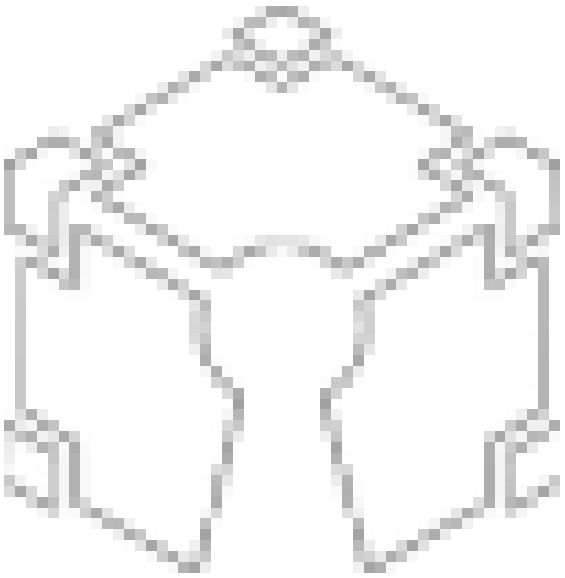
Open Source CubeSat Workshop 2019



Report of Contributions

https://events.libre.space/e/3

Contribution ID: **1** Type: **Talk**

An Open Source Implementation of the CCSDS SLE Services in Python

Monday, 14 October 2019 09:30 (20 minutes)

An Open Source Implementation of the CCSDS SLE Services in Python

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The Open Source CubeSat community is currently lacking the capability to use existing radio amateur ground-station networks to transfer live data to the end users / mission control centres. SatNOGS, the biggest network of the kind, provides services for archiving and offline distribution of telemetry data. At the moment, an operator using the SatNOGS network is not able to receive telemetry in real-time and make use of the station uplink chain, when available, for direct commanding. We believe that the community could benefit considerably from services that provide real-time monitoring and control over a distributed ground-station network.

As a first step to address the current limitations we introduce in this contribution a new free and open source implementation of the CCSDS Space Link Extension (SLE) services in Python. The SLE standard, used by all major space agencies, is one of the most adopted CCSDS standards and is key to enable the inter-agency utilisation of ground-station networks like the Deep Space Network. Additionally, it is supported by most, if not all, private ground-station operators. SLE services have proven reliable, and can be used even for missions, like most CubeSats, that do not adhere to the CCSDS telemetry and telecommand frame and packet formats. SLE provides different types of telemetry return services, for real-time telemetry reception, a telecommand forward service and the capability to receive annotation information about the current status of the space link. We take the initiative to put forward a solution based on SLE because of its proven track record and out-of-the-box interoperability with existing commercial and agency ground-stations.

Our current SLE stack offers:
1. An SLE provider, offering the ground-station (provider) side services for delivery of telemetry and uplink of telecommands. In addition, it offers some level of ground-station configuration management services over a REST API (https://github.com/visionspacetec/sle-provider)
2. An SLE management client, allowing anyone to access the SLE management services on the provider using a Python API (https://github.com/visionspacetec/sle-management-client)
3. A set of SLE common libraries (e.g. ASN.1 mapping) for the development of provider and user services (https://github.com/visionspacetec/sle-common)

In the current implementation only the Return All Frames (RAF) service has been implemented. RAF is not only able to transfer CCSDS telemetry transfer frames but also any other frame format like AX.25, which is used by many amateur CubeSats. The event-loop based implementation in Python is lightweight, cross-platform and easy to deploy. Python was chosen because of its wide use in the Open Source community and the short development cycles it allows. It provides high data throughput, enough for amateur and most commercial satellites. A heartbeat mechanism ensures that the connection is always alive and ready to transfer mission critical data. The communication between user and provider can be encrypted, using the implemented protocol features and has been verified with up to date reference software from the European Space Agency (ESA). For the REST API, the use of HTTPS is prepared and can always be combined with an authentication scheme to ensure data integrity at any time.

The current stack does not offer an implementation of an SLE user since at the time of writing at least two free and open source implementations exist: LibreCube SLE and the NASA AMMOS

framework. Our provider has been tested and proven to work with both. In addition, we have tested our implementation against the SCOS-2000 ground-station Network Interface System (NIS), showing that it holds against existing commercial implementations of the SLE user. In what concerns the interface of the SLE provider with the ground-station backend, the provider has been tested with the Cortex CRT at ESA's European Space Operations Centre (ESOC) development ground station ESOC-1.

Besides its use in a traditional ground-station setup, the SLE provider can also be used to relay telemetry and telecommand data from/to cloud ground-station service providers and satellite operators. Cloud based scheduling systems could be used to dynamically configure the ground-station network, using the SLE provider's REST API, ensuring highly efficient use of the ground-station time and minimizing the need for human interaction. Upcoming developments include not only the support for a wide range of commercial and amateur ground-station equipment and Software Defined Radios (SDR), but also extensive testing and further performance improvements. Implementation of the telecommand forwarding service is also planned.

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Presenter: STARCIK, Milenko (VisionSpace Technologies)

Session Classification: Talks

Track Classification: Software

Contribution ID: **3** Type: **Talk**

Developing a low-cost, performant microsatellite platform design for all: The Open Source Satellite Programme

Tuesday, 15 October 2019 14:20 (20 minutes)

We have initiated the development of a flexible, fully Open Source, flexible microsatellite platform, embracing an open source approach, to create an efficient fail-safe microsatellite platform that is performant, capable, modular and robust.

The platform can be readily tailored for different missions, can be upgraded and configured after launch and can operate with multiple ground station networks. The platform is being developed using COTS parts, processes and tools; and the design will be made available to the small satellite community. We are targeting high performance at a cubesat price: USD1m for a 50kg variant, GBP1m for a 100kg variant, even when manufacturing single or low quantities of satellites.

This presentation will start by defining and explaining the reasoning behind the target performance characteristics: Launch mass 25kg to 250kg; >70% payload mass fraction; Payload volume 600x600x450mm; Payload power 10W to 1kW; 3-axis stabilised; adaptable pointing knowledge, control and agility; orbit 400km to 850km; 5-7 year lifetime; <14 month recurrent schedule.

We will then move on to a discussion of the holistic approach that we are taking to capture and satisfy the diverse technical and programmatic needs of different stakeholders: addressing the requirements for: a modular, versatile, scalable, robust architecture; mission configurability; standard payload and equipment interfaces; dedicated and rideshare launcher capability; ground segment interoperability, a cost-effective ground-based model for development and training and a low total mission cost.

The presentation will conclude with a discussion of the principles behind our business case for the development and exploitation of the resulting open source satellite platform and how we intend to ensure that the design will be made available for the community to leverage, utilise, modify and improve.

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Presenters: BERNIE, Anita (KISPE Space Systems Limited); Mr PAFFETT, John (KISPE Space Systems Limited)

Session Classification: Talks

Track Classification: Communities, Business, and Legal Aspects

Contribution ID: **4** Type: **Round Table**

Disrupting the space industry with Open Source Satellites: What are the challenges, and how do we address them?

Monday, 14 October 2019 13:00 (1 hour)

Whilst there are examples in many software and some hardware business of the commercial success and sustainability of the open source approach, the philosophy is still very much in its infancy in the space domain.

The few examples of open source missions have been limited to very small satellites (PocketQubes and Cubesats), with a primary focus on technology demonstration within the academic community. There are also some open source capabilities emerging in discrete areas of the end-to-end value chain, but there is some way to go before all of the industrial capabilities and systems engineering and integration competences are available to enable the reliable delivery of microsatellite-class, commercial operational open source systems.

This round table discussion will follow the following format:

- Summary of the current status of open source capabilities that are either already being used for space applications, or have the potential to be developed
- Invite participants to articulate and discuss the challenges associated with the creation and cultivation of the necessary ecosystem for the Open Source Satellite industry and community to thrive
- Selection of the "Top-3" or "Top-5" issues (depending on timings) that need to be addressed
- Discussion of potential approaches, solutions and enablers that will allow the challenges to be addressed
- Agreement of some tangible, concrete next steps that can be taken/led by the OSCW community and industry supporters
- Conclusions and wrap-up

If the venue facilities are suitable, we will investigate the use of an open source brainstorming tool to capture and share the contributions and results of the round table discussion.

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Presenters: BERNIE, Anita (KISPE Space Systems Limited); Dr PAFFETT, John (KISPE Space Systems Limited)

Session Classification: Group meetings - Roundtables

Track Classification: Communities, Business, and Legal Aspects

Contribution ID: **5** Type: **Talk**

DOCKS, a growing software suite for space mission prototyping

Monday, 14 October 2019 09:50 (20 minutes)

DOCKS is a C²ERES endeavour to provide everybody with free tools for mission design, in Earth vicinity or in deep space. Modules in DOCKS include:

- A carefully validated Deep-Space propagator with enough flexibility to simulate cruise trajectories or proximity operations at a non-sphérical asteroid; for Earth vicinity, user-friendly interfaces to STELA, free software by the French agency CNES are embedded; also simple Keplerian trajectories can also be generated.
- An "easy-quaternion" generator module to simulate various pointing strategies, such as inertial pointing, slew or tracking; an ADCS early-simulation tool is also under consideration.
- An intervisibility-computation module produces Event Files for ingress or egress with ground stations' horizon or Sun eclipses.
- A Telecom module gathers and interfaces early assessments of telecom design with the orbit, intervisibility and attitude data as well as with a datalink tool by CNES to monitor the datavolume on-board.
- A Power module gathers an early-design of arrays and batteries and interfaces with a scenario (orbit and attitudes) to monitor the right sizing of the power design.

