Grenoble NewSpace Week

14-17 May 2019
Grenoble
France
The Grenoble NewSpace Week 2019 workshop was organized by the Grenoble University Space Center (CSUG). This is the second edition of a series of workshops that started with the successful 2016 workshop on The Future of Nanosatellites. The final day of the workshop is dedicated to Climate and Earth Observation. This Friday program is organized together with the French National Space-borne Remote Sensing Program (Programme National de Télédétection Spatiale, PNTS), co-financed by CNES, CNRS INSU, IGN, IRD, and Météo-France.

The official language of the conference is English, except for the public conference in French on Friday evening.

NewSpace is the term used for a new development in the design and operation of space missions that diverges from the traditional mode of operations previously established by national space agencies. Driven by the arrival of small (nano-) satellite systems and launch capabilities, non-traditional actors such as universities and small to medium sized enterprises have been given access to space. Initially focused on training a new generation of space engineers, notably through student projects involving the CubeSat standard, developments over the past few years have been towards more and more ambitious missions with real scientific, societal, and commercial returns.

CubeSats have been developed for Low Earth Orbit operation with the purpose of, among others, Earth Observation, Climate, Satellite communications, Astronomy and Space Weather studies; and even an interplanetary mission to Mars.

This workshop focuses on the advanced payloads, subsystem designs, their standardization, and supporting technology like data management, data analysis, and artificial intelligence that together make highly ambitious NewSpace missions possible. As such it addresses an audience of students, educators, policy makers, scientists and engineers in the NewSpace domain.

We look forward to very interesting and exciting presentations, and engaging discussions. It is our wish that just as the previous edition, this workshop will lead to new ideas, the start of new projects, and new collaborations in the NewSpace domain!

Finally, we thank all CSUG and other team members who helped us create the program and take care of the logistics, and in particular: Pierre, Melanie, Nathalie, Aveline, Laura, and Raluca.

For the organizing committee,

Erik Kerstel, Mathieu Barthelemy, and Eric Defer
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<td>LEADERSHIP &amp; POLICY</td>
<td>9:00 ESPI: Genevieve Fioraso</td>
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<td>9:20 CNES: Michel Faup</td>
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<td>9:40 CybELE: Robin Bouvier</td>
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<td>10:00 JAXA: Ms. Fuki Taniguchi</td>
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<td>LEADERSHIP &amp; POLICY</td>
<td>11:00 ESA: Maria-Gabrielle Sarah</td>
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<td>11:20 NASA: Timothy Tawney</td>
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<td>11:40 European Commission: Vera Pinto</td>
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<td>12:00 Min. Hi. Edu.: Alban Duverdier</td>
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<td>12:20 UGA President: Patrick Lévy</td>
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<td>(Moderator: Damien Garot)</td>
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<td>SELECTED POSTERS &amp; INDUSTRY EXHIBITS</td>
<td>14:45 CSI-Grenoble: Eric Martinet</td>
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<td>15:00 T-Minus: Roel Eerkens</td>
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<td>INSTRUMENTATION</td>
<td>16:15 JPL CRDS: Brad Gibson</td>
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<td>16:45 UGA: Silvere Gousset</td>
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<td>17:00 ALAT: Remi Vincente</td>
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<td>17:15 ThrustMe: Romain Clervoy</td>
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<td>17:30 Pyxalis: Benoit Dupont</td>
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<td>17:45 Teledyne-e2v: Joel Vaillant</td>
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## Program | Wednesday, May 15

### 8h30
**INTERNET OF THINGS**

- **8:30** Semtec: Francois Sforza
- **9:00** ThingSat: Didier Donsez
- **9:30** Teledyne-e2v: Thomas Guillemain
- **10:00** NanoAvionics: Tariq Sami

### 10h15
**COFFEE BREAK**

### 10h45
**ARTIFICIAL INTELLIGENCE**

- **10:45** Neovision: Etienne Balit
- **11:15** UA Barcelona: Miguel Hernandez
- **11:45** Delfox: Maxime Rey

### 12h30
**LUNCH**

### 13h30
**COMMUNICATION**

- **13:30** Airbus OneWeb: De Saintignon
- **14:00** Teledyne: Nicolas Chantier
- **14:15** Teledyne: Romain Pilard

### 14h30
**SELECTED POSTERS & INDUSTRY EXHIBITS**

- **14:30** TOLOSAT: Pierre Seeleuthner
- **14:45** Rad Hard: Odilia Coi
- **15:00** PAC-G: Rafael della Giustina

### 15h15
**COFFEE BREAK**

**POSTER SESSION**

**EXHIBITION**

### 16h15
**PLANETOLOGY & ASTROPHYSICS**

- **16:15** NASA MarCO: Andrew Klesh
- **16:45** ESA HERA: Ian Carnelli
- **17:15** PicSat: Lester David

### 18h00
**COCKTAIL DINNER (IUT1 Hall)**
# Program | Thursday, May 16

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<td><strong>SATELLITE COMMUNICATIONS</strong></td>
<td><strong>AMSAT/SatNOGS</strong>: Julien Nicolas</td>
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<td><strong>QUBE</strong>: Peter Freiwang</td>
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<td><strong>NanoBob</strong>: Erik Kerstel</td>
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<td><strong>Open Cosmos</strong>: Tristan Laurent</td>
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<td><strong>Hyperion</strong>: Gilles Ackaert</td>
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<td><strong>SPACE WEATHER</strong></td>
<td><strong>Picasso</strong>: Sylvain Ränier</td>
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<td><strong>ESA D3S</strong>: Melanie Heil</td>
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<td><strong>MSU</strong>: Vladimir Kalegaev</td>
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<td><strong>ATISE</strong>: Mélanie Prugniaux</td>
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<td><strong>AmicalSat</strong>: Mathieu Barthélémy</td>
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<td><strong>SCIENCE PROJECTS WITH STUDENTS</strong></td>
<td><strong>Polytechnique</strong>: Lilia Solovyeva</td>
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<td><strong>Aalto</strong>: Jaan Praks</td>
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<td><strong>Robusta-1b</strong>: Laurent Dusseau</td>
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<td><strong>OGMS-SA</strong>: Noel Grand</td>
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<td><strong>NanoAvionics</strong>: Tariq Sami</td>
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<td><strong>EXOBIOLOGY</strong></td>
<td><strong>SatRevolution</strong>: Adrianna Graja</td>
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<td><strong>LISA Paris</strong>: Noel Grand (IR-COASTER)</td>
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<td><strong>Montpellier</strong>: Muriel Bernard</td>
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# Grenoble NewSpace week 2019 I From payload to uses

## Program I Friday, May 17

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At least three main interlinked statements on the development of the international space sector during the last decades refresh the subject of regulatory systems on a global scale. At first, it should be acknowledged the exponential increase of human activities in space linked to the undeniable democratization of technologies. This first reality possesses inherent ties with the increase of privatization and commercialization on both the ground and the space segments. Finally, the two trends are connected to a multi-polarization phenomenon in term of governance due to the scattering of the entities in charge of space activities. The study of these three considerations is important to understand the disconnection between the actual space sector and the existing international legal framework. Indeed, the absence of adjustment in treaties, like the Outer Space Treaty (O.S.T), agreed in a state-centric Cold War historical context causes both insufficiency and unsuitability for the pragmatic regulation of space activities. Many emerging legal issues remain unanswered by international space law. This is, for instance, the case of property rights in outer space, the liability of private actors conducting space operation or the protection of individual rights in remote sensing activities. Several states recently engaged in a legalization process of their space sector to fill the gaps. Domestic laws notably ensure the control of private initiative to avoid being held liable for them under the international responsibility regime (related to the concept of fairing State). Yet, current comparative study of space laws reveals numerous divergences that incur detrimental effects related to the phenomenon of regulatory competition. Therefore, other legal alternatives should be sought. Such might includes the implementation of global commons regimes, under the international public law, as well as the use of insurance or international commercial arbitration tools existing in the international private law.

**Keywords:** Law, Policy, New Space, Regulation, International Law, Regulatory competition, Global commons

*Speaker*
French Space Policy : Space as Driver for Research & Innovation

Alban Duverdier *† 1

1 Ministère de l’Enseignement Supérieur, de la Recherche et de l’Innovation – MESRI – France

The presentation will focus on the French space policy and show how the French government supports new research and innovation useful to the space sector. Projects are built at the national level especially through the French space agency, CNES, and at the European level. In France, the development of new university space centers offers now a new resource creating practical courses of space studies, increasing the link between higher education and space industry, and achieving trained students with high quality skills and knowledge from the space systems to the user services.

Keywords: policy
CNES views on the Newspace challenges

Michel Faup * 1

1 Centre National d’Études Spatiales – Centre national d’études spatiales - CNES (FRANCE) – France

At the turn of the century, both USA and Europe made strong strategic decisions concerning space future. Indeed, Europe launched Galileo and GMES (well-known under its present denomination: Copernicus) in view to protect an independent access to navigation signals and to concur to the strategic monitoring of climate parameters evolutions. The American Newspace strategy consists in a public-private cooperation aiming at reducing the space infrastructure development costs and ensuring an American space dominance.

With the rise of the New Space, the way space can address the human challenges for the 21st century (climate change, globalization...) has also radically changed. This is due to the combination of several factors:

• With the emergence of a data-driven economy, Earth observation, positioning and communication satellites are today seen as vital links in the global digital infrastructure. Satellite data are fueling development of numerous services that are set to become part of our daily lives and businesses in fields such as environment, healthcare, mobility and many more. Hence, the use of space data has become a major focus for the giant businesses of the digital age and it is no surprise that the iconic leaders of the New Space are businessmen coming from the Internet world.

• The advances in engineering like 3D printing, electric propulsion, composite materials, or in digital technologies, like artificial intelligence, deep learning methods and powerful algorithms make access to space affordable to more and more people, private and institutional entities, in more and more nations. Originally external to the space business, the new comers bring a fresh approach to space activities in the way they carry out their activities, with keywords such as: pioneer spirit, boldness, simplicity, reactivity and customer-oriented services, incremental deployment newcomers to freely imagine new disruptive ideas.

• This burgeoning new space era is also triggering the emergence of a new generation of dreamers who intend to progressively introduce an industrial activity in orbit (in orbit manufacturing, extra-planetary resources exploitation), pave the way for human conquest of the Moon and Mars and organize touristic trips in orbit. The dreams of these new innovative entrepreneurs, if they come true, and we can reasonably assume that they will come true, will also contribute to change our business and our lives.

• Space may no longer be seen as an independent ecosystem, applications will no longer rely on space data but on the fusion of data coming from inhomogeneous systems: in situ measurement systems, airplanes, UAV’s, balloons, satellites from diverse entities delivering complementary data concerning various complementary parameters.

*Speaker
As a conclusion, newspace approach leads to a strong increase in the sector dynamics and complexity. The best way to face this challenge is to increase our cooperation capacities, at the level of countries for more ambitious scientific missions, at the level of space industries for suitable integrated technological solutions, cooperation between upstream and downstream actors for resilience to the global verticalization movement in the industrial chain, cooperation between ecosystems for the sake of cross fertilization, cooperation at market level for strong partnership in order to handle regional and local disparities.

**Keywords:** Newspace, challenges
Paradigm shift in Space: threat or opportunity for European research and industry?

Genevieve Fioraso *† 1

1 Chair European Space Policy Institute Advisory Board and Chair of Saint-Exupéry Institute of Technological Research for aeronautics and space, former French minister of higher education and research – ESPI and Saint-Exupéry IRT – France

I will describe the Space sector’s current revolution mainly due to digitalization, miniaturization and Californian IT newcomers and evaluate the European adaptability to this new environment. NewSpace, its various fields of application, its uses-pull culture, whereas space was formerly techno-push, can be seen as a threat but also as a fantastic opportunity for European research and industry, provided that they accelerate their cultural revolution, opening the Space sector to innovation and downstream applications.

Keywords: NewSpace, European Research, European Industry
Space means Business

Vera Pinto Gomes * 1

1 EU Space Programmes - European Commission – Belgium

Investment in the European Union (EU) space programmes is essential for Europe and its industries as we strive to maintain Europe’s competitiveness in the sector. With a proposed budget of EUR 16 Billion for 2021-2027, the European Commission is showing its commitment to Europe’s space endeavours and to its high tech industries. The European Commission also has to ensure that the market absorbs and makes best use of its space service. To make this a reality - innovators and entrepreneurs will be at the heart of this. Strong and seamless links between all sectors in Europe and the space community are crucial.

One of the European Commission’s core objectives, at least from a technology perspective, is to create conditions that enable innovation and entrepreneurship. This too is the aim for space: build a legacy of converting the benefits that EU Space technologies and services can offer into generating real dynamism in the wider economy.

To date, the European Commission is supporting R&D to support innovation in both the up-stream and downstream sectors. It is also targeting businesses and entrepreneurs with the Galileo and Copernicus Masters competitions, the Galileo and Copernicus Incubator / Acceleration programmes. These have produced very promising results since they were introduced more than 10 years ago. Now, thousands of European entrepreneurs and businesses have participated in the competitions – hundreds of prizes have been awarded with many applications relying on space technologies finding their way onto the market.

It is very clear however that the European Commission needs to do more. It has to help create a fertile playing field – to make sure that the journey from idea generation to bringing good ideas to the market is not a bridge too far.

Space start-ups, innovators, researchers that would like to become entrepreneurs have to look closer at market needs. Good solid business plans tackling real problems. Competition is tough, so start-ups need to equip themselves with business and management skills beyond pure technical competence.

Going forward, the European Commission is scaling up investment in its space programmes. Europe Commission is committed to pursing targeted initiatives that leverage innovation. In the proposal for the next EU Space Programme 2021-2027, the European Commission has included the possibility of supporting designated ‘Space Hubs’ - cooperation undertakings which bring together regional and national actors from Europe’s space and digital sectors, as well as from end-user communities. This would enable new business ventures - linking space technologies, assets and expertise to other industrial sectors and will facilitate the spill-over of ‘space’

*Speaker
into the wider European economy.

Europe will have to leverage the successes we are celebrating today, the experience of Galileo/Copernicus Masters, Incubators and Accelerators to make sure we find solutions to accompany new ideas.

In all, the European Commission is committed to its space endeavours going forward and to boosting entrepreneurism in the sector as we push to realise the potential and benefits of space for our economy.

Europe must be ambitious. It must be competitive and must fight to maintain its position as a global player in space. The European Commission is doing its part with the proposed investment in the next MFF. But business and investors, too, have a key role to play going forward. Industry has to invest where it matters: in R&D, in disruptive technologies and in our future. Investment is key.

