of the revenues of car manufacturers, will play a minuscule role, also considering that most of the 'free-floating vehicles' will soon be electric.

Morgan Stanley's Benjamin Swinburne calls 2019 a *transformational* year for the media conglomerate. Disney has taken a number of steps to fend off industry disruption, including buying up Fox's studio assets and pushing a streaming version of its ESPN network. But the big test comes later this year, when the company launches Disney+, a streaming service meant to rival Netflix.

These are just three examples of company transformations in three very different market sectors: home furniture, cars for urban transportation and entertainment. What do they have in common? They leverage the Internet and the shared economy. All the users do not own the asset they pay for.

Users are willing to spend money for a temporary use of an asset, rather than investing money to own it. This is the combination of a mentality shift of the customers: young generations are happy to listen music with Spotify, while the Author of this paper, who belongs to an older generation, is still happy owning CDs. But also, software and constant connectivity are making the shared economy possible.

We can 'uber' a taxi, listen to music, see a movie, all thanks to an app running on a smart phone constantly connected to the web, today with 4G, and very soon with 5G.

It is not technology innovation, nor technology disruption, but a combination of new software, mentality shift, fast internet, and constant connectivity that is *transforming* the world's largest furniture retailer, entertainment company, and worldwide employer: the car industry.

The question is not *if* a similar transformation will affect the space business, but rather how and when.

TURNKEY SOLUTIONS

Space business is not new to vertical integration and turnkey solutions. From Airbus to SSTL, space assets are delivered together with the infrastructure to operate the satellite, as well as ground facilities to store and retrieve large amounts of data. Training is also offered to newcomers to the space sector. Customers willing to acquire a space asset are also interested in developing the skills to operate it. The customer can use the data of their space asset for their own purpose, sell the data to third parties, or provide services using the data acquired.

New realities are materializing, such as Black Sky or Planet Lab, delivering high resolution images or global coverage. Plans to build large constellations with hundreds of satellites are announced every so often, all of them with the objective of increasing both spatial resolution and timeliness of images. If all of these plans will materialize, the market will be flooded with satellite images. Competition will be fierce, therefore the cost of images per square km will drop exponentially. Satellite images will be affordable to a larger number of users, and it will, most likely, generate new applications and markets for the products and services obtained with satellite imagery. This is novelty in regard to what has happened in the last twenty years. The phenomenon is accelerating in the recent years thanks to the development of small satellites and their inherently low cost.

THE SWISS ARMY KNIFE OF REMOTE SENSING

If high resolution images will be easily available, why should anybody be willing to buy a satellite or even think of renting one? So far, whenever we speak about remote sensing images, we think about panchromatic, RGB, or at best, of multispectral images with a limited number of spectral bands accurately selected to target specific applications.

The recent developments of hyperspectral systems will be a game changer in the remote sensing landscape. A number of systems are being developed and some of them recently launched. Hyperspectral systems have been compared to a Swiss army knife: for anything we may need, the hyperspectral system will have the required spectral band. The number of publications on hyperspectral remote sensing is growing at a very high pace. Applications of hyperspectral imaging is mushrooming similarly to the use of drones for remote sensing.

The bottleneck for using hyperspectral systems is the data rate they generate. Even a compact hyperspectral instrument produces a massive amount of data, in the order of TB per orbit. Downloading hyperspectral images acquired by a single instrument saturates the bandwidth of any satellite.

Very soon it will be possible to deploy large constellations of compact and cost-effective hyperspectral instruments, with performance ranging from few tens of meters with hourly revisit, to systems able to reach spatial resolution in the range of a few meters and high signal to noise ratio. To download all the data will be unmanageable, also with the next generation of optical link. The ground facility to store and retrieve the data will be very complex and costly. A paradigm shift is needed to fully exploit the potentialities of the next generation compact hyperspectral instruments: to perform the data processing on board and to deliver on ground only the information required by the user.

Powerful microprocessors developed for AI and image recognition can now be used to extract information from hyperspectral images on board and in real time. Applications and possibilities are countless. However, solutions where the on-board software is dedicated to extract some specific information will only satisfy a limited set of users, and not a wide community, as it is the case for data were stored on ground.

Why not then perform a first logical step: several algorithms can be run in parallel to process the hyperspectral images temporarily stored on board to extract any information of interest of a large community in real-time.

Given the fast pace of hardware development stemming from commercial applications, this opportunity will materialize sooner than we think. The only physical limitation to the number of applications that can run in parallel will be the data rate to download the information needed by several users. However, with a little math it is easy to discover that the number of applications that can run in parallel before saturating even a modest bandwidth of a small sat is practically limitless.

THE NEXT LOGICAL STEP: SPACEBNB

In order to imagine a concept where a user can rent a satellite for their own use with a scheme–let's call this Spacebnb–we need a few assumptions and a little bit of imagination.

Let's assume a constellation of compact hyperspectrals that offers hourly revisit. This is already achievable with a limited number of HypersScouts [1], for example.

Each hyperspectral can be equipped with a powerful microprocessor able to run in parallel ten (or more) applications for extracting user information for a given area, such as the stress on vegetation due to drought, or irrigation needs for precision farming. This means that for each region, ten (or more) users can run their own application every hour to increase the likelihood to obtain their product on a cloud free area, or to evaluate the diurnal evolution of the specific phenomenon.

The other assumption is that the user prefers to have direct access to their own data and not to share them with a wide community because their results could be commercially sensitive.

The user will request the owner of the constellation to upload their application, similarly to what is done on a smart phone. The user will pay per square km on which they are running their application and for the data volume of the products they need to download.