All these modules read or write their interfaces in CIC-CCSDS ascii format and configure a 3D display of their results, permitted by VTS, another free software by CNES for space data visualization.

Spread the word: only open source or 100%-free code, mainly in Python. Early releases are freely available. Experts are invited to cross-check our results and provide data or modules. Textures or configuration panels could be greatly improved with the support of the community.

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Presenter: Mr SEGRET, Boris (C²ERES - Paris Observatory - PSL University)

Session Classification: Talks

Track Classification: Software

Contribution ID: **6** Type: **Poster**

PLUTO to Python Parser

PLUTO (Procedure Language for Users in Test and Operations) is a domain specific language for writing procedures to be used for testing and operation of space systems. It was created by the European Committee for Space Standardization (ECSS) in the frame of the ECSS-E-ST-70-32C standard and is published as an open standard, freely available on the ECSS website (ecss.nl).

The PLUTO language has a syntax that is easy to read, by humans as well as by machine. Thus, it is ideal for automation. PLUTO is used for the automation system in use at ESA, to control GAIA and Sentinel missions and others.

But PLUTO is not limited to space application, in fact, it can be used for any other domains where monitoring and control of a system is needed.

Today, no open source implementation of a PLUTO parser is available, and to our knowledge there is not even a commercial implementation, except for the one used at ESA.

We run a project during the Google Summer of Code 2019 to create a prototype of a PLUTO to Python parser, to demonstrate the feasibility of converting PLUTO scripts to native Python code to be run on any computer that runs Python.

We present here our findings regarding the implementation of this standard, the Python libraries we used and those that we created, and some examples to demonstrate the capabilities, caveats and advantages of the PLUTO language.

Primary authors: Mr SCHOLZ, Artur (LibreCube Initiative); Mr JAIN, Vidit (University of Delhi); Mr BUCHNER, Christoph (FOTEC Forschungs- und Technologietransfer GmbH)

Presenter: Mr SCHOLZ, Artur (LibreCube Initiative)

Track Classification: Software

Contribution ID: **7** Type: **Talk**

DOSA, an Open-Source Dynamic Analyzer for Satlink

Monday, 14 October 2019 10:10 (20 minutes)

Classical way of calculating link budgets consists of considering static values of every parameter taken at their worst-case scenarios. This usually provides a good overview for mission analysis, sizing of the communication sub-system and preliminary link design. However, considering geometry, the worst-case scenario mainly concerns station visibility windows limits when the Free Space Losses are maximum i.e at the beginning and end of the pass over the ground station. Adopting a dynamic approach to link budget calculation allows us to take advantage of more realistic margins available during a larger part of the pass duration. Therefore this can enable us to optimize the link, for example by selecting coding techniques according to available margins

DOSA (Dynamic Open-source Satlink Analyzer) is an open source (AGPL v3 licence) software tool dedicated to calculate a dynamic link budget, by computing some parameters as a function of time, over the course of the visibility window above a ground station. To the authors knowledge, no open source tool allows such calculations.

This tool calculates Free Space Loss, Pointing Loss and Doppler Shift values using orbital mechanics inputs such as satellite Orbit Ephemeris Message (OEM), Attitude Ephemeris Message (AEM) data files and Antenna Gain measurement values. As outputs of interest, we get C/N0 and Eb/N0 margin variations throughout the pass duration. Multiple passes over a period of time can also be calculated, which allow the possibility to forecast link performance during operation phase and select the most beneficial passes and adapt bitrates accordingly.

DOSA include Python and Octave source code and working example (https://sourceforge.isae.fr/projects/dosa_link_budget_
OEM input files are expected to be in CIC protocol (based on CCSDS standard). In our case, Celestlab (Scilab open source CNES library - https://logiciels.cnes.fr/fr/node/67?type=desc) was used to generate the OEM files.

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Presenter: Mr ROUX, Guillaume (ISAE-SUPAERO)

Session Classification: Talks

Track Classification: Software

Contribution ID: **8** Type: **Workshop**

SpaceCAN - A reliable and robust monitor and control bus for CubeSats

Tuesday, 15 October 2019 09:00 (1 hour)

The control and monitoring bus is the backbone for routing commands and telemetry among spacecraft subsystems. Typically, a central processing unit is commanding other intelligent nodes (such as the power system, communication system, and payloads) and collects status information from them. The data to be exchanged on this bus is of moderate volume but must be transmitted in a reliable way.

Almost every CubeSat uses the I2C bus as system bus. This is a problem because the I2C bus is not fault tolerant and has been reported as the source of mishaps to a number of satellite missions. We propose to replace I2C bus with CAN bus, which is heavily employed in automotive and industrial applications since decades and has been qualified for use in space. For this, we have developed the SpaceCAN protocol, which utilizes CAN as transport technology and combines elements of ECSS CAN Bus Extension Protocol for reliability and robustness, and the ISO-TP protocol for large message transfer.

In this workshop we use pyboards, running MicroPython, to demonstrate a typical setup and operation of this reliable system bus. Participants of the workshop will learn how the time distribution works, the synch service, and how to exchange messages (telecommand and telemetry) between the master node (ie. on board computer) and attached slave nodes (ie. subsystems).

Primary authors: SCHOLZ, Artur (LibreCube Initiative); STARCIK, Milenko (TU Darmstadt Space Technology e.V.); Mr MADER, Peter (Technical University of Darmstadt); Mr SCHLEGEL, Jesper (Technical University of Darmstadt)

Presenter: SCHOLZ, Artur (LibreCube Initiative)

Session Classification: Workshops

Track Classification: CubeSat Missions and Systems

Contribution ID: **9** Type: **Talk**

LibreCube Activities 2019 - A Review

Tuesday, 15 October 2019 14:00 (20 minutes)

LibreCube – Open Source Space and Earth Exploration

LibreCube's vision is to enable everyone to get involved in building systems for exploration of near and remote locations using open source hardware and software. We believe that discovering new worlds and getting scientific insights should be a matter to all humankind.

This presentation reviews the various activities conducted in 2019. This includes the development of the following open source prototypes:

- a PLUTO to Python parser for automation of tests and operation,
- a SLE User application to connect to Space Link Extension Service Provider,
- a breadboard setup of a basic and robust Power Control and Distribution Unit (PCDU) for onboard power systems,
- some rudimentary prototypes for demonstrating CCSDS MO services.

Also, an update of the CubeSat standards book has been published.

Finally, we give an update on the next prototypes and programs one can get involved in.

Primary authors: SCHOLZ, Artur (LibreCube Initiative); Mr MAASS, Jan (LibreCube Initiative)

Presenter: SCHOLZ, Artur (LibreCube Initiative)

Session Classification: Talks

Track Classification: Communities, Business, and Legal Aspects

Contribution ID: **10** Type: **Lightning Talk**

LinkPredict - Dynamic and Modular Link Budget Tool

Wednesday, 16 October 2019 11:04 (4 minutes)

Do you need to create a link budget? If so, chances are high you download Jan King's Excel spreadsheet, fill in your numbers, and take the result from there.

But that is a cumbersome, manual process that only outputs one result per case.

Now there is LinkPredict!

LinkPredict is a Python3 library for defining radio links in a generic and modular way and provides time-dependent outputs of the link performance.

Generic means that one can construct radio links for terrestrial applications as well as space-to-ground, ground-to-space, orbiter-to-rover, and others.

Dynamic means every input value to the link budget can be supplied as a time-varying function. This way, the time-dependent effects (such as change of distance) can be analysed and visualized.

Primary authors: SCHOLZ, Artur (LibreCube Initiative); Mr SAFFER, Jona

Presenter: SCHOLZ, Artur (LibreCube Initiative)

Session Classification: Lightning Talks

Track Classification: Software

Contribution ID: **11** Type: **Talk**

EQUiSat: Space for $3,776.61

Wednesday, 16 October 2019 09:00 (20 minutes)

As electronics decrease in size and complexity, CubeSats have become more popular and more accessible than ever. Thousands of high schools, universities, companies, and hobbyists have launched or are working on CubeSats. However, the industry is dominated by premade modules that sell for massive markups, meaning that cost is still a barrier to entry for many groups. EQUiSat, a 1U CubeSat designed and built by Brown Space Engineering, an undergraduate club at Brown University, aimed to change that. Costing only $3,776.61, with a reproducible, completely open source design using off-the-shelf electronics, EQUiSat's successful launch and deployment proves that anyone can make their own satellite. Operating nominally for more than six months at the time of writing, it has produced significant amounts of data for its secondary mission: testing LiFePO₄ batteries in space for the first time. This data corresponds to testing on the ground, giving developers of future satellites the confidence to use them.

Primary authors: Mr LEIKEN, Jacob; Mr MANI, Sarang; Mr SWAIN, Asutosh

Presenter: Mr LEIKEN, Jacob

Session Classification: Talks

Track Classification: CubeSat Missions and Systems

Contribution ID: **12** Type: **Poster**

Class 1 laser setup for generating cosmic radiation events in electronic components

In this presentation, an overview and update of a compact laser setup for generating Single Event Effects (SEE) of cosmic radiation is presented. After my talk at OSCW'17, many new features were developed and will be addressed. Especially the Laser-Scanning-Microscope functionality opens the door for generating SEE with a known absolute position on the chip. The attached pictures show a surface scan of a MSP430 microcontroller as well as a memory map of the ADC-registers in the same controller. The map is generated by overlaying Single Event Upset (SEU - flipped bit) positions above a scanned picture. This might be very helpful for software failure injection testing, as we discovered regions, where more than one bit flips when one position is hit. Beside that, for example sensitivity maps can be generated. The colourful picture shows the area of a memory bit flipped with different laser intensities. Similar investigations are currently ongoing with Single Event Latchups (SEL).
I plan to publish the project open source.

