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SAFEGUARDING HUMANKIND'S HERITAGE, THE GREAT CHALLENGE FOR ENGINEERS

# New Technologies and Service Prospects for the Space

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**Abstract**

Progress in technology has pushed the space community to focus on miniaturization of conventional satellites. Now the small satellite term does not just mean the educational satellite but extends to business for a large number of industries and large service companies. The miniaturization of satellites has opened new business opportunities for Telecommunications and Earth observation services.

Contrary to their size, the amount of data captured by these small satellites is large and growing. Existing data aggregation satellite systems (like Copernicus or GEOSS) will directly benefit from increased data from small satellite transmission capacity. This will have an impact on the amount of data available for some humankind safeguarding applications such as control of migratory flows of refugees and asylum seekers, control of natural disaster, control of agricultural resources and pollution.

The future of satellite services and applications will be measured by the ability to integrate different technologies, constellations and spatial segments (GEO, MEO, LEO) with the next generation 5G Mobile Terrestrial Network in order to reach the user directly.

Keywords: small satellite, cubesat, microsat

## 1. Small Satellite - Introduction

Small satellites are located on Low Earth Orbits (LEO) between 400 km and 800 km above the Earth's surface and have a visibility time from the receiving earth station in the order of 8 to 15 minutes. In this short period, all information gathered along a full orbit must be discharged to the receiving ground station. The characterization of these small satellites is shown in Figure 1.

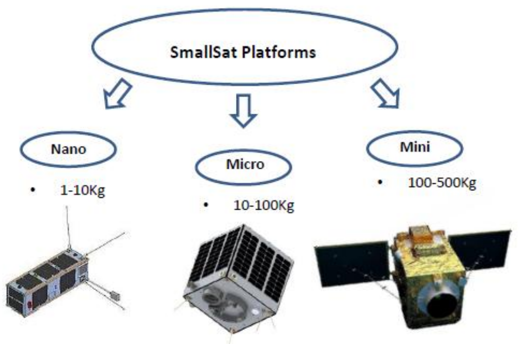
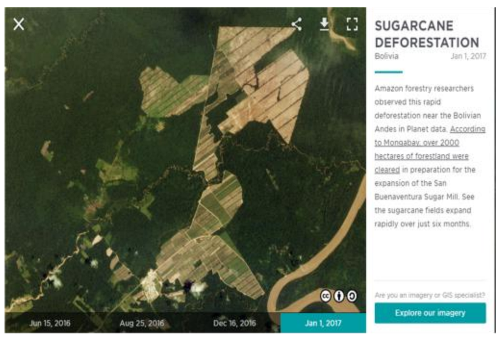



**Figure 1. Small Satellite Characterization**

The most commonly used frequencies for data transmission from small satellite (nano, micro and mini) to ground facilities are the C (5-6 GHz) and X (7-8 GHz) frequency bands while the S (2 GHz) frequency band is normally used for telemetry and remote control.

Crucial applications for this kind of small satellites could be:

- Control of migratory flows of refugees and asylum seekers in the Mediterranean Sea;
- Control of Natural Disasters in Italy;
- Monitoring of Agricultural Resources and Pollution.




Imagine acquired by Cubesat Doves (©Planet)

## 2. Bit Trasmission Rate and Technology

The maximum bit rate reached up to-date by these nano and micro-satellite missions is about 100 Mbps.

So there is a great deal COTS (commercial off the shelf) technology to increase the transmission capacity of up to 500-1.000 Mbps on board these small satellites by:
- Standardization of Nano satellites;
- Frequency bands less crowded such as the Ka (26 GHz) band;
- Communication Technologies like Software Defined Radio (SDR);
- Photonic technologies for signal processing and optical signal transmission systems;
- High-definition sensors/cameras for data acquisition.

Another important aspect of this technological revolution is the integration of these small satellites and their constellations with the 5G terrestrial mobile network to provide services such as:
- Dissemination of Data to End Users;
- Realization of Integrated Services Centers with the 5G Network;
- Android Applications for Data Dissemination.

**3. Standardization of Nano Satellites**

Just like smartphones, satellites are becoming smaller and better. The Nano satellites today can do almost anything that a conventional satellite does, and even at a fraction of the convention satellite cost. And though no one contests that small satellites can not replace larger conventional satellites because of the pixel high resolution that the latter offer, both governmental and start-up organizations are trying to get a piece of the small cake. Only in 2016 about 300 satellites were launched, weighing between 1 and 50 kg.