Keywords: New Space, Galileo, Copernicus, start, ups, investment, Europe
The European Space Agency and New Space

Maria-Gabriella Sarah *† 1

1 Agence Spatiale Européenne – European Space Agency – France

With the emergence of new players in the Space arena, ESA is adapting its way of working and of interacting with young and rapid decision makers, stemming from small to medium sized companies. How is this new reality impacting the financing of programmes and how is ESA integrating these new talents in its programmes? Has the Old Space something to bring to New Space? And what are the prospects for the future years?

Keywords: ESA, NewSpace

*Speaker
†Corresponding author: Maria-Gabriella.Sarah@esa.int
Space Activities in Japan: New Ways of Partnerships with the Industry

Ms. Fuki Taniguch *† ¹

¹ JAXA, Japanese Space Agency, Paris Office – Japan

In Japan, the number of main players in the Space activities area was limited so far. However, Japanese companies are getting involved in Space activities and now some startups are very active in the global field. This presentation provides the Japanese governmental challenges and supports to encourage industrial new business in this field.

Keywords: JAXA, Japan, Space Agency

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*Speaker  
†Corresponding author: taniguchi.fuki@jaxa.jp
The role of the changing Commercial Space landscape in NASA’s planning

Timothy Tawney *† 1,2

1 NASA – United States
2 U.S. Embassy Paris – U.S. Embassy Paris, 2 Avenue Gabriel, Paris Cedex 08, 75382 France – France

The presentation will examine the ways NASA, and the broader United States Government, is working with commercial partners, including New Space actors, to encourage and promote the development of a thriving commercial space sector. It will look at how this evolving space economy is changing the way agencies plan programs and think about future partnerships. It will also consider several long-running mechanisms that NASA continues to utilize to support start-ups.

Keywords: NASA, United States, Space Agency

*Speaker
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Development of an integrated iodine space thruster for CubeSat missions

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1 ThrustMe – ThrustMe – France

With the disruption into the market of new actors that will play an important role in the development of research in space, the need of more accessible propellants is key for the improvement of the space systems. This abstract focuses on the research and development of an integrated iodine cold gas thruster, and on its benefits for the CubeSat ecosystem.

Iodine has a relatively low vapor pressure at ambient temperature, allowing the design of systems without any pressurization requirements. It is easily sublimated at moderate temperatures, making for a simple cold gas propulsion system. Iodine has a lower cost and a higher storage density than Xenon making it ideal for low-cost missions with volume small volume constraints, however it has the drawback of high chemical reactivity.

The extensive research performed during the three experimental campaigns of 2017 and 2018, has provided an understanding of the corrosion mechanisms of iodine, providing comparative data on the change of mechanical (changes on weight, fracture mechanisms, mechanisms of delamination and cracking), optical and electrical properties.

The control of the flow is performed through a nozzle which expands and accelerates the gas to supersonic conditions (typical velocity at the exit for iodine of 130 m/s). These flows are choked in vacuum, and under-expand at the exit, being of importance the reduction of flow divergence.

The manufacturing of these systems is challenging, and the effect of iodine on the roughness of the walls may be critical for the operation. Therefore, the simulation and performance of these devices in new materials is key for the development of the system and has been thoroughly done for the different regimes of operation. The cold gas thruster developed can provide a thrust of 0.2 mN, with a power consumption of around 3 to 5 W in steady state conditions. The low power consumption was a necessary feature to satisfy the requirements of CubeSats which have very limited power resources.

This cold gas propulsion system can deliver over 50Ns of total impulse in a 0.5U package. For a typical 4kg 3U CubeSat, this represents over 10m/s of DV. This added maneuverability is important at a time where debris avoidance regulation is becoming a growing concern and regulating bodies are suggesting the compulsory use of propulsion for CubeSats above the ISS’s orbit. It provides a simple and low-cost collision avoidance solution for LEO CubeSats. CubeSats without propulsion must resort to differential drag maneuvers which are imprecise and reduce the
satellites’ orbits thus reducing their lifetimes. For satellites on orbits below 450km, this cold gas propulsion system also helps compensate for drag, therefore ensuring the satellite’s orbital maintenance and extending its mission lifetime.

**Keywords:** Propulsion, Iodine, CubeSats
A novel compact Hyperspectral platform for auroral imaging

Benoit Dupont * 1

1 Pyxalis – Pyxalis (FRANCE) – France

With the down-size of spacecraft for earth observation in volume, power and budget, there is a pressing need for new, more affordable, easier to integrate, instrumentation sensor. Within these constraints, CSUG and Pyxalis have developed a new sensor platform for earth observations, with the primary application of measuring the spectral content of aurora borealis, both in day and night time. In the frame of a European Space Agency contract, the team is breadboarding two variants of the imagers: one visible light version and one BSI UV imager with the intend ot reach ultimate payload capacity for such mission.

In this presentation we will share the instruments being developped, the intended mission profile and a focus on the image sensor being used for this development, as it was developed for hyperspectral imaging and one of the primary application for this device is new-space imaging and earth observation.

this work is carried under ESA contract.

**Keywords:** image sensor, CMOS, earth observation, ESA, Pyxalis, CSUG, cubesat

*Speaker*
A Miniature Ring-Down Spectrometer for CubeSat-Based Planetary Science

Bradley Gibson * 1

1 Jet Propulsion Laboratory – United States

Although most CubeSat applications to date have focused on Earth orbital uses, the recent success of the Mars Cube One mission opens the way for additional planetary science missions. In this presentation, we will discuss the possibility of using a CubeSat bus to deliver an atmospheric probe based on a miniature cavity ring-down spectrometer to planetary targets such as Venus or Saturn. This would provide a relatively inexpensive means of developing flight heritage for a modernized version of the Tunable Laser Spectrometer (TLS) instrument deployed as part of the Mars Science Laboratory (MSL) mission while also delivering meaningful science returns. We will focus on the basic components of an in-situ absorption spectroscopy probe and how implementing modern instrument designs allow us to fit these components within the limited space of a CubeSat bus while still improving performance relative to the MSL-era TLS. We will also discuss a laboratory prototype instrument developed at the Jet Propulsion Laboratory as a first step towards a CubeSat-based instrument. This prototype improves upon the sensitivity of TLS by a factor of nearly 200, while also decreasing the sampled volume by a factor of nearly 200. The approach used should be applicable to any wavelength from the UV to 5 microns with comparable or improved performance, enabling a wide array of spectroscopic targets.

Keywords: Spectroscopy, Infrared, Miniaturization, Planetary Science

*Speaker
NanoCarb: a miniature imaging spectrometer for greenhouse gases monitoring from small satellites

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3 Laboratoire des technologies de la microélectronique – Commissariat à l’Énergie Atomique et aux Énergies Alternatives (CEA) - Grenoble – France
4 Airbus Defence and Space [Toulouse] – Airbus Defense and Space – France

The Space CARBon Observatory (SCARBO) European program aims at assessing the monitoring of anthropogenic emissions of GreenHouse Gases (GHG) with the uncovered goal of a daily and global revisit of the Earth at an affordable cost. One of the main project’s scopes is the feasibility study of a hybrid constellation including both high accuracy reference missions and multiple small satellites based on innovative miniaturized payloads. The key GHG sensor of the project is the NanoCarb concept: A unprecedently kilogram-class Fourier Transform imaging spectrometer achieving both large swath (128 km), high spatial resolution (2 km), and high spectral resolution (R between 3000 and 5000) in near-infrared. The concept exploits 1) a new kind of silicon based micro-optical component, and 2) an unusual sparse interferometric sampling strategy to target only the useful information. These key features enable an optimal use of large focal plane array, maximizing signal to noise ratio while achieving a very compact design for a high GHG sensitivity. The SCARBO project addresses many challenges concerning NanoCarb: technologic development, optical design, data processing, from theoretical analysis to airborne proof of concept. We introduce first the NanoCarb concept and its specificities, illustrated by a presentation of the adopted design strategy. Then we derive some key performances, and finally present some lab realizations and experiments.

**Keywords:** Imaging spectrometer, GreenHouse Gases monitoring, Earth Observation, small satellites

*Speaker
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**COTS : Application of CMOS image sensors for Space**

Joel Vaillant * 1

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During this last decade, Space Imaging has faced at least 2 major evolutions: one is the progressive transition from CCD to CMOS image sensors and the second is the Newspace environment especially linked to nanosatellite development. CMOS COTS image sensors are being discussed and raise several fundamental questions such as reliability, compatibility to the space environment, irradiation, performance, long term availability, and traceability. Due to both a long history in developing CCD image sensors for space programs and high volume CMOS image sensors for industrial applications, Teledyne e2v is at the crossroads of these technologies and evolutions and can bring well fitted solutions to this new era.

COTS and full space components are compared. Several topics are studied in order to bring useful solutions to overcome certain drawbacks inherent to COTS. Exploring COTS imagers domain show that there is a bridge from COTS to space because additional qualification and screening are often necessary to upgrade the COTS. Based on our experience and existing facilities currently used for space image sensors delivery (such as visual inspection, temperature screening, burn in etc.), we show that the upgrade of COTS is key to accessing Newspace. ‘Upgrade’ covers selection, upscreening, test and qualification, and can be applied to our Teledyne industrial CMOS image sensors or to any externally bought image sensor. The COTS ‘upgrade’ could also start at various states, from wafer level up to encapsulated packaged sensors.

As COTS are not originally designed for space, the key is to evaluate their performance to get pertinent characteristics for space. This presentation illustrates how COTS initially designed for bar code readers or industrial inspection applications can eventually fly in nanosatellites.

**Keywords:** CMOS, COTS, image sensors

*Speaker*
Laser cooling for low earth orbit observation satellites: an analysis in terms of size, weight and power

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Laser cooling in solids is a breakthrough technology allowing vibration-free cooling down to a temperature of 100 K in a miniaturized way. It appears as a promising technology to improve future observation satellites performances and at the same time reduce their launch costs. In this paper, integration of a laser cooler onboard an observation satellite is studied for the first time. Our study focuses on size, weight and power (SWaP) criteria, at both satellite payload and platform level. Its goal is to assess the interest of using an optical cryocooler over a mechanical cryocooler for low earth orbit (LEO) infrared observation missions.

A preliminary space-borne laser cooler architecture is proposed. It is composed of two parts. The first part is the cooling head, based on state-of-the-art cooling crystals 10%Yb:YLF and an astigmatic multipass cavity. The second part is the cryocooler opto-electronics, based on redundant laser diodes and fiber coupled to the cooling head.

The cooling power is estimated for a small focal plane, taking into account the thermal load of an infrared detector and the parasitic heat fluxes inside the cryostat. The required optical and electrical powers of the laser cooler are then estimated considering the crystal efficiency, the thermal link losses and the opto-electronics efficiency.

Assuming a 5 years long LEO microsatellite mission, the sizing of the necessary electrical power systems (PCDU, solar array, batteries) and thermal control systems (heatpipes, radiators) is performed. An additional mass margin is added to take mechanical support structures into account. At the end, payload and platform masses and volumes are summed respectively to obtain a SWaP balance at satellite level, representative of the overall impact of a laser cooler. The same study is repeated for the case of a miniature pulse tube cooler architecture under the same mission and platform assumptions.

Finally, the two architectures are compared. We show that even if the power requirement of a laser cooler is high, the reduction of mass and internal volume makes it suitable for small satellite payloads.

*Speaker
Keywords: Laser, Cryocooling, Earth observation, Satellite, Payload, Low earth orbit
Cubesats: A low cost opportunity for IoT satellites

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2 Centre Spatial Universitaire de Grenoble (CSUG) – UGA, G-INP – Bâtiment C Phitem 120 rue de la piscine 38400 Saint-Martin-d’Hères, France
3 IPAG – Observatoire de Grenoble – France
4 Géopôle du Pacifique Sud, University of French Polynesia (GePaSUD) – Outumaoro Campus, BP 6570, 98702 Fa’a’a, Tahiti, French Polynesia

The Internet of Things is considered the third wave of the Internet. In this talk, we will describe the potential of cubesats for IoT applications in space and on the ground. Different configurations will be adapted to different use cases, especially for covering objects in isolated areas of the world (oceans, deserts, rain forests, polar regions, ...). The CSUG ThingSat project is evaluating promising low-power, long-range radio technologies for new space and IoT applications. We will describe our first experiments with sounding balloons for evaluating the link-margin performances of the LoRa™ radio modulation.

Keywords: CubeSat, IoT, LoRa, long range, low power

*Speaker
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Quad ARM® Cortex® A72 Processor & Common Compute Platform introduction for Space applications. De-risking the use of such technology into Space

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Abstract
Designers of Space systems are facing today a "Commercial Space dilemma" by willing to perform always more complex and powerful data processing into space, while ensuring at the same time a decent level of radiation tolerance, a reduced payload SWaP (Size, Weight & Power), and using devices with significant space heritage to ensure a predictable behaviour ... at an aggressive price if possible.

Rationale for embedding more powerful data processing into space may be one of the following:

- Direct on board data processing
- Increased on board data processing requirements
- Higher level of data selection, higher level of accuracy of data to be transmitted,
- Increased Quality Of Service
- Increased observation capabilities

...

Teledyne e2v is introducing two Radiation Tolerant Space Microprocessors based on ARM® Cortex® A72, in both standalone version and packaged as a common computer platform (microprocessor & DDR4 memory), to answer New Space requirements.

The challenge will be to demonstrate that this will be safe and reliable for space applications.

Introduction & Overview

*Speaker
The 2 ARM based compute intensive solutions proposed by Teledyne e2v for space applications are:

A Space qualified NXP LS1046 Microprocessor, Quad Core ARM® Cortex® A72 running at 1.8GHz (standalone Microprocessor). This is LS1046-Space

A Teledyne e2v Space specific version of its Qormino® Common Computer Platform, based on NXP LS1046 and 4GB of DDR4, on a custom & specific Teledyne e2v substrate. This is LS1046-4GB-Space.

We will present the NASA / ECSS Space qualification Flow that will be applied to these devices to make sure they are the most reliable candidates for space applications.

We will also introduce the current plan for radiation testing of these devices, and what Teledyne e2v will specifically put in place to ensure the platform can overcome possible radiation effects.

Applications & Benefits

Teledyne e2v foresees an interest among the following space applications:

Communication satellites, civil & military
Observation satellites, meteorological satellites
Cubesats & constellations
Scientific missions
Short space missions

LEO (Low Earth Orbit), GEO (Geostationary Orbit) as well as manned space missions can be contemplated. Multiple benefits can be listed by bringing ARM based microprocessor solutions into space:

Direct and increased amount of on board data processing, in constant or reduced power envelope,

Increased Software capabilities and offering, access to new types of applications,

Reduced / Optimized development lead-time from a wider Software ecosystem

Optimized payload SWaP, brought by Qormino Common Compute Platform.