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Presenter: Mr ZÖLLNER, Hannes (EAH-Jena)

Track Classification: Development, Testing, and Lessons Learned

Contribution ID: **13** Type: **Round Table**

Open Source Rocketry, Is there a roadmap?

Wednesday, 16 October 2019 15:30 (45 minutes)

Amateur rocketry is abundant with global uptake of High Power rocketry through organisations like the Tripoli, NAR, UKRA. We see organisations like Copenhagen sub orbitals build large scale projects with a roadmap towards human flight beyond the Karman line. We also see innumerable student teams building larger airframes, for projects such as the Spaceport America Cup, we see limited opensource development in this field. This roundtable seeks to explore some themes pertaining to possible uses and potentials for developing open source rocketry communities working on larger scale projects. Identifying what purposes Open Source rocketry might serve and an exploration of what tools and projects and resources are already available to this emergent community. For example might opensource rocketry serve organisations such as CANSAT, can the CANSAT model be extended to use perhaps Pocketqubes allowing scale from amateur competition to LEO missions. Could Opensource rocketry be utilised in science missions as sounding rockets and indeed could opensource rocketry be used to verify and test cubesat components in high g, low atmosphere missions.

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Session Classification: Group meetings - Roundtables

Track Classification: Ground Networks, Launchers, and Operations

Contribution ID: **14** Type: **Poster**

Cubesat Subsystems Preliminary Design: Nanostar Software Suite (NSS) First Prototype

NSS (Nanostar Software Suite) aims at helping to get a strong data consistency between expert software during a mission analysis preliminary design. In fact, designing a nanosatellite requires close interrelation between different fields, with respectively strong level of expertise, all the more so as development progresses.

A lot of software bricks already exist for such a purpose, e.g. space mechanics libraries that are extendedly used during mission analysis. Expert tools inputs, outputs and models are then often strongly intertwined in this kind of projects. Event if efforts on standardization are undertaken (e.g. CSSDS), strong and rigorous data management, update, and checking is currently required all along project development cycle.

For this purpose, we are currently developping NSS. It is not an heavy client application. It has an Angular GUI (Nanospace) frontend, accessible through a browser, a graph Neo4j database deployed on a distant server and a constellation of possible softwares to be connected with, seen from NSS users as web applications. It allows user to be easily (or at least that what we hope!) connected with a simple RESTful interface,using a common and centralized database, in order to ease some interdependent data update and visualization. One of our requirement is to let the user define to which point he/she wants to automatize the interaction with the database, and to re-use already existing softwares and libraries as far as possible - users use to be attached to their own codes, and we don't want to force them to use one expert tool or another.

NSS is currently under development. We are trying to focus especially on favoring standards as far as possible, providing something easy to use (especially for students) and a way to work concurrently for engineering teams. NSS is Open source (AGPLv3 Licence), a prototype is available on https://sourceforge.isae.fr/projects/nanospace. A test server is also deploy on https://dcas-nanostar/. Part of this work is supported by SUDOE Nanostar project (http://nanostarproject.eu/).

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Presenter: GATEAU, Thibault

Contribution ID: **15** Type: **Workshop**

MetaSat: Defining Metadata for Small Satellite Missions

Monday, 14 October 2019 15:00 (1 hour)

MetaSat, an open metadata schema in development, will function as a common way of describing hardware, software, and data across small satellite missions to improve interoperability between them. This new digital infrastructure will help missions learn from each other now, and help people share information about past missions with future generations.

Capturing the breadth of work being done with small satellites is impossible without input from the small satellite community. For this reason the MetaSat team is inviting the community to participate in conversations at conferences and online that will shape the schema design. We invite the OSCW community to contribute ideas and feedback to MetaSat's on-going development to ensure it supports the open source community's evolving needs.

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Session Classification: Workshops

Track Classification: CubeSat Missions and Systems

Contribution ID: **16** Type: **Lightning Talk**

Introducing MetaSat

Wednesday, 16 October 2019 11:00 (4 minutes)

Open source satellite missions need open metadata standards. Without open metadata, interoperability between missions and systems is impossible and the ability for the community to learn from each other's past experiences is limited. MetaSat, an open metadata schema in development, aims to address these needs with input from the community of people already planning and participating in missions, as well as satellite novices.

Primary authors: BOUQUIN, Daina; CHIVVIS, Daniel; FREY, Katie; CARVER, Nico

Presenter: CHIVVIS, Daniel

Session Classification: Lightning Talks

Track Classification: CubeSat Missions and Systems

Contribution ID: **17** Type: **Talk**

Open Source Development of Low Cost, Low Power, Sub-Joule Micro-Pulsed Plasma Thrusters for PocketQubes and Cubesats

Wednesday, 16 October 2019 09:20 (20 minutes)

Since the first successful use of electric propulsion aboard the Zond 2 in the 1960s, electric propulsion has served an important and critical role in satellite applications. However, despite the numerous advances over the decades in the field, cost and accessibility of propulsion has remained prohibitive for lower funded educational and enthusiast groups. With current trends in research initiatives and funding models for propulsion development, there is little-to-no market incentive to pursue low-cost simplified propulsion solutions outside of those for critical defense, military, space-agency, and major corporations. Due to the nature of development, technical aspects of these thrusters remain closely guarded secrets by companies developing them, or restricted to limited information published in academic papers. Scaling, especially for the emerging class of small-sized low-cost PocketQube satellites, in terms of power and form factor, has also not yet been realized in a practical, deployable solution. While numerous propulsion solutions do currently exist for Cubesats, these options have remained costly.

Work is currently underway to develop a new class of open-source, low power, small-form factor micro-propulsion thrusters based on a novel low-profile pulsed plasma thruster. The AIS-gPPT, or Applied Ion Systems Gridded Pulsed Plasma Thruster series is at the forefront of these efforts, offering a unique and radically different approach towards propulsion solutions, focusing on a fully open-source design and development approach, with emphasis on ultra-low cost construction (estimated less than $1k for a complete thruster module), as well as a simplified topology for ease of manufacture.

Currently, the second-generation AIS-gPPT2 thruster has passed successful high vacuum ignition testing and impulse bit measurements, operating from an input energy range of 0.40J to 0.84J, with corresponding impulse bit ranging from 0.78uN-s to 3.52uN-s. The thruster has also been demonstrated at main capacitor bank energies as low as 0.23J (680V charging voltage), and repetition rates up to 2Hz. Current lifetime limits for this thruster are on the order of 500 pulses.

The third generation of thrusters, the AIS-gPPT3 series, is currently in the manufacturing and testing stage, and aims to greatly increase lifetime with improved fuel bore geometry, as well as exploring the use embedded permanent magnets for a magnetic output nozzle to improve thrust. This thruster series also explores the use of novel propellants in addition to standard Teflon, including Ultem, PEEK, and Bismuth-Tin. This class of thruster aims to radically improve micro-PPT lifetime and performance in a form factor compatible with 1P PocketQubes, and will allow for propulsion clusters to be implemented to further increase overall lifetime. It is expected that a cluster of 9 thrusters can be incorporated in a single 1P frame, with a total cross sectional area not exceeding 1P, and a total depth not exceeding 0.25P. Expected power requirements for such a thruster will be limited to 1W max, and utilize fully integrated electronics with the stacked-plate thruster assembly to create a complete low-profile module.

By starting out with the smallest scale thruster size possible for pulsed plasma thrusters, it becomes possible to not only accommodate solutions for the smallest class of satellites, but allows for scaling to larger Cubesats. In particular, due to the larger available power budget and volume for Cubesats, scaling up power, size, and cluster number becomes simpler. A highly experimental version of the gPPT series, the AIS-gPPTx-MAGE1, will explore new concepts for pulsed plasma thrusters, including magnetic confinement and enhancement of plasma, high surface area fuel, and gridded electrodes in a flat profile, for larger Cubesat applications. The normal gPPT series thrusters could also be employed for Cubesat attitude control, as well as clusters for the main propulsion drive.

Significant advances through novel and unconventional approaches, such as low profile geometries and new fuels must be implemented to overcome challenges associated with scaling to such small form-factors and power levels. With open-source accessibility to fully characterized and simplified thruster technology, new possibilities can arise in the small satellite community. Increased orbital lifetimes, orbital maneuvers, and planned deorbiting offer significant opportunities to advance the field and ultimate capabilities of small satellites.

Primary author: BRETTI, Michael

Presenter: BRETTI, Michael

Session Classification: Talks

Track Classification: CubeSat Missions and Systems

Contribution ID: **18** Type: **Talk**

Open Source Development of Advanced Vacuum Testing Infrastructure for Space Hardware - TVAC and Radiation Dosing

Tuesday, 15 October 2019 16:40 (20 minutes)

High vacuum testing is a crucial and integral part of space hardware qualification for Cubesats and other small satellites, but presents a major hurdle and challenge in terms of cost and technical barrier of entry. In particular, thermal vacuum (TVAC) systems are necessary for testing hardware such as electronics boards and other subsystems to the extreme temperature variations encountered in space. Currently, such capabilities have remained mostly exclusive for university laboratories, government research centers, and space technology companies, and are only offered as costly custom vacuum solutions.

