CuSP: The CubeSat Mission for studying Solar Particles

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The **Cu**beSat Mission for studying **S**olar **P**articles is a NASA Science Mission Directorate and Heliophysics Division sponsored 6U Interplanetary CubeSat Science Mission. CuSP is scheduled to launch in December 2019 as a secondary payload on the SLS (Space Launch System) EM-1 (Exploratory Mission One) flight. CuSP is a pathfinder mission for Space Weather Research as it will be the first heliophysics science mission to be placed in heliocentric orbit outside the influence of the Earth's magnetosphere. CuSP features three complementary, miniaturized sensors to address two science objectives:1) study the sources and acceleration mechanisms of solar and IP particles in near-Earth orbit, and 2) support space weather research by determining proton radiation levels during Solar Energetic Particle (SEP) events and identifying properties of suprathermal ions that could help predict the arrival of strong coronal mass ejection-driven interplanetary shock waves that produce geomagnetic storms. The Suprathermal Ion Spectrograph, or SIS, is built by the Southwest Research Institute to detect and characterize the low-energy suprathermal and solar energetic particles. NASA Goddard's Miniaturized Electron and Proton Telescope, or MERiT, will meausre high-energy solar energetic particles. Finally, the Vector Helium Magnetometer, or VHM, from NASA's Jet Propulsion Laboratory, will measure the strength and direction of the interplanetary magnetic field. In addition to its science objectives, CuSP's primary technical objective is to increase the technological readiness level (TRL) of our novel SIS instrument concept so that it can be proposed and flown with significantly reduced risk and cost on future Heliophysics missions. This talk discusses the challenges, progress, and status of the CuSP project.

REAL: A CubeSat to Study Energetic Electron Precipitation into Earth`s Atmosphere

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The REAL (Relativistic Electron Atmospheric Loss) CubeSat will characterize different modes of atmospheric electron precipitation by making high time resolution measurements of precipitating electron pitch angle and energy distributions. Although significant progress has been made in identifying plasma waves that drive energetic electron precipitation (EEP) [e.g., Thorne, 2010 for review], there are missing links in our understanding, including the physical “modes” of wave-particle interactions. For example, electrons may be scattered slowly through a diffusive process [e.g., Shprits et al., 2008 review], or rapidly through nonlinear processes [e.g., Albert, 2000; Bortnik et al., 2008, Omura et al., 2015]. The physical mode determines the scattering rate and thus the impact on Earth`s radiation belts. REAL will distinguish between these modes of precipitation by measuring the pitch angle distribution of electrons over a wide energy range, from keV to MeV, in a low Earth orbit (LEO), and with time resolution sufficient to resolve electron microbursts. LEO is ideal for measuring precipitation since the atmospheric loss cone is larger (~60 deg) than at the equator (few degrees). The pitch angle-resolved measurements will also distinguish between precipitating, quasi-trapped, and trapped populations, thus more accurately quantifying the electron loss rate and the impact on Earth`s atmosphere.

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GTOSat: A Next-Generation CubeSat to study Earth's Radiation Belts

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GTOSat is a 6U CubeSat mission currently under development and targeting a launch ~2021. While a number of previous CubeSats have studied the radiation belts from low-Earth orbit (LEO), GTOSat will launch into a low inclination geosynchronous transfer orbit (GTO) to directly study the core trapped particle population. From this orbit, it will measure energy spectra and pitch angles of ~hundreds keV - few MeV electrons and ions, with the primary science goal of advancing our quantitative understanding of particle acceleration and loss in the outer radiation belt. Instrumentation includes the high-heritage Relativistic Electron Magnetic Spectrometer (REMS), which is a customized version of the MagEIS instrument onboard NASA's Van Allen Probes mission, and a boom-mounted fluxgate magnetometer to provide 3-axis knowledge of the local ambient magnetic field. The GTOSat bus consists of a 6U spin-stabilized structure with a Sun-pointing spin axis. Mitigation of radiation effects is accomplished through a multi-pronged systems approach consisting of spot shielding, parts selection, and a 'vault' that utilizes a novel z-graded radiation shielding developed by NASA LaRC to reduce the total dose for 1 year on orbit to less than 25 krad. Communication is achieved via an S-band transceiver, enabling high data throughput through the Near-Earth Network (NEN) and low-latency radiation belt monitoring via the Tracking and Data Relay Satellite System (TDRSS). GTOSat will pave the way for highly reliable, capable CubeSat constellations and missions beyond low earth orbit (LEO).