Space Qualification Flow
Teledyne e2v is offering two types of Space Microprocessors:

Ceramic Non Hermetic Flip Chip Solutions

Organic Package Solutions

Both families are following long and complex Teledyne e2v Space Qualification steps. The main difference between families is that Ceramic Non Hermetic Flip Chip Solutions follows QML-Y standard (robust ceramic packaging handled by Teledyne e2v from a bare die, with columning options), while the Organic Package Solutions are Commercial devices up-screened and following ECSS / NASA Space Qualification.

**Radiation Testing**

First radiation results available on LS1046 device are encouraging. Teledyne e2v plans complete Radiation Testing activities on both LS1046-Space and QLS1046-4GB-Space. Current initial plans defined to date are:

- **TID target** 50 krad
- **SEE target** 40 LET

First level of radiation activities are planned to take place early Q2 2019, and preliminary results will be presented in Q3 2019. Teledyne e2v will follow up with dedicated and additional radiation test campaigns on both devices to conclude on TID, SEL and SEFI mitigation.

**Conclusion**

In this paper, Teledyne e2v has presented its plans to introduce and more importantly to de-risk the use of state of the art multi-core ARM based compute intensive Microprocessors solutions in Space applications. In terms of radiation testing, Teledyne will proceed with defining mitigation solutions for both LS1046 and QLS1046-4GB-Space. In terms of products Space qualification, the next steps are the following:

- Prepare the space qualification of LS1046-Space Flight Models, which includes the material & tools definition and manufacturing.

- Complete specific Space qualification for QLS1046-4GB-Space. This includes, and is not limited to Vibration Testing, Board Level Reliability (BLR) Tests.

Teledyne e2v is planning to have Flight Models shipped to customers during first half of 2020 for LS1046-Space, and one year later (first half of 2021) for QLS1046-4GB-Space.
Keywords: Rad Tolerant, Processing, Compute Intensive, SWAP, ARM
The M6P Platform & the IoT

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NanoAvionics as a New Space platform provider is supporting IoT development. This discussion will look at the global business case, the current and future market and the future infrastructure required to support IoT from a nanosatellite perspective

Keywords: IoT

*Speaker
IOT in Space - How LoRa LPWAN technology can enable true global coverage

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We will show the complementarity of Macro, STB/Router & Space network deployment using the same Long-Range (LoRa), Low-Power Wireless Access Network ecosystem in order to benefit from mass-market sensor availability.

Keywords: LoRa, low, power, long range, wireless network

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Recent Advances in Computer Vision for Satellite Imagery

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Nano-satellites and reusable launchers promises to democratize satellite imagery. The massive amount of captured data will make more important than ever to automate the analysis using Computer Vision. The field of Computer Vision has been revolutionized in recent years by Deep Learning. It improved dramatically the state of the art on most tasks and redefined the way we conduct research. This revolution is now reaching the hardware side, bringing forward a new generation of dedicated processors. This presentation will discuss the revolution of Deep Learning, how it relates to Satellite Imagery and how it can enable the New Space movement in its pursuit of democratizing space.

Keywords: Deep Learning, Computer Vision, Satellite Imagery, Embedded hardware

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Effect of Lightweight Lossy Image Compression on CNN-based Segmentation

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Image compression is widely employed to maximize the effective capacity of limited transmission channels such as satellite links. Lossless compression provides perfect reconstruction fidelity, but only limited compression ratios. Lossy compression can offer significant enhancements at the cost of introducing some distortion. This distortion must be controlled so that the usability of the images is not compromised.

In this work, the effects of different types of lossy compression are evaluated from the perspective of CNN-based image segmentation. In particular, F1-scores are compared for circle detection tasks based on a standard UNet network, focusing on the impact of compression on the analysis, and not on the overall network performance. The types of distortion introduced by lossy compression considered in this work are uniform quantization before prediction, uniform quantization after prediction and DCT-based quantization.

Results for the tested images indicate that lossy compression based on uniform quantization does not have a negative effect on the studied detection task for step sizes of up to 5, i.e., peak absolute errors of 2. Instead, detection accuracy is consistently improved for those step sizes, as compared to the results obtained for the original images. On the other hand, DCT-based quantization can be applied with small penalties to accuracy as compared to uniform quantization approaches.

Based on these results, average compression rates of 3.01:1 can be obtained using low-complexity algorithms compatible with satellite requirements, while maintaining perfect image usability. These ratios represent a 28% improvement over the same algorithms operating in lossless regime.

Keywords: lossy compression, image segmentation

*Speaker
Artificial Intelligence : use cases for New Space

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Artificial Intelligence shall impact a wild range of industries but what can we expect for New Space ?
Delfox is a young startup specialized in Artificial Intelligence applied to Space and Defense Industry.

One of our first subject has been to develop deep learning algorithms for ArianeGroup SSA (Space Surveillance Awareness) program : GeoTracker.

Hence, we will first start by presenting Delfox and its vision before explaining our contribution to SSA.
We will then show how AI solutions can used for a wild range of New Space applications such as : Earth observation, Embedded AI on satellites, control of satellites, Space Traffic Management.

Keywords: deep learning:ssa:space traffic management:ai
High throughput free-space laser communications for CubeSats

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Free-space laser communication has recently gained interest in the space industry for establishing both ground station-satellite and inter-satellite high throughput optical data links. A couple of reasons are at the basis of this widespread interest, among which an increase in received signal strength at reduced transmitter power, which in turn enables to reach data rates several orders of magnitude higher than traditional radio-frequency (RF) links. Besides that, optical laser communication is not subject to licensing regulations and is also considered to be more data secure. All of these benefits originate from the extremely narrow spatial width with which the optical beam can be transmitted from satellite towards receiver at wavelengths in the infrared region, while the optical transmitting antenna can be kept small. While the ability to keep the optical transmitted power confined inside a narrow beam width enables to achieve higher link gains than RF antennas, it comes at the expense of extraordinary pointing capabilities that are required on board the transmitting satellite. However, overcoming this technical challenge can lead to a revolution in data communication systems for small satellites, especially during an era where payload capabilities on nano-satellites grow quickly and downlink transmission becomes the bottleneck for missions that generate large data volumes. As laser communication is also interesting from a size, weight and power (SWaP) perspective, the advantages can outweigh the added complexity in pointing the on-board laser beam towards the receiver.

Therefore, Hyperion Technologies and TNO have teamed up to build the CubeCat laser communication terminal that fits in 1 unit (1U) of the CubeSat standard. The terminal is designed to establish a bi-directional communication link between CubeSat and ground station, with downlink data rates up to 1 Gbps and uplink data rate of 200 kbps. Peak power consumption of the communication subsystem during a ground station fly-over is comfortably achievable on a CubeSat, while the terminal also takes care of data buffering during nominal satellite operation, turning this laser communication terminal into a plug-and-play device that fits into the size of the nano-satellite class.

In order to meet the stringent pointing requirements that arise from the narrow optical beam width, the laser communication terminal relies on host satellite platform ADCS capabilities only to an extent that is achievable with presently available ADC systems for CubeSats. In order to relax those body-pointing requirements and to bridge the gap between coarse body pointing error and the allowed pointing error, the laser communication system has its own fine steering capabilities.

This fine steering control loop is possible with the integration of precise sensors that measure the misalignment between the downlink beam and the vector from the CubeSat towards

*Speaker
the ground station. This information is fed back to the fine steering actuator, which requires a dedicated controller in order to precisely align the transmitted laser beam with the desired direction.

This eventually enables to steer a narrow beam modulated with an on-off keying (OOK) modulation pattern from a CubeSat in Low Earth Orbit (LEO) over a maximum range of 1000 km onto a illuminated spot size of a few hundred meters diameter on the Earth’s surface, in which the ground station is located. As the ground station simultaneously illuminates the orbiting satellite with a modulated uplink beacon, a bi-directional link capable of downlinking high data volumes is established. The risk of interference is inherently very low, making bandwidth allocation regulations unnecessary and enabling scalable space communication systems for the future.

**Keywords:** Laser communication, CubeSat, Optical link, Pointing
Innovations enabled by direct digitization of multiple frequency bands, up to Ka.

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Satellite projects are known for their high total costs from concept to start of operation. Single purpose satellites have been the only and still are dominant types of satellites being made today.

It is known that telecommunications satellites only provide communication services, usually Earth Observation satellites only provide EO services, and navigation satellites tend to provide only GNSS service.

The new space industry now enables constellations to fly more satellites, but they still tend to be constellations of many of the same satellites providing a single type of service.

However, whether a space programme is made of small or large satellites operating with a single satellite or a constellation, if a space programme investment proposal can be based on multi-purpose satellites then the economics of the programmes can become a lot more efficient than a single purpose satellite programmes.

Not only this can lead to significant economical optimization of space programmes, but it would also contribute to reduce the production of space junk.

The innovations in RF signal digitization RF signal generation now allow for a technical path to multi-purpose satellites.

The work produced within the H2020 Interstellar consortium and the resulting products push the boundaries of data conversion technology, now allowing for direct signal generation in any band, up to Ka-Band, and simultaneous operation in several bands at the same time in RF transmitter signal chains.

On-going works also aim to provide symmetric digitization technology for RF receiver signal chains.

This means that direct digital control of transmit and receive signals is now becoming possible in any band up to Ka, whereas prior to these innovations, every system architects had to plan for hardware frequency conversion circuitry which significantly reduced the frequency agility and the ability to run multiple modes of operation and services on the same system.

*Speaker
Similarly to a smartphone having generic hardware allowing the software system to provide a broad variety of services to the users of the same single device.

A highly digitized RF spectrum on a satellite payload allows for more services from the same equipment.

Typically a telecommunication service and a SAR radar 3D Earth Observation instrument can be designed to operate from the same instrument on the same satellite thanks to digital signal processing systems that will now have control over a much broader range of spectrum directly from the digital domain.

Additionally, new system benefits can also be leveraged from the ability to operate in multiple frequency bands form the same system, the radar imaging system will gain significant quality on imaging information as it benefits from backscattering data in various wavelengths, and the communication service can benefit from an ability to change frequency bands to mitigate the restricted available spectrum, or to mitigate the various signal degradation along the slant path between ground and spacecraft due to varying weather conditions.

This paper will give a 12 minute overview of this subject referencing to new developments in data conversion technology which enable these innovations at system level.

**Keywords:** Multi, purpose satellites, satellite economics, satellite communication, 3D SAR radar Earth Observation
Internet by Satellite – OneWeb

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Mega-constellation of satellites – Pioneering serial production in Space business.

Keywords: Airbus, OneWeb, Internet, Constellation, nano, satellite

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Quantum Key Distribution with Small Satellites

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Abstract:
Small satellites offer the possibility for cost effective missions with short development times. This enables the rapid implementation of new technologies like quantum key distribution for truly secure communication on a global scale. Here we present the space mission QUBE, which intends to evaluate highly integrated QKD hardware in space and to study the feasibility of using Cube-Satellites for world wide key exchange.

Quantum Key Distribution (QKD) is a provably secure method for distributing secret keys between two trusted parties either over fiber or free-space links. While fiber based systems are surely beneficial in metropolitan areas, satellite based free-space QKD can span distances of thousands of km even allowing for intercontinental links [1]. The space mission QUBE will test two highly integrated QKD sender modules and a quantum random number generator (QRNG) in a three unit CubeSat. From a low earth orbit (∼500 km) a link to the optical ground station (OGS), with a telescope size of 60 cm and located at the DLR in Oberpfaffenhofen, is provided by the optical communication terminal OSIRIS featuring an effective aperture of 20 mm.

Two completely different approaches are realized for the QKD payloads: First, a 850 nm discrete variable BB84 polarization encoding system running at a repetition rate of 100 MHz based on micro-optics assembling [2]. Here, faint laser pulses from four vertical-cavity surface-emitting lasers (VCSELs) are polarized using an array of precisely cut and assembled stripes of synthetic foil polarizers. A microlens array focuses the light into a waveguide chip, which combines the four input modes and allows for butt-coupling to a single mode fiber. Second, a system comprised of a QRNG and an optical source for quadrature-modulated weak-coherent states. The QRNG is based on optical homodyne measurements of the vacuum state [3]. The QKD source is

*Speaker
able to run continuous variable protocols [4] @ 1560 nm using a DBR laser modulated by nested Mach-Zehnder interferometers and then coupled into a single-mode fiber. The QKD-units will be hermetically sealed and mounted separately with control and driverelectronics on two 9 x 9 cm 2 boards resulting in robust and stable systems with an overall volume of 1/3 U, a weight of 200 - 300 g and a power consumption of only $\sim 5$ W, each.

The OSIRIS terminal runs a third laser source (100 mW, 1550 nm) for tracking as well as for synchronization and uni-directional communication with 25 MBit/s. Telemetry and telecommand is performed via UHF (9.6 kbit/s up- and downlink), which also facilitates software updates and post processing tasks.

For a sun synchronous orbit, we expect to have 1 - 2 overflights per night with a link duration of 4 - 7 min each. During overflight, the satellite orientation has to be pre-stabilized within 1 towards the OGS by three reaction wheels plus feedback from a star tracker sensor, allowing OSIRIS for the active beam tracking and finally one of the QKD payloads to transmit quantum signals.

Our mission QUBE will bring valuable information on the feasibility of QKD on such small satellites or of flotilla-type satellite QKD-networks for cost-efficient and secure communication. Moreover, the components evaluated in QUBE will be also well suited for implementation in other systems using optical links in space thereby bringing the high level of security to all these high-speed communication platforms.

**Keywords:** QKD CubeSat
SatNOGS: Towards a Modern, Crowd Sourced and Open Network of Ground Stations

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The majority of the small satellites missions are targeting the Low Earth Orbit. Due to the nature of this particular orbit, communication with a satellite is possible only for a few minutes per day for a given location. This raises the need for multiple ground stations in several geographic locations. Although such an infrastructure is possible, most of the times it is both complicated and expensive for research or educational entities to obtain. Given the fact that each ground station exhibits a small per day utilization for a specific satellite, the idle time can be used for reception of other missions.

SatNOGS is an open source software and open hardware project that addresses this problem by interconnecting all participating ground stations, offering their idle time to other users of the SatNOGS network.

1. Introduction

SatNOGS is a global network of satellite ground stations, designed as an open source participatory project that receives data from Low Earth Orbit satellites. This particular orbit provides the ground station with a reception window that is limited to a few minutes. Therefore, a ground station remains underutilized and idle for most of the time. On the other hand, using a single ground station means that there are only a few communication windows to send or receive data from a LEO satellite each day.

The concept of SatNOGS, is to use the deployed ground stations around the world in an efficient manner so that both the underutilization of them as well as the coverage problems can be resolved with a single solution. A ground station operator joining the SatNOGS network, provides the idle time of their ground station to other users, while at the same time they can take advantage of ground stations at various locations of the earth to schedule observations.