Currently, the Applied Ion Systems open-source micro-propulsion testing chamber offers an example of a highly compact, modular, and low-cost system exclusively for miniaturized space hardware testing, specifically related to propulsion development. The system is based off of standard surplus conflat hardware, mounted to a simple custom test stand. Ultimate pressures of mid-10^-6 Torr have been achieved, with pumping speeds of up to 400 L/s at the chamber inlet. The system allows for capabilities such as high vacuum ignition testing, impulse bit measurements, plume current, and ion velocity measurements. Work is underway to design a simplified miniature TVAC module for direct thermal cycling of propulsion modules during testing, and to provide an example of how such a module can be implemented on a low-cost, small-scale system.

The TVAC module will be inserted as a modular shroud assembly that fits within the 6” conflat chamber hardware around the device under test, allowing for cold cycling with the use of LN2, or hot cycling with integrated thermal bulbs. Such a design can be geometrically modified or scaled up for larger hardware and propulsion testing chambers, and utilizes simple, low-cost construction that will be integrated with standard conflat feedthrough hardware. This TVAC module will ultimately be used to qualify a new class of open-source micro-pulsed plasma thrusters, and will allow for thruster testing during both cold and hot cycles to verify proper operation in these extreme conditions. Various topologies are explored, between solid coil shrouds and thin-plate shrouds to compare heat distribution and effects of geometry on performance.

A modular, simplified, open-source high-vacuum TVAC insertable shroud system can be more readily scaled up to larger vacuum chamber assemblies to allow for full testing of a standard Cubesat frame. By keeping chamber dimensions small, using standard hardware, cost can be minimized, as opposed to using traditionally larger chambers. Pumping infrastructure and attachments also become less costly and simpler to manage. Particularly for TVAC, custom solutions presents a significant cost at larger scales. Employing small-scale simplified TVAC shrouds with open-design details can open the door for more affordable testing options for Cubesat development groups without the need to invest in costly, large scale, custom vacuum infrastructure, or requiring external facility testing, and can be easily adapted for a wide range of chambers.

For extended mission lifetimes or missions involving deep space, radiation testing of electronics and other sensitive hardware is a vital part of space system qualification. In particular, standard off-the-shelf non-hardened electronics have a total dose limit of only 5-10 kRad before permanent damage and failures occur. Other materials, such as certain plastics and polymers, can exhibit lower tolerances to radiation, and degrade in performance over time.

In the radiation dosing industry, currently two major solutions are employed: active source dosing utilizing large sources such as Co-60, or accelerator based machines at low and high energy, implementing direct electron beams, ion beams, or neutrons from conversion targets. However, based on operational costs, licensing, and other technical testing constraints, dosing services are

prohibitively expensive, often costing on the order of up to tens of thousands of dollars per hour. Currently, the capability remains only with major laboratories or companies specialized in dosing, and only for customers and groups with higher levels of funding. However, by utilizing older, lower-cost accelerator technology in the form of pulsed relativistic electron beam diode accelerators (REBs), basic large total ionizing dose (TID) of electronics and materials can be realized at a radically lower cost and simplicity, on a much more compact scale. This offers new and powerful capabilities for more advanced Cubesat system testing that has not been accessible to most development groups prior.

Currently, a high-power, low-energy, low cost open source pulsed accelerator is being developed in-house to run a wide variety of high power particle beam physics experiments previously unexplored before at the open source level. This accelerator, EXEDA, will be the first of its kind at this level, and offers unique and unprecedented access to high power particle beam physics for the open source community. One major use of EXEDA will be the use of direct electron beam dosing of electronics and other materials for open-space applications. Expected beam energies of up to several hundred keV, and currents in the kA regime are anticipated, with peak beam power as high as several hundred MWs. With maximum beam-spot size diameter of 8 cm, the EXEDA-RADOSE beamline will offer unprecedented access to high TID in the kRad regime for qualifying electronics and materials. In particular, the beamline in its current configuration can accommodate the full 5cm x 5cm footprint of a PocketQube satellite for direct beam dosing of critical systems and structures. Such a large beam spot size also allows for larger-scale surface dosing of boards and materials for general Cubesat development.

Adapting intense pulsed beam accelerator technology in a low-cost, open-source approach like EXEDA-RADOSE can offer unique testing capabilities ranging from low-energy surface-discharge studies to mid-energy high total ionizing dose from direct beam at kRads per pulse. Other beamlines currently in the works, such as the EXEDA-MEVI beamline can be used to explore the effects of MeV level proton dosing and single event effects, and EXEDA-FLAX for intense x-ray dosing. Such systems, taking advantage of revived, older accelerator technology, have the potential to open up new areas of testing and research for Cubesat systems that have not been openly available before.

Primary author: BRETTI, Michael

Presenter: BRETTI, Michael

Session Classification: Talks

Track Classification: Development, Testing, and Lessons Learned

Contribution ID: **20** Type: **Workshop**

Interplanetary mission analysis with poliastro

Monday, 14 October 2019 16:00 (1 hour)

poliastro is an open source (MIT) Python library for Astrodynamics and Orbital Mechanics that is easy to use, powerful and interactive. It works with physical units to avoid common errors, implements several propagation algorithms, provides common impulsive and low-thrust maneuvers, and makes visualization simple. Its source code is on GitHub, it has a growing community of developers, and it's currently used in both academia and industry.

With the current exponential growth of Python among novice and expert programmers, including the space industry (with key players like NASA, ESA, and space startups increasingly using it for several purposes), poliastro is an excellent tool that can be easily integrated both in interactive workflows and large scale analysis in headless environments, with a comparatively good performance and a simple API.

In this workshop we will explore poliastro in Jupyterlab, a web-based, interactive Python development environment, to read orbital data from several sources (CelesTrack, JPL, MPC), propagate and visualize these orbits, compute transfer maneuvers between Low and High Earth Orbit, determine visibility over ground stations, and target nearby planets, asteroids and comets.

Primary author: CANO RODRÍGUEZ, Juan Luis

Presenter: CANO RODRÍGUEZ, Juan Luis

Session Classification: Workshops

Track Classification: Software

Contribution ID: **21** Type: **Talk**

SatNOGS - State of the Union

Tuesday, 15 October 2019 13:40 (20 minutes)

An overview of the SatNOGS project, a network of satellite ground stations around the world, optimized for modularity, built from readily available and affordable tools and resources.

Low Earth Orbit (LEO) satellite launches rate increases with the participation of old and new entities. In this growing environment SatNOGS provides a scalable and modular solution to track, receive telemetry, monitor and command & control satellites.

SatNOGS global community, dedicated to its free and open source values, develops hardware ground station designs (antennas, rotators, electronics), software for SDR-based communications, satellite scheduling and mission monitoring platforms.

SatNOGS continuously develops and improves its infrastructure to allow observers use this networked ground segment and remotely operate SatNOGS ground stations around the world. It provides also an easy way to store, access and view increasingly received satellites data, by supporting VHF and UHF bands and by moving forward with higher bands like L, S and X.

This is a proposal for a "state of the union" talk about SatNOGS focusing on what has happened since previous OSCW, growth, development and trajectory for features and expansion.

Primary author: DAMKALIS, Alfredos Panagiotis (Libre Space Foundation)

Presenter: DAMKALIS, Alfredos Panagiotis (Libre Space Foundation)

Session Classification: Talks

Track Classification: Ground Networks, Launchers, and Operations

Contribution ID: **22** Type: **Talk**

Open source satellite tracking

Tuesday, 15 October 2019 13:20 (20 minutes)

Orbital elements, in the form of two line element sets, are provided by a limited number of organizations. While the vast majority is published by the US military, a small group of dedicated amateur satellite trackers maintains a catalog of orbital elements for mostly classified satellites whose elements are not made public. As part of this amateur effort, I have developed open source software to track satellites using video and photographic cameras as well as through their Doppler curves from radio data. I will present a brief overview of the software, and will discuss how it can be used for cubesats.

Primary author: Dr BASSA, Cees

Presenter: Dr BASSA, Cees

Session Classification: Talks

Track Classification: Ground Networks, Launchers, and Operations

Contribution ID: **23** Type: **Talk**

Lessons learned by development of UPSat Attitude Determination and Control Subsystem

Tuesday, 15 October 2019 16:20 (20 minutes)

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\usepackage{amsmath}
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\begin{document}
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\begin{center}
Lessons learned by development of UPSat Attitude Determination and Control Subsystem\\
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% Author names and affiliations
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Agis Zisimatos[1]\\

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[1] Libre Space Foundation\\
agis@libre.space\\

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\normalsize
The purpose of this talk is to present the lessons
that learned form development of open-source CubeSat subsystem,
the Attitude Determination and Control System (ADCS) of UPSat.
The presentation is divided into three parts, the architecture
of the ADCS, the known problems and the results of life in orbit.

The ADCS is responsible to compute the pose of CubeSat and to
control, usually, the rotation of it. In order to do the above
functions, it uses sensors and actuators. The specifications that
achieved by the UPSat is 15\degree pointing accuracy, knowledge
accuracy of 5\degree and the CubeSat recovered from tip-off
rates of up to 10\degree/sec within 2 days.