A VIEW OF A SMALL SOLAR SATELLITE

Alan Title, Alan Title

"Goldin (NASA Administrator 1992-2001) cut the time required to develop Earth and space-science spacecraft by 40 percent and reduced the cost by two-thirds, while increasing the average number of missions launched per year about four times" (NASA History Office). The Golden era fostered the idea of "better, faster, cheaper." The 183 kg Transition Region and Coronal Explorer (TRACE) was the third mission of a new generation of small science missions - Small Explores (SMEX). It was completed in less than 4 years and produced revolutionary results for nearly14 years before it was superseded by the instruments on the Solar Dynamics Observatory. At the end of its development phase the TRACE project returned 7.5 million unexpended dollars to NASA at the end of its development phase. Here I will show original movies of test, mounting to the spacecraft, launch and operations in control center as well as some of the movies that fundamentally changed our understanding of the solar atmosphere. The TRACE mission provides a glimpse of what a small team young engineers and scientists can accomplish. The TRACE launch cost $30 million. Today it could be launched for between $5 to $10. Most of the used in TRACE can now be purchased off-the-shelf. This cuts cost significantly, but much more important it means that parts can be obtained in weeks rather than months to years. Now I predict that a Trace like mission can be launched for less that $30 million

Planetology with small satellites: results and perpectives

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Under the common name of small mission actually lies a wide range of satellites from the one unit CubeSat to the S class ESA missions. The history of space exploration did indeed start with satellites that now would be considered small like the Sputnik or the Explorer one. In the years to follow the complexity of the science observations increased with the consequence of a constant growing of the size of the spacecrafts. This situation also lead to the development of larger launchers and costs increase. Consequently, the interest in small satellites, usually defined as those under 500 kilograms up to less than 1 kg, has grown over the years. The miniaturization of once-bulky satellite components, standardization of many satellite parts, and other factors have trimmed costs and realization time substantially.

No doubt that for the human exploration or for deep space exploration missions sizes and masses will continue to be very significative. In contrast, smaller and lighter satellites require smaller and cheaper launch vehicles and can sometimes be launched in multiples. They can also be launched as `piggyback` on mother satellites or planetary carriers.

Even if a quite a large number of small missions have been realized, from the Sputnik times till today a prudent estimate may count almost 900, there are very few examples of planetary missions so far.

In the next future minisats, better known as Cubesats, are under development to be used for planetary sciences as carried as piggy-back of larger missions. Also, small sats with very few instruments on boars, devoted to the measure of specific planetary characteristics will be proposed and likely they will be essential to provide answers to critical observations in a reasonable short time.

The PROBA-3 Mission

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PROBA-3 is the next ESA mission in the PROBA line of small technology demonstration satellites. PROBA-3, to be launched in 2021, is a mission dedicated to the in-flight demonstration of precise formation flying techniques and technologies. The PROBA-3 mission will place two small satellites in a highly elliptical orbit around the Earth. The two satellites will fly in a precise formation, producing a very long baseline solar coronagraph called ASPIICS (Association of Spacecraft for Polarimetric and Imaging Investigation of the Corona of the Sun). One spacecraft will carry the optical telescope, and the second spacecraft will carry the external occulter of the coronagraph. The inter-satellite distance of around 150 m will allow observing the inner corona close to the solar limb with very low straylight. The technological challenges and scientific objectives of PROBA-3 will be discussed. A particular emphasis will be put on the perspectives for future missions that could use the formation flying technology.