The realization and success of commercial-based satellites is the first indication of the need for a change of technology. Various private initiatives in the United States, aimed at dramatically either reducing the cost of satellites launches and lowering their lifecycle costs, have led to the standardization of CubeSat satellites falling within the Nano Satellite typology.

**Figure 2. Cubesat Standard**

The Nano Satellites were born as a tool of great utility in advanced didactic projects in the space sector but, thanks to the continued miniaturization of electronic components, they soon began to have similar capabilities to those of the larger satellites and attracted the attention of others aerospace world players for Earth Communication and Observation applications.

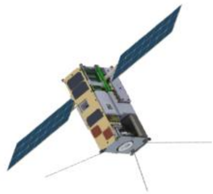


**Figure 3. Cubesat 6U Typology**

The short time period, from the design to the implementation of a micro satellite, allows to use components and payloads at the state-of-the-art. In addition, standardization in the Cubesat class has produced two great advantages: firstly, the existence of a large community of operators working on the same platform and addressing similar problems by providing solutions that are widely shared over the Web. A second advantage is that standardization has produced automatisms in the integration into the launchers. There are several launchers (Vega, PSLV, Dniepr) that accept cubesat even a few months before the launch if they are released by the standard system (the PPOD).

Contraindications are mainly related to the electrical powers that can be made available *(small satellites = little surface for solar panels)*.

**4. New Service Prospects for the future**

What is required for future satellite technology is therefore:
- Greater integration with land systems, adopting compatible standards allowing cheaper equipment and flexible bidding by operators;
- System Efficiency Increase, in order to reduce the cost per bits with limited power satellites adopting advanced technologies like DVB-S2X and SDR;
- On-board processing, more flexible and with a large number of interconnect bundles;
- Scalable satellite systems smaller and more powerful in order to avoid high costs.

Such satellites can be interconnected in orbit via inter satellite links (ISL), as well as they grow in number and flexible reconfiguration demand is required.

**5. Smallsat Application Areas**

Small Satellites in Low Earth Orbit (LEO) are often deployed in a constellation because the coverage area of a single satellite is relatively small. To maintain a continuous coverage of a particular area of the globe, several satellites are needed in low earth orbit.

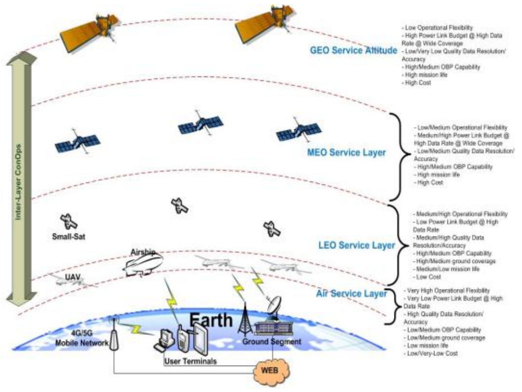



**Figure 4. Future Scenarios for Satellite Services**

Broadband applications benefit from short latency, so the LEO satellites have the significant advantage of having latency times of about 1-4ms compared to the theoretical 125ms of a geostationary satellite.
Therefore the main application areas for the smallsat constellations are related to:

- *Security* - The new geopolitical scenarios are pushing for growing security demand, both for civilian and military reasons. Particular emphasis should be placed on the management of <u>migratory flows and their territorial distribution</u>, both in terms of economic and cultural sustainability;

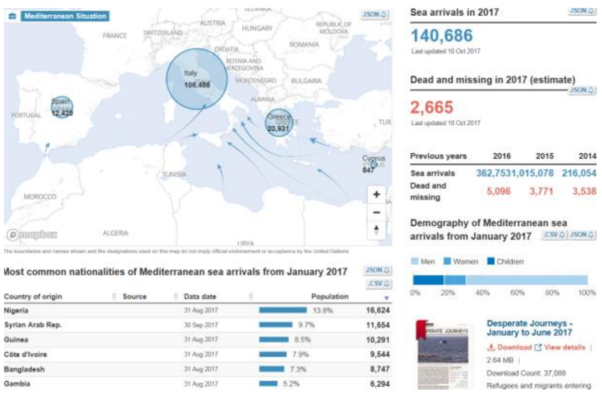



**Figure 5. Dashboard with daily tracking**
(slide of October 10, 2017)

- *Search And Rescue (SAR) operations* - The term SAR refers to a set of rescue operations conducted by trained personnel in conjunction with the use of specific naval, aerial or land-based facilities for the safeguarding of human life;

- *Environment and Territory* - <u>Climate changes</u> and previous environmental stress, also determined by human action, <u>require increased attention both in monitoring and emergency management</u> and after natural disasters.