2. The SatNOGS Architecture

The SatNOGS ecosystem consists of several components operating interchangeably. The SatNOGS

*Speaker
Network infrastructure orchestrates the scheduling of each ground station, based on the trajectory of the targeted satellites and the online available ground stations, while allowing the owner of a ground station to have complete control over her hardware. The SatNOGS Database is responsible for keeping the orbital elements and communication related information of each satellite. It also holds decoded frames from the deployed ground station network. The Data Warehouse, visualizes graphically the gathered data from each satellite using a web interface and the Grafana visualization framework. Last but not least, the SatNOGS Ground Station is the necessary software and hardware, that allows satellite tracking, the control of the RF front-end, signal reception and demodulation of possible data frames.

3. Results

Back in 2015 when the project started, only a couple of ground stations were available and their functionality was limited. However, the continuous interest in CubeSat missions and the need for easy access in their data, resulted in an exponential growth in the registered ground stations of the project. This growth is also due to the continuously evolving features of the SatNOGS ecosystem. New features like automatic data frame decoding and visual spectrum analysis added significant value to the project and the data provided.

Currently, the infrastructure utilization is at about 1200 satellite observations per day, whereas back in 2015 this number was limited to few dozens. 70% of them contain useful information. The rest of them, are either bad or failed observations. With the term bad, we classify those observations that successfully uploaded back to the network infrastructure the report for the observation. However, due to various reasons this observation did not contain any valuable information. This may happen due to interference, antenna misalignment, RF front-end faulty configuration or it could that the satellite did not transmit any information during this particular pass. Currently the vetting for good or bad observations is semi-automatic and requires human intervention. For those observations that an automatic decoder is available, observations containing decoded data are automatically vetted as good. The rest of them are vetted manually from community based contributions or the ground station operator.

In par with the observations per day, are also the number of the decoded frames that the automatic decoders produce. At the present time, SatNOGS DB stores about 2500 decoded frames each day.

4. Conclusion

This cost effective solution, allows satellite operators to manage their missions effectively and efficiently, while at the same time increasing the mission coverage by using other deployed SatNOGS stations around the globe.

satnogs.org

Keywords: ground station network, ground station, open source, crowd source, software defined radio
NanoBob: Quantum Secure Communication with a CubeSat

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Quantum Key Distribution, the quantum secure exchange of secret keys between two parties, provides a level of communication security that cannot be obtained by classical cryptographic means. Quantum information can be coded into polarization states of single photons and the experiment designed such that eavesdropping on the exchange would necessarily lead to detectable errors. The intrinsic security largely outweighs the disadvantages of additional complexity and cost, at least in the case of certain critical infrastructures. QKD has already proven its practicality in fiber network implementations, for which commercial solutions are available. However, losses limit the distance between two parties to a few hundreds of km, as the no-cloning theorem prohibits the use of simple optical amplifiers, whereas quantum repeaters remain an extremely challenging solution. For the foreseeable future, satellites are the only option enabling exchanging secret keys on a global scale, while limiting the number of trusted relay nodes in the network. NanoBob will demonstrate QKD between an optical ground station (OGS) and a nanosatellite. Keeping the entangled photon source on the ground, the space segment becomes less complex, yielding a lower power consumption, smaller package, and increased reliability; all at a lower cost, especially when multiple satellites service a limited number of OGSSs. The lower link efficiency of the uplink configuration can be countered by implementing adaptive optics in the OGS. The space segment payload is also versatile: the receiver is compatible with multiple QKD
protocols and other quantum physics experiments. In order to extend the geographical reach of the OGSs at the metropolitan scale and the number of end-users that can exploit the same OGS we will design a "plug-and-play" synchronized quantum network, thus demonstrating a complete infrastructure for global and metropolitan scale QKD.

We discuss the mission concept and the outcome of the definition and feasibility studies carried out so far. To our knowledge, NanoBob, having completed its Mission Definition Review following CNES/ESA guidelines, is so far the most advanced European project focusing on the use of entangled photons and a CubeSat platform [1].


# The CSUG NanoBob Team is composed of the following engineers, students, and educators who all contributed at different stages to the current study: Yves Gilot (STMicroelectronics), Etienne LeCoarer (UGA), Juana Rodrigo (Rolls Royce), Thierry Sequies (UGA), Vincent Borne (UGA), Guillaume Bourdarot (UGA), Jean-Yves Burlet (UGA), Alexis Christidis (UGA), Jesus Segura (UGA), Benoit Boulanger (UGA), Véronique Boutou (CNRS), Mylène Bouzat (Air Liquide), Mathieu Chabanol (UGA), Laurent Fesquet (UGA), Hassen Fourati (UGA), Michel Moulin, Jean-Michel Niot (Air Liquide), Rodrigo Possamai Bastos (UGA), Bogdan Robu (UGA), Etienne Rolland (UGA), and Sylvain Toru (UGA).

**Keywords:** QKD, Quantum Communication, CubeSat
Enhanced ADCS nanosatellite bus for laser communication applications

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Open Cosmos is developing a high accuracy attitude control technology to allow optical communications between a CubeSat in Low Earth Orbit and fixed optical ground stations as well as mobile optical high altitude platforms (HAP) stations. Archangel Lightworks are developing optical communication terminals for space-air optical data links and have selected Open Cosmos as their CubeSat partner. The Lightworks team will be the first customers for our new enhanced attitude determination and control system (ADCS) cubesat. In order to achieve a stable optical link good pointing and tracking is required. Open Cosmos has been developing a high accuracy pointing system for an in-orbit demonstration of a full space-to-ground optical link solution. Although the enhanced ADCS will be offered on both beeSat6u and beeSat12u, this demonstration mission will first be performed making use of a beeSat6u CubeSat alongside with a HAP carrying an optical station. The pointing and stability will be achieved through the combination of the Open Cosmos ADCS and Archangel Lightworks’ optical communication terminals.

Typically pointing performance is given as a subsystem performance - i.e. a given pointing knowledge (often expressed in arcseconds) and pointing accuracy (often expressed in degrees). However when considering an entire satellite mission, it is important to consider the problem of optimizing satellite pointing accuracy as a system-level architecture rather than a simplistic subsystem + cubesat bus combination with a given ADCS performance. Indeed achieving a given pointing performance depends on the combination of sensors, actuators, and system-level architecture chosen. Elements to be taken into account are specifically: stiffness of the structure for jitter mitigation; orbit propagation; thermal deformation of the structure between the main sensor and the payload in different orbit conditions; sensor and actuator characteristics & behaviors whilst slewing; and statistical confidence value of the performance numbers needed for successful payload operations. Therefore rather than trying to reach a given pointing performance at ADCS subsystem level, our objective is to achieve a given range of performance at given slew, orbit, and payload operations scenarios to enable LEO-to-ground optical communication.

The state-of-the-art performance for cubesat platforms of TRL9 ADCS architecture elements has not progressed much over the past four years, consisting of: Star Tracker of 25 arcsec pointing knowledge; Sun Sensors of 0.1 accuracy; Earth Sensors of 0.25 accuracy; Gyrosopes of 1 h–1 bias stability, 0.1 h–2 random walk; GPS Receivers of 1.5 m position accuracy; Magnetorquers of 5 A m2 peak dipole; and Reaction Wheels of 0.1 N m peak torque, 1.5 N m s; and Integrated

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Unit 0.007 pointing capability. [1]

While our ADCS architecture will achieve at minimum the current state-of-the-art performance at subsystem integrated unit level, our objective is to achieve a satellite system-level performance of 40 arcsec pointing accuracy and 30 arcsec pointing knowledge with a 1.5/s slew rate and less than 15 arcsec/s jitter. This will be achieved by the combination of state-of-the-art miniaturized sensors (star trackers and gyroscopes) and actuators (reaction wheels) with innovative control loop.

The integrated beeSat6u will be compatible with a wide range of laser communication modules, including flight-heritage as well as currently under development systems. It will be used to support a variety of applications ranging from Quantum Key Distribution (QKD) to Remote Sensing (RS) and other use cases requiring either secured communication or high datarate [1 ; 100 GBps] capabilities. In addition to the optical link capability, this beeSat6u platform will provide 40W OAP to payloads and is designed for an operational lifetime of 3 years. Subsequently we intend to integrate the enhanced ADCS into our beeSat12u bus to provide further capabilities including propulsion for mission orbital lifetime > 5 years, up to 100W of payload Orbit Average Power (OAP), and ≈ 6u of volume to the payload.

The in-orbit demonstration mission is scheduled for launch by beginning 2021.

References


**Keywords:** Cubesat, Nanosatellite, ADCS, Laser, Optical communication.
Amateur satellite service

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The story of Amateur radio satellites begins closely after the launch of the first satellite Sputnik. At about that same time, a West Coast group of Hams began toying with the idea of launching an Amateur Radio satellite into orbit. After a series of high level exchanges among Project OSCAR members [1], the American Radio Relay League, and the United States Air Force, a launch opportunity on Discoverer XXXVI was secured for the very first Amateur Radio satellite called OSCAR I. It was successfully launched the December 12, 1961...barely four years after the launch of Sputnik I.

The Radio Amateur Satellite Corporation [2] (as AMSAT is officially known) was formed in 1969 as a not-for-profit, educational organization chartered in the District of Columbia. Its aim is to foster Amateur Radio’s participation in space research and communication. Since that time, other like-minded groups throughout the world have formed to pursue the same goals. Many of these groups share the ”AMSAT” name. While the affiliations between the various groups are not formal, they do cooperate very closely with one another.

In France, the first Amateur Satellite service organization (RACE) was created in order to support the development of the satellite Arsene launched in 1993. In 1996, they support the creation of AMSAT-France. After its dissolution in 2011, a new organization has been created AMSAT-Francophone [3] with two objectives. AMSAT-F provides support to users to operate satellite and promote this activity.

Currently, more than 300 satellites using amateur frequency has been launched since 1961. And more than 100 are planned in the coming years. The number of launched has drastically increased since the Cubesat concept creation. Before 2003, the Amateur satellite was mainly design, build and commissioned by AMSAT organization. Thanks to the volunteer time and material, the cost was kept to the minimum. Nevertheless, the cost of the launch remained a challenge. With the help of space agency, AMSAT was benefiting of free space as a piggy back on the launcher or was experimenting with innovative concept which could provide extra benefit to the launcher provider.

With the Cubesat, the majority of the satellites using amateur radio satellite frequency has been designed, built and operated by university and hamradio satellite organization even if some people with amateur radio licensed are involved. Even if theses satellites have their frequency declared at the International Telecommunication Union [4] (ITU) and coordinated by the International Amateur Radio Union [5] (IARU), some of them does not respects amateur radio rules and spirit.

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The ITU has long regulated the global community’s use of radio frequencies. According to Article 1.57 of the International Telecommunication Union’s (ITU) Radio Regulations (RR), Amateur-satellite service is defined as "A radiocommunication service using space stations on earth satellites for the same purposes as those of the amateur service.”. Amateur service is defined as a radiocommunication service for the purpose of self-training, intercommunication and technical investigations carried out by amateurs that is, by duly authorized people interested in radio technique solely with a personal aim and without pecuniary interest.

The IARU, established in 1925, is the worldwide federation of national amateur radio societies. IARU provides, on a voluntary basis, the coordination amateur projects and gives its opinion on the “compatibility” with regulations. The national administrations authorities do not coordinate what’s happening inside the bands allocated to radio amateurs. These administrations should not can therefore allocate a frequency in the amateur bands.

As several abuses were noted, increased vigilance was required and implemented in frequency coordination. The justification of a non-profit educational/experimental mission is necessary. In addition, significant satellite access time at the amateur radio community must be allocated. Radio amateurs must be involved at all stages of the project. Cubesats teams must use open communication protocols and give useful information to decode them (except Remote Control of course).

The provision of new resources for amateur radio people and the ability to retrieve data from ground stations spread over the entire earth for cubesat team are beneficial for the both. In addition, often base on this collaboration, educative outreach can be performed during the development and the operation of the satellite.

https://projectoscar.wordpress.com
https://www.amsat.org
http://amsat-f.org
https://www.itu.int
http://www.iaru.org

**Keywords:** Amateurs satellite service, amateur frequency, AMSAT, ITU, IARU
Latest Data Converter development at Teledyne e2v: 12-bit 8 GSps DAC enabling signal generation up to the K-band

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Designers of microwave systems are constantly looking for DACs which provide not only large Nyquist zones (> 2.5 GHz), but also offer a flat frequency response over these large instantaneous bandwidths. Such DACs allow simplifying the architecture of the complete microwave generation system, thus saving costs.

This paper presents the latest DAC proposed by Teledyne e2v capable of sampling at a rate of 8 GSps, enabling the direct conversion of signals with a large instantaneous bandwidth. The component inherits from the success of previous DAC versions extending the sampling rate to reaching higher performance. The component architecture will be described and measurement presented with output frequencies up to 26.5 GHz in a COTS version. While the maximum instantaneous bandwidth is limited to 3.2 GHz (i.e. 6.4 GSps) due to the limited performance from the FPGA LVDS interface, the higher sampling rate allows reaching higher output power in the X-band for instance.

The DAC is ready for space applications, designed for Newspace systems, and will be offered in various reliability grades. Together with its low latency, this DAC opens a path towards innovative ways of designing the RF signal chain up to Ku-band and even Ka-band in satellite telecom payloads and SAR systems, for example.

Keywords: Broadband data converter, K band, Direct signal synthesis, Microwave

*Speaker
Hera, an innovative planetary defence mission

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Hera is the proposed European component of the international Asteroid Impact & Deflection Assessment (AIDA) mission. It is a small mission with the main objectives to investigate a binary asteroid, to observe characterise the outcome of a kinetic impactor test on the Didymos binary asteroid (1996 GT), and the necessary physical and dynamical data to fully validate the kinetic impactor asteroid deflection technique (so as to be applicable to other asteroid targets). In addition for asteroid impact threat mitigation, Hera will provide bonus investigations relevant to future in-situ resources utilisation activities (camera filters will provide clues about possible compositional heterogeneity. The other NASA component of AIDA is NASA’s Double Asteroid Redirection Test (DART) mission. DART’s primary objective is to impact the small moon of the binary asteroid system, thus performing the first asteroid deflection test, and to observe the outcome from ground-based observatories (Cheng et al., 2016). DART entered phase C in June 2018, CDR is planned in June 2019. It is a single string (i.e. no redundancy of onboard equipment) single payload spacecraft carrying a narrow-angle camera for deep-space navigation and terminal guidance toward Didymoon impact. The target is the binary near-Earth asteroid (NEA) (65803) Didymos (1996 GT). Within the NEA population, Didymos provides currently the best astrodynamics properties to conduct an informative and efficient deflection mission. In particular, the secondary component of Didymos, called hereafter Didymoon, is the target of the DART mission. With its ~163 meters diameter, it allows for the first time to gather detailed data not only from a binary asteroid but also from the smallest asteroid ever visited. Hera is completing phase B1 with SRR in June and the phase B2 as been approved at ESA for planned kick-off in September 2019.