Before the UPSat get in orbit, known issues in firmware and
hardware existed. The biggest of all was about the Global
Positioning System (GPS). The GPS wasn't fixed the position
in test campaign. This issue has led to the determination
algorithm hasn't worked properly. Other firmware issues
are presented, such as the counter that measured the number
of resets of ADCS. Also the test campaign didn't contain test
for control algorithm due to limiting time of development. For

the same reason a non open-source software used for simulation of the system.

When the UPSat was in orbit, limited extended Whole Orbit Data (WOD) was received. Using these data we conclude that the sensors have worked properly, the ADCS has time synchronization with On-Board Computer (OBC) and part of control algorithm worked. Due to GPS issue the determination algorithm and pointing controller didn't give the right results.

Last but not least, this presentation is an open-call for open-source software and hardware development of testing tools for ADCS.

To conclude, this talk summarize the success and the failure of the ADCS, a process that is valuable for the open-source development.
\end{document}

Primary author: Mr ZISIMATOS, Agis (Libre Space Foundation)

Presenter: Mr ZISIMATOS, Agis (Libre Space Foundation)

Session Classification: Talks

Track Classification: Development, Testing, and Lessons Learned

Contribution ID: **24** Type: **Talk**

Foresail: An Open Satellite Platform Beyond the LEO

Wednesday, 16 October 2019 09:40 (20 minutes)

The FORESAIL project is a scientific Cubesat-satellite project by the Finnish Centre of Excellence in Research of Sustainable Space. The project is funded by the Academy of Finland and it focuses on research of the solar wind interactions in the Earth's magnetosphere in high temporal resolution 1 and investigates new sustainable methods for space technology and research. The project aims to design and build two Cubesat-sized satellites, FORESAIL-1 and FORESAIL-2, for Low Earth Orbit (LEO) and Geostationary Transfer Orbit (GTO).

FORESAIL-1 is a 3-unit sized Cubesat designed for scientific mission on LEO. The main payload of the satellite is dual particle telescope (PaTe) instrument which measures the energy dependent pitch angle spectra of the precipitating radiation belt particles, and solar ENA flux. As secondary mission, FORESAIL-1 will demonstrate the effectiveness of the plasma brake (PB) as a means of manipulating the spacecraft orbit in operation and lowering the spacecraft altitude to speed up de-orbiting at the end of the mission, thus addressing the sustainability of LEO space operations. Additionally, the satellite will carry a commercial of the shelf (COTS) camera and a scientific magnetometer for technology demonstration. Satellite's avionics system and the platform, consisting an Electrical Power System, UHF Communication System, On-Board Computer and Attitude Determination and Control System, is completely designed and built in Aalto University, Finland. The design and build process of the satellite was started in the beginning of 2018 and planned to be launch in 2020 with five years operational lifetime in orbit. 1

FORESAIL-2 aims to be one of the firsts Cubesats launched GTO orbit. The satellite aims to investigate similar solar wind phenomenons as its predecessor but at greater altitudes. In the GTO, the satellite experiences high radiation environment due to trapped high energetic particles in Van Allen belts. To cope with the radiation environment, the FORESAIL platform is designed to be radiation tolerant in affordable manner and utilizes techniques such as radiation protecting vault as shielding, varying redundancy strategies in sub-component level and results learned from component radiation test campaigns. Many of these design requirements of GTO environment are already taken in consideration in FORESAIL-1 system design. Building of Foresail-2 is planned to start in the beginning of 2020.

To achieve its goals for more sustainable space technology, the Foresail's platform team aims to publish the designs of the avionics platform for the benefit of the Cubesat community. Professional designed platform aims to help new arising Cubesat teams to get involved to space technology without need to reinvent the wheel by themselves and thereby supporting more sustainable technology development. The project does not aim to create an open sourcely managed project but a professional open space-grade designs and documentation for a complete satellite which can fulfill the requirements of a complex high reliability satellite mission. Beside the Foresail-project, the research group guides a student lead Aalto-3 Cubesat mission which aims to design and build an open source 1U Cubesat technology demonstration satellite.

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to measure radiation belt losses and demonstrate de-orbiting. Journal of Geophysical Research: Space Physics, May 2019.

Primary author: Mr NIEMELÄ, Petri (Aalto University)

Co-authors: Mr PELTOLA, Tatu (Aalto University); Mr CHEREMETIEV, Kiril (Aalto University); Mr ALHO, Arno (Aalto University); Mr CLAYHILLS, Bruce (Aalto University); Mr KETTUNEN, Ville-Valtteri (Aalto University); Mr JOVANOVIC, Nemanja (Aalto University); Mr RIWANTO, Bagus (Aalto University); Mr BOSSER, Alexandre (Aalto University); Mr MUHAMMED, Mughal (Aalto University); Prof. PRAKS, Jaan (Aalto University)

Presenter: Mr NIEMELÄ, Petri (Aalto University)

Session Classification: Talks

Track Classification: CubeSat Missions and Systems

Contribution ID: **26** Type: **Talk**

AcubeSAT: A lab-on-a-chip CubeSat mission from the Aristotle University of Thessaloniki

Wednesday, 16 October 2019 10:00 (20 minutes)

Plans for the return of humans to the Moon and the imminent manned exploration of Mars drive an increased need for research in the fields of space physiology and biology. This need can be fulfilled with low cost solutions such as CubeSats, by obtaining results from experiments which were previously possible only on crewed spacecraft such as the International Space Station and required maintenance from astronauts on-board.

The Aristotle Space & Aeronautics Team (A.S.A.T) is designing and building a 3U CubeSat to perform a biological experiment, probing the dynamic regulation of gene expression of eukaryotic cells in Low Earth Orbit (LEO), utilizing advances in Synthetic Biology and MEMS (micro-electromechanical systems). We aim to investigate the molecular mechanisms that are affected by space conditions and enable future high-throughput studies and easily scalable lab-on-a-chip applications, to assess the effects of spaceflight on living organisms.

Based at the Aristotle University of Thessaloniki in Greece, the team is composed of 40 students with the goal of participating in ESA Academy's Fly Your Satellite! programme. Given the special requirements of the mission, including a pressurized compartment, a miniaturized optical microscope and a high amount of data to be downlinked, our team has come up with different solutions and approaches to system integration.

In this talk we will discuss the aforementioned design of the satellite, with an emphasis on our scientific payload, the challenges our team has faced so far and our contribution to the open source community.

Primary authors: Mr KOTSAKIACHIDIS, Ioannis (Aristotle University of Thessaloniki); Mr RETSELIS, Anastasis (Aristotle University of Thessaloniki); Mrs KARAKOSTA-AMARANTIDOU, Ilektra (Aristotle University of Thessaloniki); Mr VELENTZAS, Iason (Aristotle University of Thessaloniki); Mr ARAMPATZIS, Asterios (Aristotle University of Thessaloniki); Mr OUSOULTZOGLOU, Orestis (Aristotle University of Thessaloniki); Mr KANAVOURAS, Konstantinos (Aristotle University of Thessaloniki); Mr MAKRIS, Dimitrios (Aristotle University of Thessaloniki); Mr PAVLAKIS, Grigorios (Aristotle University of Thessaloniki); Mr GIANNITSIS , Charilaos (Aristotle University of Thessaloniki)

Presenters: Mr KOTSAKIACHIDIS, Ioannis (Aristotle University of Thessaloniki); Mr RETSELIS, Anastasis (Aristotle University of Thessaloniki)

Session Classification: Talks

Track Classification: CubeSat Missions and Systems

Contribution ID: **27** Type: **Talk**

Open-Source Software-Defined Radios for CubeSat Operations

Monday, 14 October 2019 10:30 (20 minutes)

Software-defined radios (SDR) have become an integral part of many CubeSat missions. The availability of low cost, high-performance SDR hardware enables cost-effective solutions to complex telecommunication tasks, including unattended, interactive, and remote operations.

In this presentation, we take a look at recent developments in open-source SDR applications and demonstrate how they can be efficiently used for CubeSat communications.

Primary author: CSETE, Alexandru (AC Satcom)

Presenter: CSETE, Alexandru (AC Satcom)

Session Classification: Talks

Track Classification: Software

Contribution ID: **29** Type: **Talk**

Towards autonomous satellite operations and monitoring using machine learning

Monday, 14 October 2019 10:50 (20 minutes)

More than 60 years after the first orbiting human-made space object (1957), we've reached about 1800 satellites in Earth orbit (2018). They are currently operated by private corporations, governmental and multi-governmental space agencies. They orbit along with about 2600 other satellites, whether decommissioned, retired or non-functioning.

The recent trends in New Space involve space industrialisation, more open designs and wider access to launches for labs and universities (public institutions). The supply chain for satellite manufacturing has also been improved and optimized to deliver not only the one large satellite mission but the several hundreds to thousands of satellites in each fleet. Building time for a spacecraft has been reduced to something between 6 months and 2 years, depending on the mission complexity. Fleet mission such as OneWeb announce the average rate of the construction of one satellite a day for a final constellation of about 900 satellites.

Helped and pushed by the democratization of cubesats and industrial 3D printing, the satellite supply chain is scaled up to soaring rates. Nevertheless the ground operations services haven't scaled to fit these near-future needs. Spacecraft missions from most space agencies have a sufficient level of automation: in most known failure cases, the spacecraft has its own procedure, and for more complex failures satellites generally enter a safe-mode until ground operators find a solution.

Ground operations need to be disrupted to live along with the scale of future missions. It requires experimentation with new techniques in a rather conservative domain: space operations. The Polaris project aims at providing open source functional tools using machine learning to support space operators in understanding the situation. Open data from the SatNOGS project, lead by the Libre Space Foundation, is the incredibly valuable raw material we use to build models across multiple cubesat missions and set the first machine learning procedures to build common inter-missions knowledge.