Project of the spacecraft "Gravisat"

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All modern gravitational space missions, such as GOCE or GRACE, can not provide autonomous measurements of the parameters of the gravitational field of deep space, since the instrumentation used on board is a kind of accelerometer that can not function without external measurements (navigation and ballistic).

This task can be solved by the relativistic gravimeter developed by the author, which uses the effect of gravitational displacement of the frequency of electromagnetic radiation. The principle of the relativistic gravimeter is that on board the spacecraft is a highly stable frequency standard and at least three receivers of electromagnetic radiation, which are orthogonally spaced relative to the frequency standard. The frequency standard and the receivers are interconnected. By measuring the gravitational frequency shift between the frequency standard and the receivers, we determine all three components of the acceleration of gravity. The technical prerequisite for the development of such a spacecraft is the creation of optical femtosecond frequency standards, the dimensions of which do not exceed the match head. In addition to the absolute value and gradient of the acceleration of free fall, such a spacecraft could also measure the mass of cosmic objects.

The relativistic gravimeter, the method of measuring the parameters of the gravitational field and the mass of space objects are patented. Also, the original design of the spacecraft "Gravisat"is patented. At present, the first sample of a relativistic gravimeter was created in 2017 and is in trial operation.

Status of Venus Missions and A Proposal for a Possible Venus Mission by the Turkish Space Agency

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New data is definitely needed for a more complete and consistent picture of our so called “sister planet” which has many parameters similar to Earth.But some of these parameters are very different from Earth and from any other planets in the Solar System.The knowledge of the status and history of the development of existing runaway greenhouse effect on Venus will shed important light on global warming and climate change effects on our planet.International cooperation, individual national or private Venus missions may provide significant information on the present and the past situations. New technological breakthroughs and advances in the existing techniques will be useful for achieving the scientific goals for terraforming and colonizing as proposed by NASA, RosCosmos, etc. As the most recent of national agencies, The Turkish Space Agency (TUA) was established on 13 December 2018. The agency is expected to develop a schedule on the one hand satisfying national aspirations and on the other hand achieving international recognition.A mission to Venus as an orbital with some remote sensing and radiation detection capabilities would fit both aims. It would fulfill also the call made by the Indian Space Agency for international cooperation in their upcoming Venus mission. In this respect, it is our goal to participate in the international research for the estimation of the any possibilities of imaging the surface of Venus by a nanoprobe as a first flagship project of TUA to Venus. This project would be a very meaningful as a Flag Project on the behalf of the 100th anniversary of the establishment of the Turkish Republic, in 2023.

An overview of the Israeli Lunar Lander

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The Israeli Lunar lander (ILL) has evolved on the solid base of SpaceIL`s Beresheet lunar lander, and provides with a unique and cost effective solution for small to medium payloads.

In this presentation we shall present the ILL`s key features, planned evolution and overview its incorporation in current and/or future lunar payload delivery services.

The ILL platform is aimed at providing maximal mission flexibility for lunar orbit and surface missions. Its key features are: ul

- Multiple payload housing options, optional payloads release in lunar orbit (e.g. cube-sats) or on the lunar surface (e.g rovers or ejectable payloads).
- Total payload capacity of several tens of kg for ILL-1, and expected increase in future revisions.
- Flexibility in landing site selection and precision landing. Ability to land in permanently illuminated areas near the poles and thus support long term operations.
- Continuous allocation of resources (power, communication) to payloads while in orbit and on surface activities. /ul
- Finally, we shall present a roadmap for future builds of the lander aimed for increased payload capabilities, and describe the current status of cooperation with service providers and space agencies.

COSPAR Capacity Building and Small Satellites

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The Capacity Building Programme (CBP) is considered today one of the flagships of COSPAR (COmmittee for SPAce Research) activities. The Programme started in 2001 as a tentative project designed to widen expertise in space sciences and promote the use of data archives from space missions in developing countries, as a way to foster in those regions of the world first quality scientific activities. In these last 19 years we have held 35 workshops with more than 1000 participants in 21 countries, covering practically all space science disciplines (Astronomy, Earth Observation, Solar Physics, Planetary Sciences, Ionosphere, Magnetosphere, even Planetary Crystallography). Target of the highly practical COSPAR workshops are advanced students (PhD level) and young researchers.