## 6. Control of Migratory Flows via Smallsat Mission

In recent years, one of the major social problems is the illegal immigration of refugees. This 'Exodus' does not concern individual states, but it involves the entire European Community at different levels:

- Humanitarian
- Safety

How to minimize or prevent a migratory stream now out of control? Is it possible to use smallsat platforms to support existing resources? That is possible with smallsat mission having as a scenario of observation a portion of the Mediterranean Sea, with its sensitive areas, as a starting point for migratory flows. Area considered: square of about 500 km per side

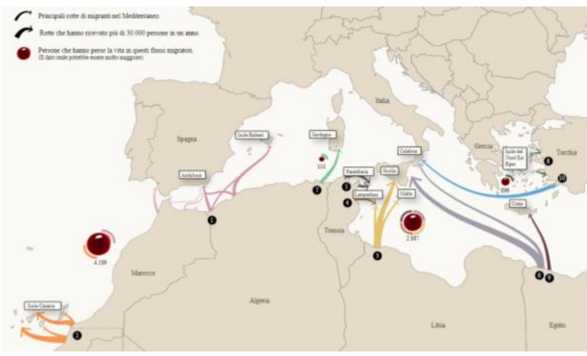


**Figure 6. Scenario of the migratory flow in the Mediterranean Sea**

An example of a satellite mission consists of a constellation of 8 cubesat 6U that make Earth Observation with optical sensors on a helium-synchronous orbit 650-750 km away from the earth.

- Optimal orbit and Smallsat number
- No. of satellites: 8
- Inclination: 35 °
- Estimated time of observation of square area for orbit: 2.5 min
- The maximum time between one observation and another (GAP): 100 min
- Operating Life: about 2 years

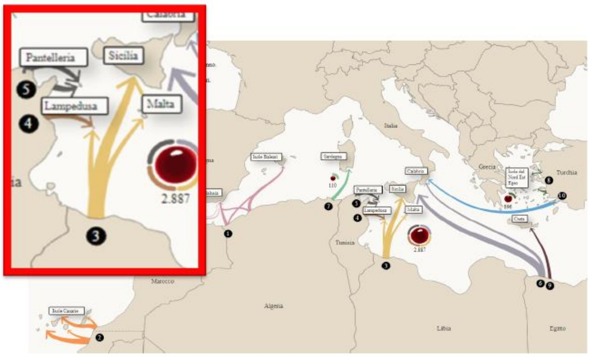



**Figure 7. Example of Satellite Mission in the Mediterranean Sea**

## 7. Ka Band Utilization and SDR Technology Developments

Regarding the use of new COTS technologies applicable to Small Sat particularly for Earth Observation (EO) applications, the advanced developments in the following fields are reported:

- Ka band at 26 GHz provides bandwidth 4 times greater than X bandwidth. The final report of the 2016-11-18_LEO26SG Expert Group says: "The 26 GHz frequency is a viable option for ground-based communications from low orbital space vehicles (LEOs). Mission planners may neglect the frequency of 26 GHz because of their insecurity, perceived risks, or the ease of implementation of a mission using a standard approach. Not considering the use of the 26 GHz band, however, missions may miss the opportunities offered by higher frequencies. " The generic functions of a 26 GHz communication system are shown in the block diagram of Figure 8 (extracted from the final report 2016-11-18_LEO26SG).

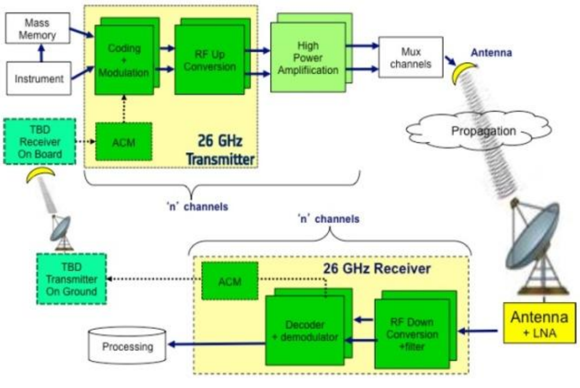



**Figure 8 - Communication System at 26 GHz**
extracted from the final report 2016-11-18_LEO26SG

- On ESA programs compact Ka antennas (20x20 mm size patch antennas) and low cost RF (LNA and SSPA) devices are under development in order to be installed on SmallSat satellites to illuminate the Earth Receiver with sufficient beam widths during the passage in sight on the LEO orbit (8-15 minutes); moreover, the next GaN (Gallium Nitride) SSPAs will soon become a much more attractive solution since their efficiency and output power (approximately 10 W) will generally double the performance of the existing SSPAs already existing in GaAs (Gallium Arsenide);