Suppose that the charge is 99$ per application for an area equivalent to Oregon, where the extensive irrigation of corn can be optimized to reduce the use of water. Suppose that three passes per day are enough to accurately evaluate the need of irrigation. The cost to accurately monitor the crops to the user will be 297$/day. As it takes 80 days for corn to reach harvest, the cost to accurately water corn will be need 25,000$. Considering that the value of production of corn in Oregon, according to the Oregon Department of Agriculture, was 36M$ in 2017, the cost to accurately grow corn is less than 0.1% of the total value, a negligible portion of the overall value of corn production.

A little bit of extrapolation.

The corn was produced on 44,000 acres, corresponding to an area of 176,000 square km, or easier to visualize, an area of 420 x 420 km.

The cultivated areas, according to FAO, cover 38% of the world's land area, or better 49 million square km. Seventy-percent of this area is dedicated to pastures, and 30% to crops (i.e. 12% of world lands), corresponding 15,5 million square km.

Focusing only on the area dedicated to crops, and limiting the cost to approximately 0.1% of the revenue, the rent of a hyperspectral system has the potential to generate a revenue of several hundreds of million per year. This is only one possible application to areas dedicated to crops, without considering the cultivated areas for pastures, forests for production of wood, and finally monitoring other areas such as rainforest and subarctic areas like tundra that are critical for our eco-system.

Without doing the math for all these areas and different applications, it is clear that even if the 99$ of Spacebnb will conquer a small portion of the possible market, the

potential turnover is in the range of hundreds of millions of dollars.

It is worth noting that the only application mentioned in the example is agriculture, or better, just one of the trends of precision farming. Applications are countless, running from forestry to water management, the latter being an area with numerous applications requiring hyperspectral imaging with fast revisit time or quick access to information. One example is monitoring coastal water for dredging after a heavy rainfall. Management of water basins for bird migrations is another example of a very specific application where end users may benefit from hyperspectral imaging only if the information stemming from hyperspectral systems is easy to access and affordable. Even if each of these applications may add only a few thousands of dollars to yearly revenue, they will contribute to the bottom line of the Spacebnb system, exactly as in Airbnb where the revenues are generated by a large quantity of small incomes and not by big customers. This requires a mentality shift and a transformation in the way satellites are designed, built and run.

The first and foremost transformation is the way the satellite manufacturer will need to approach the market. Satellites manufacturers shall, from the start, set the business to reach the final users. As it was impossible for Airbnb to operate without internet, it will not be possible for the Spacebnb to operate without bridging the cultural gap between the user and the space business. This is surely the big barrier to overcome to generate this new business scheme.

The Chicken and the Egg Paradox

The Author will not be surprised if by now the reader is shaking their head, and is doubting the credibility of the very shallow 'market analysis' presented above.

Regardless of how many use cases are presented, we find ourselves in the 'chicken and the egg paradox'.

The Spacebnb presented here is a 'Non Market', to use the terminology introduced by Clayton M. Christensen[2], as there are no users ready to pay even 99$ for the service, as the final users are too far from Space technology and its use. As a metaphor, nobody will be willing to invest in chickens in a world where nobody knows how to use eggs. Nobody will be able to predict how many eggs a chicken will produce and at which price they can be sold, at least until the moment the first pie will be put on the market. But there is no way to make a pie and sell it without the eggs and experimenting with the recipe to make it.

In the case of the hyperspectral at 99$, not only do we need to enter the market not knowing how many eggs we will produce, but we need to also be willing to transform the business without knowing what other products can be offered as 'derivatives' of hyperspectral images. Similarly to the urban transportation, where the total turnover is not coming from the car rental, but from the additional services, Spacebnb will be a wide combination of products and services.

Other users interested in the Spacebnb could be developers of new algorithms, such as research institutions willing to experiment on hyperspectral data. These research institutions could also be minor universities that do not have access to space assets.

Another business is education: anybody willing to learn how to use a remote sensing system will be given the possibility to experiment and learn with hyperspectral imaging systems and to operate them in real time for an affordable price.

Finally, one more business is the revenue generated by 'third party apps', similarly to what happens with smart phones. A developer of an app to process hyperspectral data could sell it to other users with the same needs, but not having the resources or the capability to develop it.

Again, this will require the proper infrastructure where hyperspectral systems will need to be developed to ensure compatibility of third party apps. Therefore, another cultural shift is needed by the developer of hyperspectral systems toward the use of open architectures and interoperability of hyperspectral systems.

DRIVING A REVOLUTION

The free press and its impact on the society was a consequence of the invention of Gutenberg's printing press. Surely, Gutenberg could not imagine the extent of the cultural revolution induced by his invention. The internet has impacted our society in a fashion that goes well beyond any imagination we had when it was introduced. Giving access to worldwide hyperspectral images for a very affordable price will surely have an impact on our society. Similarly to the internet, where information can be manipulated to generate fakes news or used by terrorists, access to hyperspectral images can have undesired applications.

As for all the revolutions, it will be necessary to foresee something that now cannot be predicted from the start. This is nothing new in our world. Social media, perhaps the most recent cultural revolution, is a very recent example: companies may face charges because of misuse of the information they made available.

Hyperspectral systems from space has the capabilities to detect, identify, and classify any categories of land of any part of the globe with resolution down to meters. It is not difficult to imagine that these tools could be used to harm other people if they fall in the wrong hands.

In the Author's opinion, the biggest challenge Spacebnb may face is to ensure that this revolution will provide a new powerful system solely dedicated to help humanity grow organically and in harmony with our planet.

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