The advent of a new era of unique explorations in space sciences using small satellites opens new challenges and possibilities for developing countries. There is a need to raise awareness of their potential in those regions and to form scientists and engineers at all related levels from observational techniques to mission concept design.

The achieved experience by the CBP could surely help in establishing a related program, although we think that a new type of workshops is needed hereby, due to a somewhat different target (final year or even younger science / engineering students) but also due to the multi-disciplinary type of work associated with small satellites. The interest of local industry in developing countries is another distinctive element of such a program, opening different funding ways than the traditional ones followed so far.

We aim to discuss several related questions to the establishment of a new type of COSPAR workshops, devoted to Small Satellites, also in the light of the CB workshop held in the week previous to the Symposium.

Lessons Learned in Advancing Academic Space Science Programs

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The ability to economically launch small satellites (Cubesats) is opening up many new space-based opportunities. In academia this is enabling to space program creation through classroom problem-based learning (PBL) exercises where student groups of all abilities are able to explore questions related to space and technology. While modest investment of funds and resources opens this pathway quickly, a more substantial teaching and training experience reveals itself as the academic program evolves along space science and engineering disciplines. This paper discusses some of the programmatic and technical challenges inherent in advancing academic space research from a PBL exercise to a sustainable space science program, where the science and engineering interactions become important supportive elements of a more complex and challenging endeavor. Reference is made to two academic programs: the National Space Science and Technology Center (NSSTC) at United Arab Emirates University (UAEU), and the University of Colorado's Laboratory for Atmospheric and Space Physics (LASP) – a US academic space research institute. Using experiences and lessons learned from both, suggestions are offered to establishing and evolving an academic space program.

The role of Givatayim Observatory in promoting science education

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Givatayim Observatory is the main center for astronomy education for all the ages in Israel. The professional knowledge of astronomy is both in the operation of telescopes and their accessories and also in instruction and teaching. The Givatayim Observatory is also the link between the amateur astronomers of the Israeli Astronomy Association, IAA and the professional astronomers, especially from Tel Aviv University.

The visitors of all the ages are fascinated by the night sky and topics such as solar system, astronomical events, star death, and black holes. New discoveries are often published on the front pages of newspapers and media. The Givatayim Observatory organizes lectures for the general public, special events and annual educational programs for all the levels combining astronomical observations with hands-on activities. The interest in astronomy provides an opportunity to engage children in science learning for higher education.

This work is supported by the Kehilatayim, Givatayim and the Israeli Space Agency, Ministry of Science and Technology.

Lessons Learned After 20 Years of Running a University CubeSat Lab

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The Cal Poly CubeSat Lab has played a large role in twelve launched spacecraft missions since its inception twenty years ago. CubeSats have evolved from non-existant to a major market player during this time. The lab`s longevity and experience comes with many lessions learned. Early in the program there was minimal guidance surrounding best practices and expected testing. The integrator would provide most of the assistance to ensure minimum safety criteria were meet, and no guidance on mission success criteria. With the advent of low-cost commercial integrators and the overall maturity of the community, there is still oversight of safety criteria, but little guidance on how to meeting those requirements within the launch schedule. Cal Poly has addressed these challenges largely through the continuity provided by dedicated faculty and staff.

The interdisciplinary lab consists of approximately 60 students, plus three full-time staff members and two associated professors. The lab`s operation and training is largely driven by the students, and includes activities such as weekly symposiums to present specific technical and managerial areas in greater detail. Despite these efforts, the limited productive time of undergraduate students is still challenging. Most of the continuity is provided by the lab`s staff and faculty in the form of guidance and oversight. This presentation will discuss some of the lessons learned over the past twenty years, and how the lab`s structure has evolved to meet the challenges.