Keywords: HERA, AIDA, DART, Didymoon

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PicSat, an astronomical CubeSat mission

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The goal of the PicSat satellite was to observe the transit of planet Beta Pictoris b. More exactly, it was to survey the photometry of Beta Pictoris during the few months when the Hill sphere of the planet was passing in front of the star. The payload was built around a 50mm off-axis parabola and a novel type of single mode photometer. The satellite platform subsystems were bought off-the-shelves from private companies. After 3 years of design and qualification, the satellite was successfully launched on a 505 km orbit in January 2018. First contact was obtained within hours, and commissioning of the sub-systems was performed during the next 10 weeks. However, on the 20th of March the satellite fell silent. During this talk, I will present the science, the satellite, as well as the technical difficulties we have faced. The interest for small space missions (of the order of a few million Euros) is still debated inside the scientific community. Mostly because the technology is not yet fully mature. But I’ll show that it has interesting prospects for the near future, and transiting exoplanets is one of them.

Keywords: exoplanet, cubesat, photometry, telescope

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MarCO: Flight Results of the First Interplanetary CubeSats

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On November 26, 2018, the MarCO spacecraft flew by Mars, successfully relaying data back from the InSight lander during the so-called "seven minutes of terror" sequence of entry-descent-and-landing. This accomplishment, while significant in its own right, was the culmination of 6.5 months of travel, through over 480 M km of interplanetary space by a pair of CubeSats. The CubeSats had to separate from the launch vehicle near Earth, orient themselves, and begin communications with the Deep Space Network. They then each performed deep space maneuvers, demonstrated a bent-pipe-relay, and navigated to a precise position and timing to support EDL. This talk will provide an update on mission status, lessons learned from flight operations, and implications for the next generation of small interplanetary spacecraft. Several images will be shown from the Mars flyby, as well as a discussion of data collected.

Keywords: Mars Interplanetary CubeSat

*Speaker
The AmicalSat auroral imaging mission

Mathieu Barthelemy *† 1,2

1 IPAG – Observatoire de Grenoble – France
2 CSUG – CSUG – France

will follow

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ESA’s Distributed Space Weather Sensor System

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Space weather refers to the environmental conditions in space as influenced by solar activity. Monitoring of the Earth’s and Sun’s environment is an essential task for the now- and forecasting of Space Weather and the modelling of interactions between the Sun and the Earth. Due to the asymmetry and complexity of Earth’s magnetosphere, the involved particle environment and its dynamics, it is necessary to capture the state of the magnetic field and the particle distribution in a sufficiently large number of sampling points around the Earth, such that it allows state-monitoring and modelling of the involved processes with sufficient accuracy and timeliness.

Within the Space Situational Awareness (SSA) programme, ESA is implementing a space weather monitoring system, including the establishment of a Distributed Space Weather Sensor System (D3S). Such satellite systems should benefit from the continuously improving performance of CubeSat, NanoSat and in particular the SmallSat systems between 50 and 100 kg currently under development in different application areas. An important aspect for the realisation of miniaturised satellite observation systems for SSA is the need of high reliability, sufficiently long lifetime and low data latencies if considered for operational purposes. Space weather instrumentation traditionally is highly miniaturised, and therefore appears to be well suited for small satellite systems, which could become competitive to the usually followed hosted payload approach while allowing for more flexibility with respect to the flown payload and orbital requirements.

The following observations and corresponding payloads are being considered for these mission types:

1) Remote sensing of the Earth’s Aurora utilising an EUV imager and a white light imager.

2) In-situ measurements in the Earth environment with the following payloads: magnetometer, radiation monitor (protons, ions, electrons), Langmuir probe, plasma analyser, neutral atoms monitor, atomic and molecular oxygen sensors.

We will present the current status and future plans of ESA’s Space Weather activities focussing on the potential use of small satellite systems for D3S.
Operational monitoring of the Earth’s radiation environment

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Solar activity determines the physical conditions in the interplanetary medium: parameters of the solar wind, interplanetary magnetic field, energetic solar particles fluxes. Interplanetary environment factors influence Earth’s magnetosphere, its global structure, large-scale current systems and particle populations. The coupled processes and phenomena occurring under the influence of solar activity in the region from the Sun to the Earth’s upper atmosphere form the physical conditions in near-Earth space - space weather. Space weather factors associated with non-stationary, explosive processes on the Sun can affect the technological infrastructure both in near-Earth space and on Earth, especially in high-latitude regions. One of the most important and dangerous space weather factors is radiation.

Radiation conditions in the near-Earth’s space are resulted from joint action of the three main factors: galactic cosmic rays, solar energetic particles and radiation belts. Energetic particles originated from radiation environment of the Earth can cause effects like ionizing dose and displacement damage, as well as electrostatic discharge and single event effects that damage spacecraft materials and electronic components. During geomagnetic disturbances, radiation conditions in some regions drastically change and become much more dangerous for spacecraft. We need the continuous monitoring of the radiation conditions in space to give alerts for satellite operators.

Nowadays, NOAA/GOES series satellites in the magnetosphere as well as ACE in solar wind give the operational monitoring data on radiation environment of the Earth. Russian Electro-L2 (GEO) and Meteor-M2 (LEO) complement data that reflect the outer radiation belt dynamics and SEP penetration due to solar flares. Space weather centers generalize these information using operational models and provide forecast for space operators. Space monitoring data center from Moscow State University provide the operational analysis of radiation conditions in the near-Earth’s space based on data from GEO and LEO satellites. The new MSU space project based on small satellite constellation that can enhance space weather centers efficiency.

Keywords: space radiation, monitoring, magnetic storm, radiation belts

* Speaker
The ATISE auroral spectrometry mission

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will follow.

Keywords: ATISE, Aurora
Monitoring of the Upper Ionosphere with SLP on Board PICASSO

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The Sweeping Langmuir Probe (SLP) instrument, which will fly on board the Pico-Satellite for Atmospheric and Space Science Observations (PICASSO), has been developed at the Royal Belgian Institute for Space Aeronomy. PICASSO, an ESA in-orbit demonstrator which will be launched in summer 2019, is a triple unit CubeSat of dimensions 340.5x100x100 mm. SLP is a four-channel Langmuir probe instrument with four independent cylindrical probes. By sweeping the potential of a probe with respect to the plasma potential while measuring the current from this probe, the instrument will acquire a current-voltage characteristic from which the electron density and temperature, ion density and S/C (spacecraft) potential are retrieved. It is designed to measure the plasma parameters at an altitude around 500 km from a high inclination orbit. Therefore, the plasma density is expected to fluctuate over a wide range, from about 1e8/m^3 at high latitude up to several times 1e12/m^3 at low/mid latitude. The electron temperature is expected to lie between approximately 600 K and 10,000 K.

Given the high inclination of the orbit, the SLP instrument will allow a global monitoring of the ionosphere with a maximum spatial resolution of the order of a few hundreds of meters for the electron density and temperature, and up to a few meters for electron density only. By combining the data from SLP with complementary data sources such as GNSS TEC tomography, whistler stations in AWDAnet and WHISPER instruments on Cluster, the main goals are to study: 1) the ionosphere-plasmasphere coupling, 2) the subauroral ionosphere and corresponding magnetospheric features, 3) auroral structures, 4) polar caps, 5) for the density, the multi-scale behaviour, spectral properties and turbulence of processes typical for the auroral regions, and 6) ionospheric dynamics via coordinated observations with EISCAT’s heating radar.

An important issue implied by the use of a nano-satellite platform for a Langmuir probe instrument is the limited conducting area of the spacecraft, which leads to spacecraft charging and drift of the instrument’s electrical ground during the measurement. A specific measurement technique that includes the simultaneous measurement of the potential and current of different probes has been developed to retrieve consistent current-voltage characteristics that can be used to estimate the plasma parameters mentioned above. This technique has been tested in a plasma chamber at ESTEC with a satellite mock-up which is electrically representative of PICASSO. Preliminary results of these measurements together with simulations performed with SPIIS (Spacecraft Plasma Interaction System) will be presented and discussed.

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Keywords: Space weather, CubeSat, Langmuir probe, Plasma
The Robusta-1B mission: two years of in-flight data

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ROBUSTA-1B was developed by the Centre Spatial Universitaire de Montpellier (CSUM) at the University of Montpellier (France) with the support of the Van Allen Foundation in the framework of the French Space Agency (CNES) JANUS Program. The mission was proposed by the Radiation and Components research group of the Institut d’Electronique et des Systèmes (IES). Robusta-1B was launched on June 23rd 2017 from India on PSVL C-38 through ISL on a 530km SSO to investigate radiation effects on Integrated Circuits (ICs) in Bipolar Junction technology. Every five hour, the payload data, electrical and functional parameters of the Devices Under Test (DUTs) are recorded and broadcasted to be received and decoded at the mission control center via the CSUM UHF ground station. Almost two years of data show clear trends in the degradation of the devices under test. The purpose of this paper is to present these trends and correlate with the environment variations.

The mission and the satellite itself are described. It is worth noting that the entire CubeSat was designed and built in house, involving bachelor and Master students. Special attention was paid to the radiation effects mitigation, taking advantage of the 30 year experience of the Radiac group in this field.

The major outcome of this successful mission is a set of two year experimental results such as the evolution of the input bias currents, output voltages and supply currents of the two quad LM124 and two quad LM139 with time (and dose). BJT ICs parameters are sensitive to the temperature variations clearly visible on the raw data and require correction and normalization to a standard temperature. Once this correction is performed, the impact of the Total Ionizing Dose (TID) is evaluated. Although TID is evaluated to two krads only, a significant drift (up to 30%) in the electrical parameters is clearly observed. This low dose radiation induced degradation is attributed to the so called Enhanced Low Dose Rate Sensitivity which is typical from bipolar Junction transistors.

After almost two years in flight, it appears that the degradation rate of DUTs correlates perfectly with the solar activity. This is consistent with the fact that the solar cycle is currently very close to the minimum with poorly charged radiation belts providing very little shielding to a spacecraft flying below the belts. As a consequence, the degradation is close to zero when the sun is quiet, which was the case in December 2017 and January 2018. On the opposite, the series of solar flares and CMEs that occurred in September and October 2017 had a very strong

*Speaker
and long lasting impact on the degradation, probably due to the charging of the radiation belts. Coronal holes, by accelerating the solar wind electrons also produce a non-negligible impact.

Up to now, radiation effects are usually ignored for CubeSat missions, for which the mission duration is limited to a few months only. Sometimes, the mitigation of Single Event Effects is achieved at software level with a relative success. However, CubeSats mission duration is planned to increase, along with new expectations in terms of scientific objectives or service causing the mission duration to increase significantly. The impact of this new specification on the reliability deserves in-depth investigations. After two years in flight, the radiation effect mitigation strategy implemented on Robusta-1B is validated. The satellite has recovered from a couple of anomalies. Following this return of experiment, the mitigation strategy was improved on CSUM next two 1U missions using the new v3 platform. MTCube twill be launched during summer 2019th with and ESA experiment on board. CELESTA, developed in partnership with CERN is expected to be launched in 2020 in the frame of the ESA Education Fly Your Satellite Program. Both will embark radiation effects payloads for the assessment of the SEE rates on memories and the monitoring of the radiative environment. Robusta-3A, a CubeSat based on CSU 3U platform developed in the frame of CNES JANUS program with the support of the Van Allen Foundation will benefit from an even more robust mitigation strategy at system level. Again, this is made possible by the full custom in house design of all the subsystems.
At this stage, the sun has reached the minimum of its activity and during the next few years, as the cycle rises up to the maximum, CubeSats will have to face more and more intense solar events. The joint efforts made by CSUM, IES RadiaC and their partners should make possible to provide a reliable technology to make nanosats more reliable and improve their chances to survive in harsh radiative environments.

**Keywords:** Cubesats, Radiation Effects, Total Ionizing Dose, Solar activity
OGMS-SA is a 3U CubeSat designed by students.

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OGMS-SA is a 3U CubeSat dedicated to students training in Space Engineering. The goal is that students develop through the years a full 3U CubeSat platform considering all the system level aspects. All the developments, integration and tests are performed by the students during internships since 2013. The Satellite will be ready to launch in summer 2020.

OGMS-SA is a 3U CubeSat with 2 deployed solar panels connected to a power supply distribution in charge to control the batteries and to provide the power buses to the satellite. The CubeSat structure is in polymer WindForm XT 2.0, build in additive manufacturing. The communication with the ground stations is done by UHF/VHF on the amateur radio band. The Attitude Control is performed by magneto-torquers associated to sun sensors, accelerometer, gyrometers, magnetometers and GPS. The On Board Computer is in charge to control all the satellite.

OGMS-SA is a technical demonstrator for a space cavity ring down spectrometer (CRDS). The goal of the demonstrator is to show that the two mirrors of the cavity will be not misaligned during launch and thermal behavior in orbit and that this technology can be used for space mission. Other parts like the acousto-optic, the piezo and the opto-electronic as also to be qualified for space.

This year, we are manufacturing the qualification model that will be tested fully integrated starting in October. The Flight Unit will be manufacturing beginning of next year to be ready to launch starting July 2020.

OGMS-SA is the opportunity to work on new technologies for space such as additive manufacturing and SURE software development. About the additive manufacturing we are working with CNES on the material, not only about the mechanical specification but also the aging of the material due to UV and cosmic rays. On the software part, students are working on code that can be self-tunned and secured with parts that can be uploaded from the ground.

All these development and training are now performed in the brand-new Campus Spatial de l’UPEC (CSU). In the CSU we have starting to acquire all the essential tools and facilities.

*Speaker
needed to develop, integrate and test CubeSats and Space Instruments. During this presentation we will introduce the Campus Spatial de l’UPEC, describe OGMS-SA subsystems and all the tests to be performed previous to launch.

**Keywords:** CubeSat, Demonstrator, Student, CSU, Additive Manufacturing
From student satellite program to space business and science

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Rapid development of technology has induced rapidly decreasing prices and eased significantly access to space. Satellites are smaller, rockets are better and nowadays wide community can live their dream by building equipment for their own space mission. Space is a source of inspiration and also a good brand, which helps to access funding and accelerates careers. The paradigm change, called often New Space, has started at universities and is still propelled by students. In order to keep the New Space developing, the universities need to embrace working model which is closer to start-up company than traditional lecture based teaching.

Finland joined the CubeSat revolution relatively recently. The first satellite project started in 2010 and the first satellite was finally launched 2017. Despite the slow start, determination and embrace of new trends have made Finnish New Space scene successful. Aalto University entrepreneurship spirit and technical excellence is a combination which produces new companies and supports also challenging science projects.