Polaris is a Python module that can be used to explore satellite telemetry data mainly obtained from the SatNOGS network. Thanks to having similar orbits and form factors, the assumption is that data from different satellites can be compared to each other. It can also be merged to create bigger datasets and obtain better models.

The project is divided into three different parts: *polaris-fetch*, *polaris-learn* and *polaris-viz*. The second part is where all the machine learning and data science falls into. All of these parts play an important role in the building of a future artificial intelligence support system for space operations:

- *polaris-fetch* downloads raw demodulated data from the SatNOGS network. That has to be then decoded and converted to a common units system in order to compare data from different satellites. Glouton is used for accessing the database retrieving the telemetry, sanogs-decoders for decoding the binary data. The conversion to SI units is still being worked on. Other information is gathered to describe the spacecraft context as detailed as possible (orbits, operations commands, etc.).
- *polaris-learn* is the heart of Polaris. A data-driven approach is used to learn the behavior of the different spacecraft subsystems. Models are created to learn the links between telemetry parameters but also with respect to external factors, the spacecraft context (orbit, mission commands, etc.). Prediction and segmentation are used to create an anomaly detection system to enhance situation awareness of operators and explanations of anomalies.

- *polaris-viz* visualizes the results of the analysis (where have potential outliers been detected, telemetry predictions…). Currently, Grafana and InfluxDB are being used. Widgets to represent network relations and to input user feedback will be also considered.

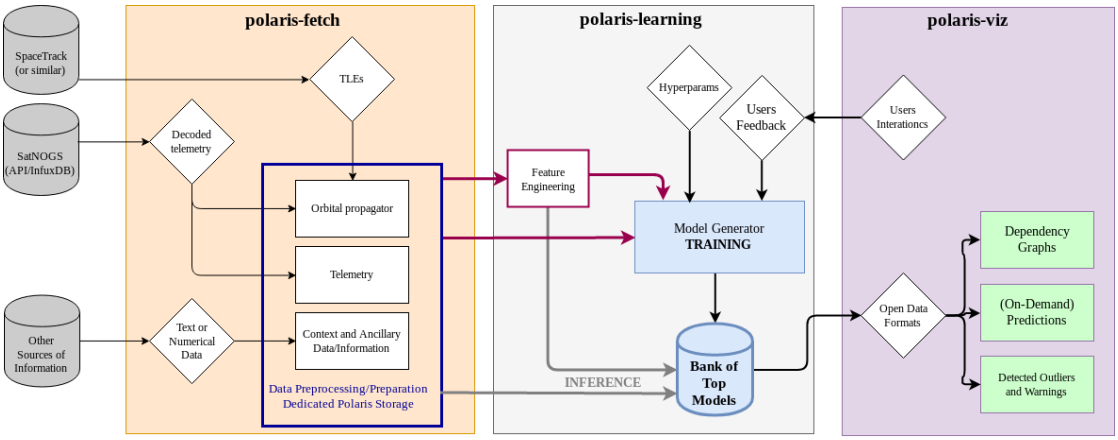

Figure 1: polaris_arch

Polaris has been selected to participate in the Google Summer of Code (GSoC 2019) and in the European Space Agency's Summer of Code in Space (SOCIS 2019) as part of Libre Space Foundation projects. The idea was born during the workgroups at the Open Source Cubesat Workshop 2018 where work on testing embedded device for machine learning training and inference was exposed.

In this talk will be presenting the results obtained during this period and the future steps. We will also briefly explain what we have learned, as mentors of the project, by participating in summer mentorship programs.

Primary authors: Mr CRESPO ÁLVAREZ, Xabier (Co-founder of scrobotics); Mr BROWN, Hugh; Dr BOUMGHAR, Redouane

Presenter: Mr CRESPO ÁLVAREZ, Xabier (Co-founder of scrobotics)

Session Classification: Talks

Track Classification: Software

Contribution ID: **30** Type: **Talk**

Orbit Determination Using the SatNOGS network and Orekit

Monday, 14 October 2019 11:10 (20 minutes)

The SatNOGS network is a global network of open-source ground stations that allows users to track, monitor, receive telemetry, and command satellites without the need to build their own network of stations. This helps to reduce the costs and complexity of operating and communicating with a spacecraft, which is especially important for CubeSat missions which are usually run by small teams with limited resources.
Orekit is an open-source spaceflight-dynamics library that is widely used across the space ecosystem to carry out mission analysis, studies, and in operational systems. It provides many low level features such as frame conversions, orbit propagation and more. Orekit also provides a very high level feature in the form of a complete orbit determination system.

Currently many CubeSat projects make use of the publicly available TLEs provided by SpaceTrack and online pass predictors to schedule connections to their satellites. TLEs are by their nature low accuracy and if accurate predictions are to be made using them the prediction model used must introduce periodic variations in the same manner that they were removed, otherwise a less accurate prediction will be produced.
Orbital position predictions based on TLEs are sufficient for simple data access but they break down for more ambitious missions.
The complexity of CubeSat missions have been increasing as a result of the ever expanding capabilities of CubeSats, and this is a trend that is expected to continue for the foreseeable future. As such the spacecraft location needs to be known to a greater degree of accuracy, both to improve the scheduling of connections to the satellite for telemetry and data retrieval by its operators as well as to improve the geo-location of measurements and imaging from the onboard instruments. The access to improved orbital models also allows mission planners and operators to more accurately schedule observing runs if they are interested in a particular region of the planet surface below or space above.

As part of the ESA SOCIS 2019 programme a project was carried out to investigate the feasibility of using Doppler Shifts from the SatNOGS network to carry out orbit determinations in an Orekit-based system. If possible it would mean the SatNOGS network could provide a large set of measurements from around the globe that would allow for more accurate orbital determinations to be carried out and could allow for multiple determinations to be carried out per day. The work on this project primarily focused on determining the accuracy of SatNOGS Doppler measurements that would be required for metre-level precision orbital determinations to be carried out successfully.

Primary author: JANES, Noel (University of Glasgow, Luleå University of Technology)

Co-author: MAISONOBE, Luc (CS-SI)

Presenter: JANES, Noel (University of Glasgow, Luleå University of Technology)

Session Classification: Talks

Track Classification: Software

Contribution ID: **31** Type: **Round Table**

The future of OSCW

Wednesday, 16 October 2019 16:00 (30 minutes)

A round table discussion on the future of Open Source Cubesat Workshop, its audience, possible directions, broader ecosystem and format considerations.

Primary authors: Mr PAPADEAS, Pierros (Libre Space Foundation); PAPAMATTHAIOU, Manthos

Presenters: Mr PAPADEAS, Pierros (Libre Space Foundation); PAPAMATTHAIOU, Manthos

Session Classification: Group meetings - Roundtables

Track Classification: Communities, Business, and Legal Aspects

Contribution ID: **32** Type: **Round Table**

Mapping the Open Source Cubesat ecosystem

A round table discussion on the developments so far of the open source cubesat community and industry.

The goal of this round table is to bring together developers, integrators and operators of open source (or partially open source) cubesat missions, to identify synergies, gaps and opportunities, in an effort to map a way forward as a broader roadmap with milestones.

OSCW is the perfect setting for such a roundtable since it brings together the majority of the stakeholders for such a discussion.

Primary author: Mr PAPADEAS, Pierros (Libre Space Foundation)

Presenter: Mr PAPADEAS, Pierros (Libre Space Foundation)

Session Classification: Group meetings - Roundtables

Contribution ID: **33** Type: **Talk**

Space Development Program ”Edu Cubesat”

Tuesday, 15 October 2019 16:00 (20 minutes)

National Technological University - Córdoba Regional Faculty

Space Development Program “Edu CubeSat”

Robotics Club 1

Córdoba, Argentina
July 21, 2019

As the result of the enthusiasm for space environment, the researches and studies done, brought us to different activities and networking throughout this two years.
In this opportunity we present the bellow program proposal.

In support of the Argentine Educational System, the Robotics Club (CdR) of the National Technological University, Córdoba Regional Faculty 2 (UTN-FRC) joined together with the Preparatory Committee of UNISEC-Argentina [3] (PCoUA) have prepared the next Space Development Plan (PDE).

Introduction

The general objective of this program is to awaken and develop scientific-technological vocations, related to spatial issues, in undergraduate students of Public Universities; cultivating a passion for engineering, promoting advanced technologies and the socio-economic growth of our country. This program also seeks to encourage spatial development based on open technologies (Open Source philosophy). All the material generated around this program is open and can be used by any public university to start its own academic space career.