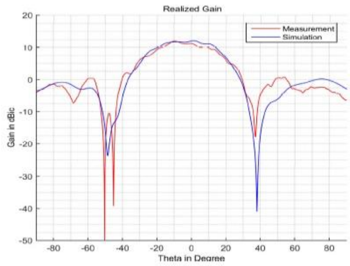



**Figure 9 - Patch Antenna at 26 GHz - Radiation Diagram**

Development of Modem based on SDR Communication Technologies utilizing programmable FPGA (Field Programmable Gate Array) signal processor, which provides a communication system capable of adapting to changing weather conditions with variable modulations from 8PSK up to 64 APSK, using Adaptive Codes and Modulations (ACM and VCM).

**Figure 10- FPGA Board**

## 8. Integration with the Terrestrial Network 5G and Service Development

The Integration of the Satellite Network with the 5G Terrestrial Mobile Network can create a variety of Service and Application Opportunities for mobile users. The architectural scheme of this network is shown in Figure 11.
With this architecture and with Reliable Terrestrial Smart Gateways as an interface for 5G Mobile Terrestrial Network, several Services and Applications could be created, such as:

- Processing of Received Data from Smallsat;
- Dissemination of Received Data to End Users;
- Realization of Integrated Services Centers with

the 5G Network;
- Data dissemination applications.

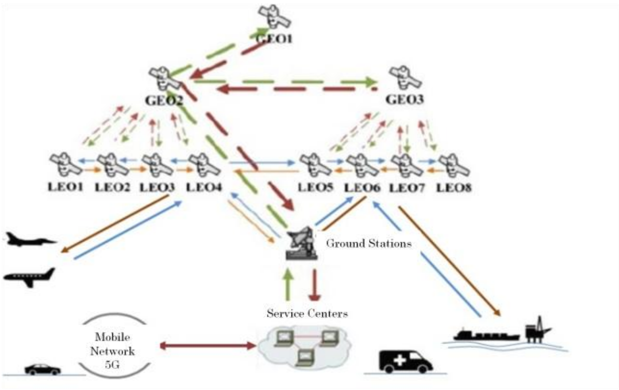



**Figure 11- Architecture Space-Terrestrial Network**

The development of new technologies in the terrestrial segment (such as low-cost and low-power satellite equipment, electronically controllable dynamic beam, phased-array satellite systems) will make the use of satellite interesting for the IoT.
The future of satellite services and applications will be measured by the ability to integrate different technologies, constellations and spatial segments (GEO, MEO, LEO) with the next generation Terrestrial Network in order to reach the user directly.
Some examples of the Satellite integration in the 5G Network are shown in the following figures.

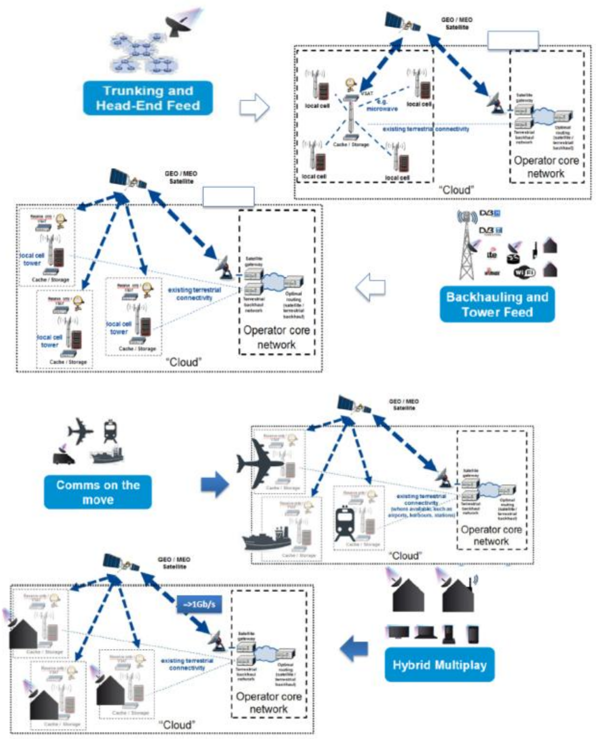



**Figure 12- Examples1 of Integration 5G-Satellite**

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