Currently, the Aalto University CubeSat program belongs to Space Science and Technology major and connects wider community of interdisciplinary students, companies and research groups. The launch of the student satellite keeps the students motivated and support of the community provides development directions in science and business to every student.

This presentation gives an overview of Aalto University student satellite program, its linkages to Finnish Centre of Excellence in Research of Sustainable Space science missions and start-up activities.

*Speaker
Uni Space Projects, Start-ups & Career Advice

Tariq Sami * ¹

¹ NanoAvionics – United Kingdom

This talk will discuss space projects and how those evolve into the startups in New Space that are often started by graduates. It will also offer career advice to students considering their next steps.
X-CubeSat results, the first nanosatellite of Ecole polytechnique’s student space center.

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X-CubeSat was launched into orbit (415 km) on May 17th 2017 from the International Space Station, after six years of development by Ecole polytechnique’s students (57 students and 8 engineers have built from scratch this double CubeSat). Our satellite finished its mission on February 4th 2019.

Firstly, we would like to present the X-CubeSat data analysis results. In particular, the post mission analysis, our experience feedback and the X-CubeSat latest date obtained by amateur radio operators.

Thanks to more than one and a half worth of housekeeping data collected by our ground station and le collection of two-line elements across the satellite lifespan, we have the physical measurements of the CubeSat, such as solar cells temperature, voltage and current, battery charge and temperature other subsystems states, regarding the satellite position at the time of their emission.

Secondly we would like to present our students projects (balloons, rocket, CubeSat) and their developments in École polytechnique’s student space center.

Keywords: X, CubeSat, CubeSat

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IR-COASTER: a 6U CubeSat for In-situ observation of organic compounds degradation in Earth Orbit by Sun UV exposition

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The LISA (Laboratoire Interuniversitaire des Systèmes Atmosphériques) laboratory in Créteil university is known for many years for its expertise in Exobiology and for its development of dedicated instruments in order to study this matter and collect new sets of data. Inherent goal is to get a better understanding of chemical reactions in planetary, interplanetary and interstellar mediums. In parallel of experiments on the ground of moons and planets like Titan or Mars, or cometary environment as per on Rosetta mission, the LISA as used Internationnal Space Station to expose known organic species and samples to space environment and have the opportunity to take it back on Earth for a posteriori comparative analysis in the EXPOSE and EXPOSE-R experiments. By comparing identical samples, one that stayed on Earth, and on that spent several months in space on ISS, we detect and characterize the degradation of organic molecules under radiations.

IR-COASTER is the logical continuation of this test campaign, aiming for the realization of an in-orbit demonstrator for in-situ and continuous analysis of these organic molecules degradation. This time, the cinematic of the degradation will be studied on-board, by the use of a Fourrier-Transfor Infrared Spectrometer, firing regularly on the samples’ cells during the duration of the mission. A carousel and samples exposure mechanisms will permit to have up to 20

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different samples on-board, and to choose time and duration of exposure, as well as number and frequencies of IRTF analysis.

The entire project is built in two distinct phases. In 2020, a first version of the experiment will embark in a CubeSat 6U form factor module on the AIRBUS Bartolomeo platform, once again on-board of ISS. This module is not a satellite, as it will be fixed, and directly interfaced with the ISS. It will continuously communicate with the station, allowing easy power and data budget management in this less restrictive type of mission. Exposure profiles of the organic samples will therefore be constrained by the ISS orbit and attitude, but the expected duration will be notable and degradation measurable several times during the mission.

In the second phase of the project in the horizon of 2022, the same instrument will this time be integrated in a complete 6U CubeSat platform. The satellite and the mission are completely dedicated to the payload (IRTF and exposure mechanism) and therefore satellite maneuvers will allow choosing angle and duration of exposure of each sample. The use of S Band telecommunication subsystem is required to download high amount of data collected from spectrums through the orbit and the entire mission. The payload mechanisms, as well as most of the platform electronics will be developed in house, and be part of the flight heritage of OGMS-SA 3U Student CubeSat.

**Keywords:** CubeSat, Exobiology, Expose, Organics, Spectrometry
LAUnch Vibration on fish Embryo (LAUVE) Project

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The LAUnch Vibration on fish Embryo (LAUVE) project is a joint project between the University Space Center of Montpellier (CSUM) and the MRU MARBEC to evaluate the feasibility to launch and travel fish eggs into space. The objective of the overall project is to prepare the human exploration of solar system celestial bodies, mainly Moon and Mars, by providing an innovative nutritive resource to space travellers. Indeed, fish shall provide a significant lipid contribution to a constraining diet due to limitation of embedded mass at launch. Fish eggs are light, small and relatively robust. As they are embedded into a water tank, they are easy to handle into space environment and they are naturally shielded from space radiation by the surrounding water inside the water tank. Fish embryos and fishes swimming into a fishball are also very attractive considering the need to entertain astronaut during a long interplanetary journey.

The project planning show in three steps : (1) First, to shake fish eggs into a sealed tank to observe the vibration constraints on the hatching rate evolution, (2) Second, the in-orbit demonstration is done by putting into Low Earth Orbit (LEO) a CubeSat 1U volume with several hundreds of fish eggs and observing through a miniaturized camera the fish eggs evolution (3) and finally, the lunar demonstration by having some fish eggs embedded in a lunar mission as part of the living payload. This third step shall be led in the frame of a lunar hatch project.

LAUVE project consists in performing the first step : the proof of concept.

The project has started on January 2019, the first stage shall last two years. Several tasks have been done in parallel: the design of a robust tank to place several hundred of eggs and the selection of the fish eggs species that best match all the mission, biological and technical requirements.

A sealed water tank has been designed to be placed into a 1U CubeSat Structure. The team has experimented several technical solutions to properly seal the tank and fill it without any air bubbles. An evolution of this tank shall be developed thanks to the advices provided by CNES.

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Considering the objective to fly the experiment on board of the International Space Station (ISS), the tank must comply with sudden external pressure decrease requirement. The CNES has a very long experience in developing such solution. A robust globe with creative ways to fill and empty it has been developed. It includes the use of material and processes compliant with space activity.

The selection of fish egg species for step one has been done considering the experience already acquired by the MARBEC laboratory into aquaculture innovative solutions. The selection criteria was the capability to easily produce fish eggs and the evolution timing of eggs. For the first experiments, the fish species chosen is the European seabass (Dicentrarchus labrax). It is a type of fish used for aquaculture research activities. Four decades of knowledge have been accumulated concerning its physiology. In a second step, a detailed bibliography shall consider all the aquaculture species recommended by Food and Agriculture Organization (FAO). The selection criteria shall be, among others, the nutritive contribution, the gustative value, the easiness to handle and eat (few fishbone and removable scales).

At the time of writing this abstract, the team has already performed several experiments with very promising results. Several fish eggs have been shaken into vibrating equipment at MARBEC and preliminary results show a very good robustness of the water tank (no leak observed) as well as a significant number of surviving eggs after vibration constraints. The hatching rate has been evaluated and it appears that the vibration has no significant impact. Further investigation must be performed to confirm this result and to test the water tank using the vibration exciter of the LMGC that allows to mimic launch vibration environments. This complementary work is expected to be performed in June 2019.

The authors would like to thanks Cecile THEVENOT from MEDES (CNES – CADMOS), Didier CHAPUT from CNES/DNO/SC/EM and Jean MIGNOT from CNES-DNO/SC/EM (CADMOS and MEDES) for their fruitful contribution in this project.

**Keywords:** Fish eggs Moon space food
A new concept of the astrobiological nanosatellite applying miniaturized lab-on-chip platform as a payload

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Biological scientific experiments conducted in the space have been focused mainly on the investigation of the influence of microgravity and radiation onto widely understandable life. So far this research has been provided among others on the ISS by qualified astronauts and required to invest a lot of money to launch and our maintaining. Nowadays appeared new thinking about biological research also as a part of the NewSpace industry. Utilizing nanosatellites to those goals allows obtaining direct cosmic environment influence to the sample by simultaneously with the lower cost of the mission and possibility of quicker access to the results. Still, a huge challenge is maintaining appropriate conditions and tools for providing a complicated experiment. But the possibility of those activities can be approved by several missions carried out so far, concerning among others about investigating DNA mutations [1], antibiotics treatment [2] or growth and metabolism of microbes [3], which were realized mainly with the use of 1U and 3U CubeSats (1U=10×10×10 cm3).

Despite that, the biological experiments seem to be quite complex and are requiring to provide special conditions and support, new solutions also in the microengineering have appeared which perfectly correspond with the NewSpace tendencies. The LOC (lab-on-chip) devices using microfluidic dependences allow to conducting many biological experiments in a microscale with precise process control and minimalization of reagents using. Thanks to a collaboration between the SatRevolution company and Faculty of Microsystem Electronics and Photonics from Wroclaw University of Science and technology the concept of the astrobiological satellite in the CubeSat standard was proposed. The lab-on-chip payload, compatible with a nanosatellite bus structure, will allow for long-term culturing of different biological objects, by the creation of repeatable micro-aquatic habitats on-chip. Moreover, intentional disturbances of the microenvironment can be precisely introduced, towards an investigation of behaviorism of microbes, e.g. drug resistivity, mutation. Cultures are observed constantly and based on the acquired image sequence, software-enhanced metrological analysis of the cells is conducted. Eventually, parameters, e.g., culture population, cells size, shape, mobility, migration paths, etc., can be quantitatively indicated, to unambiguously assess the development potential of the cultured objects.

*Speaker
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To date, the platform has been successfully utilized for the culturing of different biological objects – microorganisms (E. gracilis), cancer cells (SKOV-3), and porcine oocytes. Tests conducted in the Earth conditions have shown a notable population growth of these cultures and appropriate – consistent with the literature data, behaviorism. These results are a good base and may constitute a reliable reference to conduct further experiments in outer space. The lab-chip platform will be integrated with the dedicated nanosatellite bus, equipped with special subsystems, controlling thoroughly the experiment in outer space: DOBC (Dedicated On Board Computer), ADCS (Attitude Determination Control System), EPS (Electric Power System) and CM (Communication Module). Payload mass (\(~0.3\) kg), dimensions (\(~80\times80\times80\) mm) and power consumption (\(<3\) W) classified final CubeSat structure as 2 kg/2 U. The first test in the microgravity conditions is planned for 2020. The experiment will verify the possibility of oncology treatment of cells. To evaluate the results, stop-motion visualization and fluorescence signals will be utilized.

**Keywords:** nanosatellite, astrobiology, LabOnChip, microengineering
Spectral Imaging Technologies for Small Satellites

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In the recent years, VTT Technical Research Centre of Finland Ltd has developed several miniaturized spectral imaging instruments, that are suitable for small spacecraft operations. The imagers are based on a spectral filter, a tunable Fabry-Perot Interferometer. This filter allows the acquisition of images at a single, freely selectable, wavelength, i.e. it is possible to record a complete 2D image at any single wavelength with a single snapshot. In the past similar functionality has been usually achieved by filter wheels, which are not very suitable for nanosatellites due to their bulky construction. Also the tuning speed of VTT’s spectral filters is very fast, which enables the recording of the complete spectrum in a short time. The filter structure is very simple, compact and robust, and thus makes this technology usable for nanosatellites, which has not been possible in the past.

The technology was first demonstrated in space on-board the Aalto-1 nanosatellite mission, which was launched in June 2017. The Aalto-1 Spectral Imager operates in the visible and near-infrared wavelengths between 500 and 900 nm. Aalto-1 Spectral Imager was also the first nanosatellite compatible camera capable of hyperspectral imaging ever to be flown in space. The second demonstration mission was for the shortwave infrared wavelengths (900 - 1400 nm) on-board the Reaktor Hello World nanosatellite, which was successfully launched in November 2018. The Hello World Spectral Imager was the first demonstration of shortwave infrared spectral imager on a nanosatellite. Both of these missions have been successful, and all the technical objectives have been completed.

On-going developments include the Asteroid Spectral Imager ASPECT, which is to be flown on the APEX CubeSat in ESA’s HERA mission to the binary asteroid Didymos. ASPECT is a combination of the Aalto-1 and Hello World spectral imagers, and will be capable of performing spectral measurements from 500 nm up to 2500 nm, in order to characterize the surface composition of the asteroid. Another recent development is the Cubic-inch Spectral Imager, which will be a next step in instrument miniaturization. The Cubic-inch Spectral Imager operates between 600 and 1000 nm, and as the name implies, can fit in an envelope of 1 in3. This kind of imager could be used as a microscope in a lander or a planetary rover.

Miniaturization of technologies has generated several new applications and possibilities in our every day lives. The same development is currently on going in space as well. This presentation will give an overview of the spectral imaging technologies at VTT, the current applications and how the technology can be utilized in the near future.

*Speaker
Keywords: Imaging, hyperspectral, SWIR
Monitoring of greenhouse gases from space: achievements, challenges and expectations

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Over the last 15 years, space agencies have supported a series of pioneering space-based instruments designed to monitoring anthropogenic greenhouse gases, carbon dioxide (CO2) and methane (CH4), at high spatial resolution over the globe. These include ESA’s SCIAMACHY, JAXA’s GOSAT, NASA’s OCO-2, Chinese TanSat, Feng Yun-3D, GAS and GaoFen-5 GMI, and ESA Sentinel 5 Precursor TROPOMI. Additional missions are already planned, among which CNES/MicroCarb and CNES/DLR Merlin, and more an in preparation by governments, private companies, and non-governmental organizations. These missions have already brought a new vision of these compounds, which are the main cause of climate change. However, difficulties persist for taking full advantage of the restitutions of CO2 and CH4 columns from spaceborne observations made in the short-wave infrared part of the spectrum. In this talk, we will give an overview of current and planned missions dedicated to anthropogenic greenhouse gases. We will detail the challenges in interpreting measurements collected by space-based sensors in terms of column-averaged dry air mole fractions of CO2 and CH4, which requires unprecedented precision and accuracy to resolve the small variations caused in gas column by surface fluxes from natural and anthropogenic sources and sinks. We will present ways forwards and the role that constellation of nanosats, such as those studied in the SCARBO European project, could play in the near future for participating to the Measurement, Reporting and Verification global system for anthropogenic emissions. We will finally discuss the needs in improvement fundamental aspects of radiative transfer modelling, in developing end-to-end modelling systems for estimating surface CO2 and CH4 fluxes from atmospheric measurements on scales ranging from individual power plants to continents, and in developing cal/val activities.

Keywords: Greenhouse gases, Nanocarb, radiative transfer, validation

*Speaker
An overview of ONERA activities on small satellites

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ONERA is increasing its investment in nanosatellites technologies and mission design in order (i) to develop an expertise in miniaturized sensor for space application and (ii) to propose new concepts meeting current and emerging needs with a focus on Dual Use technologies and Earth Observation.