Phases

- **First phase** of the PDE consist about the Cor-E Sat Project (educational satellite based on 3D printing technology and commercial components for use in the laboratory and in the classroom), presented at the OSCW editions 2017 (Darmstadt) and 2018 (Madrid), in IAA-LACW 2018 (Ubatuba, Brazil), FLISoL 2018/2019 Argentina and CATE 2019 (Argentina).
  As of May 2019, a maintenance and continuous improvement phase begins, focusing on the development of the bibliographic material necessary to be able to give a workshop-course based on this technology. Initially, a series of extracurricular courses-workshops will be given using the CorE-Sat platform, theoretical-practical bibliographic material, dictated mainly by the developers. Once these experiences have been completed and the material polished, a university extension course will be proposed.
  Infrastructure support: for this first phase the use of the laboratories of the University is proposed, with the aim of sharing and disseminating the initiative among the students and teaching staff.
- **Second phase** is about the Space-Satellite Mission Proposal for Fire Management (ARTI) [4]. This is a simulated mission in a digital environment, covering the design, development, testing, operation, completion and subsequent evaluation of the mission, using tools for analysis and design of missions and space systems, computer models, software in the loop (SIL) and hardware in the loop (HIL). The stipulated life time of the mission is 6 months from the start of Phase A development. Technological and technological demonstration missions developed both nationally and internationally will be taken as a basis.
  Infrastructure support: In order to develop capacities around satellite communications, we propose:

Replicate a node to incorporate the UTN-FRC into the SatNOGS open satellite network of the Free Space Foundation (architecture and software provided by the network).
Develop the necessary engineering to be able to receive and transmit from and to the flight segment (satellite) with its own equipment (implementing the ground segment software, supporting several modulation / demodulation, coding / decoding schemes). This station enters the second phase of the PDE as a SIL / HIL element and could become operational to provide satellite services from the University. The general activities would be carried out between this new space (the earth station) and the laboratories of the University.

- **Third phase** of the PDE proposes insert a simplified technological demonstrator into orbit of the flight segment from ARTI Mission and a reduced but functional implementation of ground systems (with a focus on the development of communications, operations and applications, such that allow to validate the response time before a positive detection). The ground systems will be tested and evaluated using a minimum set of three drones flying in formation, with their instrument, processor and communication interfaces, and an artificial scenario initially, to then move to a real controlled scenario to observe. Once the critical design review of this third phase of the PDE has been completed, it is expected to be able to coordinate with CONAE the registration of the flight segment in the National Register of Objects Launched into Outer Space [5]. The estimated duration of this third phase is 12 months from the end of the second phase.
  Infrastructure support: With the aim of developing capacities for the development, integration and testing of space systems, the implementation of a small satellite laboratory is proposed for the realization of this third phase of the PDE and upcoming projects. This space could be used for general purposes of the various chairs with responsibilities in the area.

Participation in congresses

The participation of the students involved in the different projects in national and international congresses will be promoted, promoting the generation of publications around the themes addressed.

References

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2 https://www.frc.utn.edu.ar/
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[4] https://clubderobotica.github.io/Docs/CdR_UTN_FRC_ProyARTI_2019_revB.pdf
[5] http://www.conae.gov.ar/index.php/espanol/registro-de-satelites

Primary authors: Ms BESSONE, Talia (UTN-FRC); Mr MOLINA, Martin Ezequiel (UTN-FRC); PAEZ, Hernan (UTN FRC CdR); Mr COLLADO, Federico (UTN-FRC); Mr ALVAREZ REYNA , Marco (CONAE - UFS)

Presenter: Ms BESSONE, Talia (UTN-FRC)

Session Classification: Talks

Track Classification: Development, Testing, and Lessons Learned

Contribution ID: **34** Type: **Talk**

Multi-SDR MIMO ground station with over-the-air time synchronization

Tuesday, 15 October 2019 13:00 (20 minutes)

In this work we present a Multiple Input Multiple Output (MIMO) Ground Station comprising of multiple Software Defined Radio devices (SDRs) and uses a novel approach to time-synchronize them. The array employs four receiving antennas and one transmit antenna which is used for device synchronization using the long training sequence of the IEEE 802.11 protocol. The antennas are mounted on four LimeSDR-mini devices. On the software side, digital beamforming as well as interference suppression is provided by the underlying algorithms. The benefit of this approach is that the MIMO ground station is more easily constructed than a rotator and has multiple times higher signal-to-noise ratio (SNR) than a single omni-directional antenna. Furthermore, it has the ability to monitor multiple satellites simultaneously. To showcase the performance gains we present conparative results with the single-omni directional-antenna ground station as well as with the rotator setup. The MIMO Ground Station is implemented as a sub-activity of the SDR Makerspace project.

Primary author: VARDAKIS, George (Librespace Foundation)

Presenter: VARDAKIS, George (Librespace Foundation)

Session Classification: Talks

Track Classification: Ground Networks, Launchers, and Operations

Contribution ID: **35** Type: **Talk**

SDR Makerspace: Exploit SDR technology for Space Communications

Monday, 14 October 2019 11:30 (20 minutes)

The SDR Makerspace is an initiative of European Space Agency (ESA), implemented by Libre Space Foundation (LSF). The goal of this program is to bring together makers, open-source hackers, radio amateurs, and a passionate community for dealing with challenges related with Software Defined Radios in space communications. This activity consists from several sub-activities, covering a wide range of applications. All sub-activities and results of the SDR Makerspace are available as open-source. Some of the activities that are part of the programme are presented below.

The gr-leo (https://gitlab.com/librespacefoundation/gr-leo) is a GNU Radio module that implements a channel simulator for Low Earth Orbit (LEO) satellites. It provides both uplink and downlink channel simulation introducing most of the impairments that such channels exhibit, such as path loss attenuation, Doppler frequency shift, atmospheric and rainfall path loss based on the ITU de facto models. In addition pointing and polarization losses are also taken into consideration by the simulator. This GNU Radio module can be a valuable tool for satellite mission planning and can be used for rapid prototyping and debugging. More information can be found on the wiki page of the project (https://gitlab.com/librespacefoundation/gr-leo/wikis/home).

The gr-ccsds activity (https://gitlab.com/librespacefoundation/gr-ccsds) is a GNu Radio module that provides all the processing blocks required for reception and transmission of frames that conform with the CCSDS standard for telecommand & telemetry. It supports most of the modulation and coding schemes of the standard, including Reed Solomon, convolutional coding, Turbo codes, while there is an undergoing activity to add support for LDPC too.

Another major activity is the gr-soapy (https://gitlab.com/librespacefoundation/gr-soapy). This GNU Radio module uses the SoapySDR API in order to provide a unified way for accessing various SDR hardware devices via GNU Radio in a unified and vendor free way. A unique feature of this module, is that it exposes RF specific parameters (e.g different gain stages, antenna setups, etc) based on the corresponding hardware used.
In addition, SDR Makerspace includes a series of radiation characterization and testing activities. Currently, an initial investigation has been completed regarding the radiation immunity of the components of eight commercial SDR devices. A follow up activity will perform actual radiation tests on these devices. The results are available on the repository of the sub-activity (https://gitlab.com/librespacefoundation/sdrmakerspace/radtest/wikis/home).

Several other activities (SDR hardware characterization, SDR devices radiation testing, satellite signal classification through machine learning) are undergoing and are expected to provide also their results.

Primary authors: SURLIGAS, Manolis; CSETE, Alexandru (AC Satcom)

Presenters: SURLIGAS, Manolis; CSETE, Alexandru (AC Satcom)

Session Classification: Talks

Track Classification: Software

Contribution ID: **36** Type: **Workshop**

Satellite Hunting - NORAD ID Assignment

Tuesday, 15 October 2019 10:00 (1 hour)

In order to track a satellite you need to know its orbit. In most cases orbit is described by TLE (Two Line Elements) set which is a data format encoding a list of orbital elements. The main source of TLE sets for objects orbiting Earth is the United States Space Command (USSPACECOM) through the space-track.org website.

Soon after satellites deployment, tracked objects show up in space-track.org catalog. Each of them is now identified by a catalog number, known as NORAD ID or NORAD Catalog Number, and it comes with a TLE set.

And this is when there is a need to connect the dots and find out which of these object orbits describe better the orbit of the satellites and the debris of this deployment, a process unofficially known as TLE Lottery. It should be an easy task but there are several factors that may turn it into a real challenge.

In this workshop, we will go through this process and learn how we can assign NORAD IDs by using open source tools and projects. In addition we will discuss the challenges and we will explore ways to overcome them.

Primary author: DAMKALIS, Alfredos Panagiotis (Libre Space Foundation)

Presenter: DAMKALIS, Alfredos Panagiotis (Libre Space Foundation)

Session Classification: Workshops

Track Classification: Ground Networks, Launchers, and Operations

Contribution ID: **37** Type: **Workshop**

Satellite communications using Software Defined Radios

Tuesday, 15 October 2019 11:00 (1 hour)

This workshop will be performed in two parts.

The first part will present the Software Defined Radio technology and the most popular SDR platform, the GNU Radio. Using the GNU Radio, the attendants will have the opportunity to follow a tutorial for signal processing. Aspects like modulation, filtering, coding and digital communications will be covered with visual examples using the GNU Radio.

The second part of the workshop will focus on the satellite digital communications. The workshop will initially present the different satellite communication protocols used mainly in Cubesat missions and the satellite channel impairments (Doppler, path loss, noise). Then using captured IQ signals the attendants will follow a tutorial that will guide them to construct their own demodulator using the GNU Radio platform.

Primary author: SURLIGAS, Manolis

Presenter: SURLIGAS, Manolis

Session Classification: Workshops

Track Classification: Software

Contribution ID: **38** Type: **Talk**

Free-space optical communications for CubeSats

Wednesday, 16 October 2019 10:20 (20 minutes)

Free-space optical communications for CubeSats

Abstract

The TeideSat project was born as an initiative of students from the University of La Laguna with the desire to know more about satellites and space, which led to constitute a team whose objective is the design, construction, placement in orbit and operation of a nanosatellite based on the CubeSat ESA standard.