In this presentation, we will first describe the outline of our roadmap, and the facilities and devices we develop. It includes facilities related to the payload design, development and testing, in close link with the university space centers and the partner companies. And also simulation, mission analysis and performances assessment facilities.

The three missions that have been pre-selected for a first in house funded project, will be shortly presented.

We will conclude with a focus on miniaturized payload developments for earth observation including spectroradiometers for atmospheric sounding and greenhouse gases measurement and infrared imaging in the thermal domain for several applications

Keywords: nanosat, miniaturized sensor, earth observation

*Speaker
Image Sensor platforms : sensor customization for Earth Observation in NewSpace

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1 Pyxalis (FRANCE) – Pyxalis (FRANCE) – France

will follow.

Keywords: Pyxalis detectors
Space activity at Sofradir and new space challenges

Bruno Fieque *, Philippe Chorier *

1 Industry – SOFRADIR – France

SOFRADIR is one of the leading companies involved in the development and manufacturing of infrared detectors for space applications leading to many space studies and programs from visible up to VLWIR spectral ranges. These studies and programs concern operational missions for earth imagery, meteorology and also scientific missions for universe exploration. Numerous programs are currently running for different kinds of missions: meteorology (MTG), Copernicus with the Sentinel detectors series, Metop-SG system (3MI, Sentinel-5 and Metimage), Mars exploration (Exomars), moon exploration (Chandrayaan mission with Indian space agency)...

New space trend is increasing these last years in many different domains including earth observation. Contrarily to traditional space activity, new space obliges the different actors to renew their practices and to find a new model to answer the mission’s needs and the way to design and to build satellites for these missions. In particular, new space is calling for low costs and short schedule associated to a reasonable additional risk in terms of reliability.

In this presentation we will first describe the overview of space activity at Sofradir in terms of programs and missions. Then a focus will be done on the challenges to be tackled to enter in the new space age for IR space detectors.

Keywords: Space mission, Infrared detectors, HgCdTe, InGaAs, earth observation

*Speaker
SAFRAN Reosc is EU leader in precision space optics and is now pushing a New Space initiative with the development of High Performance EO payloads for Cubesats/Microsats under the trade name SEEING (Small satEllite instrument for Earth imagING). Designed with ultimate low SWaP factor (8 liters volume, 6-8 kg, 30W power) and offering best possible optical performance from 500 m orbit thanks to high quality optics, best COTS image sensor and high thermal stability.

SEEING 10-m is offering 10-m GSD over 60x40 km² FoV

SEEING 1.5-m is offering 1.5-m over 11x8 km² with possibility of super-resolution down to 0.8-m.

Recently we were selected by Norway for the development of a Space instruments for maritime awareness and ship surveillance in the Artic area.

Our products will be presented with latest development on our Norway project.

Keywords: EO payload, high performance, low SWaP, smallsat

*Speaker
Earth Observation at CNES

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will follow.

Keywords: CNES, INSU

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Earth observation by utilizing nanosatellite constellation

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Nowadays, Earth Observation (EO) satellites with huge telescopes onboard provide high-resolution images and allow to distinguish two objects located on Earth at a distance of fewer than 0.5 m from each other [1]. Such high-quality image requirements result in huge volume and mass of the instruments, notably increasing the costs of their launch and fabrication. Will be presented the conceptual design of a synthetic aperture telescope [2], which may meet similar resolutions as current state-of-the-art Earth observation systems, but simultaneously, having a significantly smaller launch volume.

The main application of the presented concept of satellite telescope is to monitor Earth phenomena, e.g. natural disasters, land survey, insurance and precision farming. Therefore, the key criterions during the design process were to achieve a sufficient resolution and possibly the widest field of view. Additionally, it was attempted to obtain the smallest possible volume of the structure and dimensions corresponding with the CubeSat standard, in which the basic unit is 1 U = 100x100x100 [mm]. It is assumed that the overall dimensions of the stowed telescope module in the nanosatellite structure should not exceed 7 U. The 4 U are reserved for the CubeSat bus which contains modules, such as: On Board Computer (OBC), Communication Module (CM), Electrical Power System (EPS), Attitude Determination and Control System (ADCS) – necessary for proper device operation on the orbit. The next 2 U or 3 U are intended for the telescope instrument topology. It is allowed to place part of the telescopic system in the nanosatellite bus structure.

The SatRevolution company establish your goal to create a constellation of small, light and inexpensive Earth-observing nanosatellites, utilizing the proposed CubeSat telescope solution. The greater number of devices results in a shorter time of revisit above a specific place, which may lead to the precise imaging of a chosen area in real-time. This conception was named REC - Real-time Earth-observation Constellation. The final goal is to reach 30 minutes refresh rate by placing more than a thousand of CubeSats on 300-350 km Low Earth Orbit by simultaneously less than a 1m resolution! In the presentation will explain technical assumption and restriction for optics, mechanics and electronics part of the nanosatellite telescope and sequence of planning the mission will be presented.

∗Speaker
Keywords: nanosatellites, telescope, constellation, Earth observation, high, resolution
Space Project of Russia–Azerbaijan: Small Satellite for Radiation Monitoring and Upper Atmosphere Control

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The small satellite space experiment is elaborated jointly by M.V.Lomonosov State University and National Aviation Academy of Azerbaijan. Small satellites are applicable for the study of different physical phenomena, such as transient electromagnetic events, i.e. Terrestrial Gamma-Ray Flashes (TGF), Transient Luminous Events (TLE) and space Gamma-Ray Bursts (GRB), as well as magnetosphere electron precipitation, which can be dangerous for the spacecraft and biological objects. The sun-synchronous orbit with relatively low altitude (500 - 800 km) provides the favorable conditions for the control of upper atmosphere and the study of the space radiation in different areas of the near-Earth space, including areas of trapped radiation and regions of electron precipitation from the radiation belts.

This project assumes the elaboration of a general scientific concept of satellite experiment, determination of the optimal orbits and orientation of the spacecraft, determination of parameters and technical appearance of measuring instruments (spectrometers of energetic protons and electrons), requirements for satellite platform, orientation system, data transmission and data processing. The data, which is planned to be obtained during this experiment, will be subsequently used for the scientific and applied tasks, such as the study of the processes of acceleration and loss of trapped and quasi-trapped energetically charged particles in the Earth magnetosphere, validation of existing and development of new dynamic models of Earth radiation belts, support and confirmation of the safety of space vehicles.

The additional task is the analysis of the possibility of including of Russian-Azerbaijan satellite in the Universat-SOCRAT multi-satellite group, which is also currently elaborated in the M.V. Lomonosov Moscow State University. This gives a good opportunity for the additional measurements of energetically charged particle fluxes, as well as for the detection of electromagnetic transients, Terrestrial Gamma-Ray Flashes (TGFs) at different points of the near-Earth space. The last is very useful for the TGF source localization by the triangulation technique.

*Speaker
Keywords: small satellite, monitoring, radiation, upper Atmosphere
COTS for Space: CMOS image sensors solutions

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During this last decade, Space Imaging has faced at least 2 major evolutions: one is the progressive transition from CCD to CMOS image sensors and the second is the Newspace environment especially linked to nanosatellite development. CMOS image sensors are now found in numerous markets for which they are produced in high volume. Their complexity and performances have increased significantly. They have been progressively introduced in space systems. Due to both a long history in developing CCD image sensors for space programs and high volume CMOS image sensors for industrial applications, Teledyne e2v is at the crossroads of these technologies and evolutions and can bring well fitted solutions to this new era.

As COTS are not originally designed for space, the key is to evaluate their characteristics to get pertinent performance for space. This presentation illustrates how COTS initially designed for bar code readers or industrial inspection applications can eventually fly in nanosatellites. Several examples of such applications in nanosats recently launched are described and first image results are illustrated.

Exploring COTS image sensors domain show that there is a bridge from COTS to space: sometimes customers require additional qualification, screening or lot validation testing. Others would like to upgrade the COTS by changing some features.

Based on our experience and existing facilities currently used for space image sensors flight models manufacturing and delivery (such as visual inspection, high temperature stabilization bake, temperature cycling, burn in, seal test, ...), we are looking to several possibilities to build an upscreening of CMOS COTS image sensors.

On the other hand, upgrade covers the domains of more accurate selection options and modifications that could also start at various manufacturing steps, from wafer level up to encapsulated packaged sensors.

We illustrate how upscreening, upgrading or lot validation testing can be applied to our Teledyne e2v industrial CMOS image sensors or to any other image sensor.

*Speaker
Keywords: CMOS, COTS, image sensors, screening
C³IEL : Cluster for Climate and Cloud Imaging of Evolution and Lightning, an innovative way to observe the clouds and their environment

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Clouds are key elements of the Earth climatic system. However, lot of uncertainties remains about their evolutions and their roles in the context of climate change. Increasing the knowledge of the cloud development and interactions with water vapor and aerosols is then essential.

The French-Israeli C³IEL (Cluster for Climate and Cloud Imaging of Evolution and Lightning) is an innovative spatial mission currently under study that will provide unprecedented new insights to outstanding climate questions. This demonstration mission, mainly focused on convective clouds, aims at characterizing dynamically the clouds and their environment at a high spatial and temporal resolutions of the scales of the individual convective updrafts. The different nano-satellites of the C³IEL mission will carry visible cameras measuring at a spatial resolution of about 20 meters, near-infrared imagers measuring in and near the water vapor absorption bands, optical lightning sensors and photometers. The observational strategy for the imagers will consist in 10 to 20 multi-angular measurements of a given cloudy scene during the 200 seconds of the overpass at a rate of an observation captured every 10 to 20 seconds. Lightning observations will be done continuously during the same time. The observations of these space-borne sensors will consequently simultaneously document the vertical cloud development retrieved by a stereoscopic method, the lightning activity and the distribution of water vapor at a high resolution by exploiting the multi-angle measurements for application of tomography methods.

The scientific objectives of the C³IEL mission will be introduced. Then we will discuss the nano-satellite train configuration, the observational strategy and the different sensors of the

*Speaker
mission. Finally, we will introduce the observations and products of the C3IEL mission that will give new understanding of the redistribution of the energy and water vapor in the atmosphere, and of the relation between storm vigor and frequency of lightning activity. In addition, using synergistically with measurements of others missions like the Joint Polar Satellite System mission (JPSS) and the geostationary satellites such as the METEOSAT Third Generation (MTG) Imager (MTG-I) and the Sounder (MTG-S) missions, a first use of C3IEL products will allow to disentangle aerosol impacts and cloud updrafts and to study the life cycle of convective clouds.
Sharing Science in the 21st century: a CUBESAT challenge for primary- & high-school junior engineers

Silas Bailey, Clément Biot, Cécile Blanc, Marion Bugnard, Nouchine Bouchiat, Elliot Col, Eole Doron, Ambre Dujeu

1, Zoé Evans, Félix Evrard, Thierry Griffo, Yohan Hadji

1, Alicia Köster, Elise Kudlich, Sylvie Labatte, Luna Marsol, Eric Martinet

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1, Tejus Sharma, Sophie Thuillier, Quentin Vilar, Mathieu Barthelemy

1, Eric Martinet, Pierre Mazzucotelli

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1, Tejus Sharma, Sophie Thuillier, Quentin Vilar, Mathieu Barthelemy

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The launch of its first nanosatellite AMICaSAT in June 2019 by the Grenoble University Space Center (CSUG) creates an opportunity to reinforce science in a community of schools via the "Sharing Science" educational program developed in Grenoble since 2015. School "laboratories" comprising schoolchildren, college pupils, high school and engineering school students use the space engineering process, exchange and validate data and ideas as genuine researchers. Workshops are scheduled in May 2019, with oral presentations by the elementary school children (partly in English), project reviews, poster sessions, followed by science fair and a show about space exploration.

The CNES challenge: a CUBESat in my high school

A team of 20 high-school students from Cité Scolaire Internationale de Grenoble (CSI) were
given the chance of evaluating a CUBESat kit for educational and outreach purposes at a primary and high-school level. The CUBESat educational kit was provided by CNES. It had been previously used to teach university students the process of satellite engineering via problem based learning. The CSI team reports here their achievements after 3 month of efforts, regarding technical, scientific, management and communication issues, the skills they had to develop and the difficulties they encountered.

The educational CUBESat in operation will be presented by the students with a computer as ground station, together with a "selfie" of the team taken by the sat camera, and the launch with a helium balloon of a 3D-printed "KUBE" structure designed for communication and outreach purposes. Short and long term perspectives of the project will be discussed.

The CSUG challenge: a Sharing Science community from primary school to University

During the academic year, 12 classes of elementary school students* have taken off on the space exploration adventure triggered by the "friendly" AMICal Sat from CSUG.

After an accelerated engineering course ("spaghetti challenge"), the classes have taken ownership of the missions entrusted by a pool of 8 Phelma engineering school students as Teams Exobiology, Propulsion, Power Engineering, Material Sciences, Bioinspired Techs ... each mentored by high school students. Two lab sessions were built and conducted by the high school students according to the problem to be solved by the class. The engineering school students act as outside experts, boosting project authenticity.

School pupils discover that failure and risk are part of the innovation process. They are deeply motivated when they review their work with young boys and girls from high school or "professionals" in the field they can relate to. High school students develop general skills and the meaning of citizen engagement. Engineering students develop management skills as they are responsible for organizing the workshops and online communication within a virtual community. Building up this project between elementary and secondary school teachers is a key part of this project devoted to inclusive science in school and classes with children far from the scientific culture*.

The CSUG is at the forefront of the project by providing the "trigger" for the project, cardboard models of the AMICal Sat (used in classes to address the concepts of mission, sensors and functions associated with the CubeSat system). The director of CSUG will give a talk during the workshops, discuss with the primary school pupils about their achievements, and give a live communication with some classes from Vostnotchy (Russia) where AmicalSat will be launched in June. A two-day teacher training was also offered by CSUG with the Maison pour la Science Alpes-Dauphiné, so that STEM teachers discover space science and engineering processes and the diversity careers in the space domain, via seminars and a role-play to design a satellite mission.

We acknowledge the support from CNES, Maison pour la Science, Région AURA

The Sharing Science community:

* 300 primary, > 50 high school, > 12 university students; > 30 educators.


**Keywords:** 21st Century Education, Collaborative Science, Inclusive Science, UN Sustainable Development Goals 2030, Science with students, School Labs, Teacher Professional Development

**Ref:** https://tinyurl.com/y2rzgfap
Irradiation facilities within the PAC-G: from neutron to heavy ions test

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The commercialisation of space is a powerful trend affecting businesses and academia. Pressure to reduce costs and make them affordable for companies and individuals has pushed away traditional RadHard technologies and made place for unconventional qualification approaches. In addition, increased political friction between countries bring additional risks to the supply chain of space-graded components. The use of cost-effective COTS electronics in harsh environments such as space has therefore been popularised. The demand for radiation testing is on the rise and, in opposition, the number of facilities providing industrial access to perform these tests seems to be decreasing. Moreover, new semiconductor technologies (3D structures, memories, SOI etc.) call for alternative and innovative testing methods.

The Platform for Advanced Characterisation Grenoble (PAC-G) is a service platform whose aim is to help addressing these problems. Created within the frame of the IRT Nanoelec, the PAC-G offers unique techniques for single-event effects (SEE) testing as an evaluation preliminary to protons and heavy ion testing.

Cosmic rays are primarily composed of high-energy protons and electrons originated in the sun and heavy-ions from the intergalactic deep space. Recent studies have shown the interest of using 14 MeV neutrons as a cheap and convenient way to get a bounded estimation of proton and high-energy neutron sensitivities to SEE in advanced memories. The GENESIS platform (GEnerator of NEutrons for Science and IrradiationS), hosted by the Laboratoire de Physique Subatomique et de Cosmologie (LPSC), proposes the access to an accelerator-based neutron source which can provide an intense flux of 2.5 MeV or 14 MeV neutrons. The accelerator, designed and built at LPSC, was recently upgraded and equipped with a compact ECR ion source, capable to deliver a continuous deuteron beam up to 1 mA at 220 keV. In 2018 the maximum intensity delivered by GENEPI2 was 8x10^9 n.s^-1 in 4π corresponding to a maximum flux available for the user equal to 5x10^-7 n.cm^-2.s^-1 at the closest accessible point of the target, for the D-T reaction. The neutron irradiation is confined thanks to the shielding around the accelerator bunker.

Recent investigations have also demonstrated the principle of emulating the effect of heavy-ions on semiconductors using pulsed synchrotron X-rays and equivalent LETs have already been

*Speaker
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calculated. Today, this qualitative preliminary screening is done using focused laser beams with the drawback of sample preparation. Synchrotron X-rays of appropriate energy have the advantage of crossing several levels of metallization with no need for thinning nor opening the DUT, and provide the temporal and spatial structures needed for this type of test. The flexibility of a synchrotron also allows selecting the brightness of the beam and adjusting the energy in order to test different structures with different LET. On the beamline ID09, the ESRF can offer a very complex time structure guaranteed by a chopper, with sequences of 100ps long pulses with a 5μJ per pulse (2 x 10^9 photons). The wavelength of the micro-beam can be adjusted between 8.5 and 28.0 keV and a bandwidth of 3.2%.

In advanced semiconductor technologies, determining the threshold LET (minimum LET required to cause a SEE) experimentally has become very challenging and demands facilities providing heavy ions with low and adjustable LET, which are rare to find. At the ILL, the LOHENGRIIN recoil separator uses thin targets in an in-pile position with high neutron flux. Recoiling charged particles emitted in fission or (n,a) or (n,p) reactions respectively are separated by the electromagnetic spectrometer by mass and kinetic energy. The usual applications of this instrument are detailed fission studies or nuclear spectroscopy. The wide range of charged particles with similar velocity but very different LET makes it also very convenient for the study of the response of solid state materials (e.g. Si, SiC, diamond, etc.) to such particles. Separated fission fragments have kinetic energies from 0.4 to 1 MeV/nucleon. The flux can be varied from few ions cm⁻².s⁻¹ to thousand of ions cm⁻².s⁻¹ over areas up to 4x1cm². Automatic scans in energy and mass can be programmed and beams chopped in time are possible. The ILL also provides thermal neutron irradiation, relevant to reproduce the radiative background at the sea level for terrestrial applications.

This talk will address the context of low-cost space with the advent of a service platform providing a single entry point for low-cost radiation testing, reducing the overall qualification costs and acting as an enabler of NewSpace.

**Keywords:** devices characterization, neutron irradiation, low and high energy neutrons, heavy ions, SEU/SEE tests, reliability, radiation hardness.
Expanding sounding rocket research capabilities at T-Minus Engineering

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1 T-Minus Engineering B.V. – Netherlands

T-Minus Engineering is a turn key provider for sounding rocket access to space and designs, builds and launches tailor-made rockets in-house. T-Minus is constantly expending its capability to bring payloads to space. The T-Minus DART rocket system can provide access to 120 km altitude. Its payload size is determined by the desire to keep the aerodynamic losses of the vehicle low. The boosted-dart design allows a high apogee with a relatively small vehicle, making the T-Minus DART both efficient and interesting for repeated use. The vehicle stands 3.5 meters tall and the payload is a cylinder of 300 mm tall with a diameter of 30 mm. The rocket is intended to serve both the research community as well as the military target domain, increasing production numbers, launch rate, reliability and reducing overall cost. With the limited complexity of launch and cost efficiency, scientific payloads can be launched simultaneously and/or in rapid succession. A mission to monitor a certain phenomenon over a day with multiple rockets is an expected use, as well as the launch to multiple locations at the same time to observe a phenomenon.

The obvious limitation of the DART is its payload size. With the advance in microelectronics however, it becomes more and more capable, but it is not yet suited for some larger and more demanding payloads. In order to accommodate larger experiments and potential small microgravity experiments, T-Minus is expanding its product portfolio with the DART XL.

The DART XL vehicle will be able to carry 5 kg to 200 km altitude. Its payload volume is a cylinder of 1000 mm height and a diameter of 70 mm. The rocket stands 5.5 meters tall. With this, T-Minus’ vehicle portfolio will fulfill a larger portion of the scientific needs in particle physics, aeronomy, earth observation, space weather and others. The increase in payload envelope with the DART XL vehicle and an increasing flight record will be available to the scientific community. The ease of access to space will also allow for validation of flight hardware before the launch of an instrument on a satellite. The increased payload size could also be utilized to provide microgravity environment.

The flexibility of T-Minus in launch ranges and involvement in the development of the payloads allows for a seamless collaboration. If desired, a limited involvement will reflect in a low overall cost of any of the campaigns. With our ability to quickly integrate any changes of the design, a rapid paced flight schedule is still within reach.

In our deliberations with the potential users we want to focus on three elements:

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*Speaker
Time to flight - waiting for a flight should not be a significant issue. Working with launch sites that can accommodate flights within 6 months and an internal production system that allows for either in stock on within 3 months production of a rocket.

Customization - The core design is normally used, however any deviations from this main design to accommodate additional requirements like high quality micro gravity or seclusion from external conditions or late access to the payload will be part of the expected work. Each payload is a mission on its own.

Repeated access - current sounding rocket launches are often scheduled year ahead with large budgets, payloads and complexity. In order to make room for a more rapid use of the vehicle repeatability of the flight schedule is of great importance.

Next to the uses for known sciences that use sounding rockets, like atmospheric physics, there is also an interest in high-speed test experiments. For that use case, the DART will fly at Mach 5.5 while the DART XL will reach Mach 7. The adaptation of the rocket to accommodate high speed vehicles is also a market of interest to T-Minus. The complexity of these payloads is the increased complexity in desired trajectory and the nominal aerodynamic shape of the dart. T-Minus can provide custom solutions for payloads to be flown to space. With the expanding portfolio of the DART XL the payload size has expanded significantly. Understanding the requirements of the user and accommodating any changes is paramount to the viability of the system. The T-Minus team is always interested in providing a solution to its customers’ needs and eager to collaborate on the development to a suitable solution.

**Keywords:** Sounding rocket, rockets, rocket, DART, DART XL, Boosted, dart, microgravity
Exploring the potential of Magnetic Tunnel Junction in radiation hardening integrated circuit design

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For embedded systems in space, a radiation robust circuit design is still an open challenge. Solar wind and flare, cosmic radiation and Van Allen Belt are some of the main sources of particle flux (protons, electrons, alpha particles...) involving energy ranging from hundreds of KeV to millions of MeV. Physically, the interaction of such particles with the active region of CMOS ends up in numerous undesirable events that could cause a failure or even destroy the transistors or other devices. Due to its proven immunity to radiation effects [1] and its inherent non-volatility, Magnetic Tunnel Junction (MTJ) is considered as a very promising candidate for high reliability electronic in space environment. The MTJ nano-pillar structure consists of a thin insulating barrier sandwiched between two ferromagnetic layers: a reference layer with a fixed magnetization and a storage layer with a switchable magnetization. Depending on the mutual magnetic orientation of the two layers (parallel or anti-parallel) the resistance changes being either low-state or high-state allowing the storage of bit 0 or 1 respectively. Nevertheless, when integrated in CMOS circuits, MTJs could be affected by radiations-induced errors, namely a flip of the stored bit, precisely because of the surrounding peripheral CMOS circuits. For this reason, a comprehensive approach is adopted in our study: first, we focus on developing an electrical equivalent MTJ model capable of ensuring a proper answer to the simulated error injection; second, we propose a radiation hardening solution with the aim to avoid the magnetization reversal of the MTJ. Physics-based 40nm MTJ and 28 nm FDSOI technology are used for the integrated circuit design. Simulations were run with standard electrical simulator under usual CAD tool platform. Errors injected into the sensitive nodes of the proposed circuit has shown enhanced radiation tolerance capabilities. F. Ren, A. Jander, P. Dhagat, C. Nordman, Radiation Tolerance of magnetic Tunnel Junctions with MgO Tunnel Barriers, IEEE Transaction on Nuclear Science, Vol. 59, No 6, December 2012.

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Keywords: Radiation hardening, Space environment, Unconventional electronics
Improved spatial data inversion via dimensionality reduction integration

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In the last few decades, scientific satellites have been producing large quantities of data. Moreover, as remote sensing and instrumentation technology develops, the processing complexity of the produced datasets increases dramatically. Indeed, the ambitious objectives of several scientific projects involve the reconstruction of the information present in these datasets, which is often mixed with instrumental effects and foreground signals (physical components of the data that mask or blur part of the signal of interest). In various contexts, the scientific community is confronted with the need to extract, from measurements, physical responses adapted to the different models considered, while at the same time ensuring an effective separation between these responses and instrumental effects and/or foreground signals. This problem has been extensively studied for the data processing of the Planck satellite mission, launched by the European Space Agency in 2009 to study the emission of the cosmic microwave background. Similar issues have been identified for the data processing of different Earth observation satellite missions, such as the future Surface Water Ocean Topography (SWOT) mission. SWOT, an interferometric radar altimetry mission designed for oceanography and hydrology, aims at producing, for the first time, two-dimensional wide-swath altimetry measurements of the planet’s surface. Among other objectives, SWOT will allow for the high-resolution observation of mesoscale and sub-mesoscale upper-ocean dynamics, as well as the accurate measurement of water levels in rivers, lakes and inundation areas.

As part of the Planck mission, the SRoll algorithm, used to produce the Planck-HFI (High Frequency Instrument) sky 2018 release maps, is the culmination of several years of research. The main breakthrough introduced by SRoll is the simultaneous estimation of the signal of interest

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alongside with instrumental effects and foreground signals which are not yet sufficiently understood to be accurately modeled. The separation of these different components is thus taken into account during the data inversion to reduce the impact of the instrumental effects and/or foreground signals. Effectively, this joint optimization significantly improves the information reconstruction performance, compared to a standard sequential processing, by minimizing the degeneracies between the different processes involved. Thus, this integration is essential, but also increases the number of parameters to be estimated considerably. It is therefore essential to identify new representations involving a reduced number of degrees of freedom to achieve a robust and effective inversion, while providing enhanced capabilities to accurately describe the complexity of the processes and variabilities in play.

In this context, we aim at exploiting machine learning and artificial intelligence approaches to minimize the degrees of freedom of the instrumental effects and/or foreground signals to be reconstructed by the SRoll algorithm. Indeed, such processes are currently represented using a large number of parameters, whereas more appropriate low-dimensional representations could be learned directly from data. Particularly, in the present work we focus on exploring autoencoders to learn optimal low-dimensional representations of the instrumental effects and/or foreground signals from data, simultaneously with the data inversion. This integration of the autoencoder training alongside with the data inversion constitutes the most important original contribution of the proposed approach, as it fundamentally differs from standard dimensionality reduction approaches, which are typically used as independent pre-processing steps and produce low-dimensional representations that may not always be completely adapted to the data inversion considered. This dimensionality reduction should help better handle the lack of explicit information on certain instrumental effects and/or foreground signals to effectively separate them from the signal of interest. In this work, we establish the preliminary methodological bases of this integration. We explore relevant applications of the proposed framework for the analysis of high frequency data from the Planck mission and simulated altimetry data from the SWOT mission. These preliminary applications should accurately characterize the performance improvement to be expected from this new approach.

**Keywords:** Data inversion, Machine learning, Dimensionality reduction, Remote sensing
TOLOSAT: A student cubesat for Iridium relay and gravimetry

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TOLOSAT is a student-led 2U cubesat project from Toulouse, France. The team is composed of students from engineering schools but the bulk of the members come from two associations: Club Cubesat Supaero from ISAE-SUPAERO and Astre from INSA Toulouse. There are currently around 30 students working on the cubesat. The project also benefits from technical support and experts of CSUT: Centre for nano Space systems at the University of Toulouse. It also receives help of experts from CNES, ISAE-SUPAERO and Observatoire Midi-Pyrénées.

The mission has 2 objectives: it will first explore the possibilities offered by using the Iridium Next constellation as a relay to communicate with the ground. This is complementary to a ground station and should allow communication with the cubesat even when he is not visible. It should allow the spacecraft to transmit more data per day with the ground. It can even work as a backup communication system if there is any problem with the ground station or the main antenna. Such technology is already implemented in ISAE-SUPAERO's cubesat EntrySat, which launched in April 2019. This payload will also establish a bi-directional connection for Telemetry and telecommand. A secured link will also be established using asymmetrical encryption like the SSH protocol. This method would create an innovative way to initiate a fully encrypted communication with a spacecraft.

The second mission objective is to map the Earth gravity field using a precise GNSS positioning. This position would then be derived twice to derive the acceleration of the cubesat. Accelerometers will measure the non-conservative forces and allow us to extract the acceleration due to gravity. This method was used on ESA’s SWARM mission but it was not purposely built to do it. To achieve this, the system will mainly rely on the Galileo constellation.

The main advantage of this method is its simplicity and low-cost implementation. An outcome of this mission would be to study the feasibility of a cubesat constellation providing near real-time data of the earth’s gravity field.

The TOLOSAT project is to reach the end of preliminary design phase by July 2019. This project is also an opportunity for students to apply directly into a concrete project the knowledge they have and also to learn to work in a reasonably big team. Some of the subsystems will be conceived by students, such as the payload boards and the structure.

Further reading about the project:
http://www.astre-toulouse.com/projets/

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**Keywords:** Tolosat Iridium Gravimetry cubesat
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