It is the first satellite of the University of La Laguna and one of the first entirely from Canarias. The purpose of this project is the establishment of a free-space optical link between a ground station and a CubeSat. Serving as a precursor to make a more powerful data transmission technique a more common choice for low-cost satellites while documenting all the associated problems the team may have.

The TeideSat project consists of four fundamental pillars:

- Scientific Objective: To establish an optical data downlink between the nanosatellite and the surface of Earth.
- Technological Objective: To design and build a perfectly functional nanosatellite that complies with ESA quality standards.
- Academic Objective: To learn about areas of knowledge related to space outside the academic discipline of each member, with the aim of becoming a much more complete and versatile professional.
- Dissemination Objective: The TeideSat team believes in the importance of scientific-technical dissemination among people of all ages, but with special emphasis in the young. It devotes part of its time to this end trying to increase their interest in this topic

.
The TeideSat team is composed by a huge number of members from a really wide range of areas. How to manage and organize a big group of people within these types of projects, how to search for good member candidates and how to find good ways of obtaining funding are some of the issues TeideSat has come through parallel to the technical challenges of operating the CubeSat and transmitting information using an optical link (including error correcting codes for data transmission) while we are still building and designing our satellite.

Primary author: Mr BARRIOS PÉREZ, Joshua (TeideSat)

Presenter: Mr BARRIOS PÉREZ, Joshua (TeideSat)

Session Classification: Talks

Track Classification: CubeSat Missions and Systems

Contribution ID: **39** Type: **Talk**

SatNOGS COMMS

Wednesday, 16 October 2019 10:40 (20 minutes)

Libre Space Foundation in collaboration with ESA is developing a novel versatile Cubesat communication system. The product will support UHF and S-band frequency configurations and shall be part of an end to end (E2E) turnkey solution for satellite communications. The proposed solution covers the CubeSat onboard transceiver, the ground segment for Command and Control as well as analysis of the received telemetry data into a Data Warehouse (DW).

The primary key feature of the product is certification for use with SatNOGS. Demodulation and decoding of telemetry and payload data will be fully compatible with SatNOGS ground station transceivers. In addition, a wide range of communication system configurations which shall be offered as options for the customer to select, depending on the mission requirements.

As we are very early on the development process, during this presentation will we present the proposed architecture, the key components of the board some of our initial designs.

Primary authors: SURLIGAS, Manolis; DARADIMOS, Ilias (Libre Space Foundation)

Presenters: SURLIGAS, Manolis; DARADIMOS, Ilias (Libre Space Foundation)

Session Classification: Talks

Track Classification: CubeSat Missions and Systems

Contribution ID: **40** Type: **Talk**

TFTqube Design Presentation

TFTqube is a 1p pocketqube currently under development by an amateur and professional group of electronic engineers, scientists, teachers and more called The Flame Trench. The pocketqube is tentatively scheduled to launch in the early 2020s and aims to fly a selection of student payloads from both British and American universities. As development progresses, the designs of the hardware will be released on an open source licence and made available as a one stop solution to fly any manner of 1p pocketqube payloads.

In this talk, we will present the unique 'shell' concept of the TFTqube pocketqube design, talk through some of our engineering decisions, discuss the progress of the project to date and expected upcoming milestones. We may also look to open a call for payloads during the talk.

Primary author: Mr CARTWRIGHT, Ben (The Flame Trench)

Presenter: Mr CARTWRIGHT, Ben (The Flame Trench)

Contribution ID: **42** Type: **Round Table**

Mega Constellations and Collision Propagation: Open Source Solutions to Mapping Debris and Measure Threats

Monday, 14 October 2019 14:00 (30 minutes)

Despite efforts, large quantities of space debris end up in various orbits threatening, not only current and future missions, but also space exploration as a whole. The addition of mega constellations will most likely only worsen the probability of collisions and visual exploration. Added to this, there is the fast-growing telecommunications industry, and with cube-sats becoming more in demand, certain orbits will become unusable in the coming decades. The need to discuss possible solutions is overdue. There lie two main issues: the financial burden of removal and how to initiate an international space policy. With opensource, we have the ability to get free aid from the opensource community – and that is the first step to a solution. With data, we can begin to evaluate the consequences and convince legislature. Is the solution, perhaps a cube-sat in LEO that maps debris or shoots down debris with an on board laser?

This roundtable discussion would be to brainstorm about possible ways opensource can contribute to solving the issue of first mapping the debris, and second evaluating the threat/collision propagation thereof.

Primary author: CHRISTIANSEN, Sheila (Libre Space Foundation)

Presenter: CHRISTIANSEN, Sheila (Libre Space Foundation)

Session Classification: Group meetings - Roundtables

Track Classification: Ground Networks, Launchers, and Operations

Contribution ID: **43** Type: **Talk**

Welcome

Monday, 14 October 2019 09:00 (30 minutes)

Welcome to OSCW 2019

Contribution ID: **44** Type: **not specified**

OSCW 2019 - Closing

Wednesday, 16 October 2019 17:00 (10 minutes)

Contribution ID: **45** Type: **not specified**

What happened to PQ9ISH? The QUBIK Story

Wednesday, 16 October 2019 11:08 (4 minutes)

Presenter: DARADIMOS, Ilias (Libre Space Foundation)

Session Classification: Lightning Talks

Contribution ID: **46** Type: **not specified**

Creating and managing tons of documentation

Wednesday, 16 October 2019 11:12 (4 minutes)

Presenter: KANAVOURAS, Konstantinos (Aristotle Space and Aeronautics Team (ASAT))

Session Classification: Lightning Talks

Contribution ID: **47** Type: **not specified**

Libre Space Manifesto

Wednesday, 16 October 2019 11:16 (4 minutes)

Presenter: Mr PAPADEAS, Pierros (Libre Space Foundation)

Session Classification: Lightning Talks

Contribution ID: **48** Type: **not specified**

Isotopic Pirates on the Moon

Wednesday, 16 October 2019 11:20 (4 minutes)

Presenters: Mr ESTEVES, Andre (HackAveiro and FHP - Frezite High Performance Aeroospace); ESTEVES, Sandra

Session Classification: Lightning Talks

Contribution ID: **49** Type: **not specified**

HR Helper Tool

Wednesday, 16 October 2019 11:24 (4 minutes)

Presenter: STOUPIS, Dimitrios

Session Classification: Lightning Talks

Contribution ID: **50** Type: **not specified**

High Power Accelerator & TVAC

Wednesday, 16 October 2019 11:28 (4 minutes)

Presenter: BRETTI, Michael

Session Classification: Lightning Talks

Contribution ID: **51** Type: **not specified**

Finding Radiation Tolerant Parts

Wednesday, 16 October 2019 11:32 (4 minutes)

Presenter: TREWITT, Jordan (Planetary Transportation Systems)

Session Classification: Lightning Talks

Contribution ID: **52** Type: **not specified**

Ground Segment as a Service

Wednesday, 16 October 2019 11:36 (4 minutes)

Presenter: SEDLÁČEK, Marek

Session Classification: Lightning Talks

Contribution ID: **53** Type: **not specified**

Your first open source contribution! Git, Branch, Merge!

Wednesday, 16 October 2019 16:15 (45 minutes)

Learn the basics of git and open source contributions

Presenter: CANO RODRÍGUEZ, Juan Luis

Session Classification: Group meetings - Roundtables

Contribution ID: **54** Type: **not specified**

Setup your station ready for Telemetry with SLE

Wednesday, 16 October 2019 15:30 (30 minutes)

Presenter: STARCIK, Milenko (TU Darmstadt Space Technology e.V.)

Session Classification: Group meetings - Roundtables

Contribution ID: **55** Type: **not specified**

In depth MetaSat Feedback

Wednesday, 16 October 2019 13:30 (1 hour)

Presenters: CHIVVIS, Daniel (Center for Astrophysics | Harvard & Smithsonian); FREY, Katie (Center for Astrophysics | Harvard & Smithsonian)

Session Classification: Group meetings - Roundtables

Contribution ID: **56** Type: **not specified**

Getting your mission SatNOGS ready

Wednesday, 16 October 2019 14:30 (30 minutes)

Presenters: Mr DAMKALIS, Alfredos Panagiotis (Libre Space Foundation); DARADIMOS, Ilias (Libre Space Foundation)

Session Classification: Group meetings - Roundtables

Contribution ID: **57** Type: **not specified**

PQ9ISH Bus definition

Wednesday, 16 October 2019 13:30 (30 minutes)

Help us define the PQ9ISH Bus for pocketqubes

Presenters: ZISIMATOS, Agis (Libre Spaca Foundation); DARADIMOS, Ilias (Libre Space Foundation)

Session Classification: Group meetings - Roundtables

Contribution ID: **58** Type: **not specified**

Interoperability of open-source software/tools

Wednesday, 16 October 2019 14:00 (30 minutes)

Presenter: KARAKOSTA-AMARANTIDOU, Electra

Session Classification: Group meetings - Roundtables

Contribution ID: **59** Type: **not specified**

Open Source Satellite Initiative - Repositories

Wednesday, 16 October 2019 14:30 (30 minutes)

Help us define the repository structure!

Presenters: BERNIE, Anita (KISPE Space Systems Limited); Mr PAFFETT, John (KISPE Space Systems Limited)

Session Classification: Group meetings - Roundtables

Contribution ID: **60** Type: **Round Table**

SatNOGS & Space Systems Czech cooperation on Mission Control

Wednesday, 16 October 2019 16:30 (30 minutes)

Session Classification: Group meetings - Roundtables