The Architecture of the Lucky 7 CubeSat

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The Lucky 7 CubeSat is a first private satellite and 7th satellite in the history of the Czech Republic. The project was started as a student project that was funded by private finances. Lucky 7 is 1U CubeSat that integrates several subsystems and sensors.

Power subsystems consist of a Gallium Arsenide solar panels directly charging LiFePO4 accumulators with a capacity of 4 Ah. The satellite uses 3.3 V power distribution bus. The bus integrates 2 A latch-up overcurrent protection circuit.

For improvement of the reliability, the satellite is equipped with two identical sets of onboard computers (OBC), UHF radio modems, and antennas. OBCs are switched by a special watchdog circuit. The watchdog automatically selects optimal configuration.

The instrumentation board integrates the latest version of piNAV GPS L1 receiver, space dosimeter piDOSE, spectrometer, and a low-resolution camera.

The operation and scientific data are stored to FRAM memory of size 2 MB. The memory is logically organized to the 65 536 cells of size 32 Bytes. The data format of each cell is defined in advance, i.e. after reception of the cell, the data can be instantly decoded and interpreted.

For the purpose of the reading of this data by the ground station, a simple single layer communication protocol has been developed that organizes the memory cells to the transmission frames. The protocol enables us to meaningfully operate the satellite even in case of high Packet Error Rate.

CSIROSat-1 mission - CDR and Early Subsystems Testing

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CSIRO (Commonwealth Scientific and Industrial Research Organisation (Australia)) has been working on the design aspects of its first CubeSat mission, known as CSIROSat-1, together with Inovor Technologies (an Australian space start-up company). The 3U CubeSat will comprise a hyperspectral payload imager, composed of a SWIR camera, lens and a filter, together with an on-board processing board and will be launched into a LEO orbit from the ISS in the northern summer of 2020.

With PDR completed in late November 2018, all focus is now on early integration tasks and the CDR to be completed by early June 2019. The results of the CDR and an early sub-system test program will be presented, highlighting lessons learned to date as well as the plan ahead to complete our test program, which will involve vibration testing, TVAC and day-in-the-life testing as well as repeated testing of our deployable structures such as antennas and solar panels.

An ambitious in-orbit re-programmable high performance on-board processor will form part of our mission and will be coupled with post-processing imaging capabilities on the ground to learn from the key parameters that require tweaking to maximise the quality of the data products. The optimised parameters will then be incorporated into a new FPGA image that will be uploaded to CSIROSat-1 as the mission progresses.

SERB, an innovative proof-of-concept nanosatellite mission dedicated to the measurement of the Earth radiation imbalance

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The Solar irradiance and Earth Radiation Budget (SERB) is a future innovative proof-of-concept nano-satellite. The main objective of SERB is to measure the true Earth Radiation Imbalance, which is a crucial quantity for testing climate models and for predicting the future course of global warming. All estimates (ocean heat content and top of atmosphere) show that over the past decade the Earth radiation imbalance ranges between +0.5 to +1 $W.m^{-2}$. Up to now, the Earth radiation imbalance has not been measured directly. The only way to measure the imbalance with sufficient accuracy is to measure both the incoming solar radiations (total solar irradiance) and the outgoing terrestrial radiations (top of atmosphere outgoing longwave radiations and shortwave radiations) onboard the same satellite, and ideally, with the same instrument. This paper is intended to present the configuration of the SERB nanosatellite, which is a 3-Unit CubeSat (10 x30 x 50 cm in a deployed configuration). The objective is to demonstrate the ability to build a low-cost satellite with a high accuracy measurement in order to have constant flow of data from space. Moreover, instrumental payloads (solar radiometer and Earth radiometers) can acquire the technical maturity for the future large missions (constellation that insure global measurement cover) by flying in a CubeSat.

Taranis mission

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TARANIS is a CNES scientific mission based on a microsatellite belonging to CNES Myriade series and dedicated to the study of impulsive transfers of energy between the Earth`s atmosphere and the space environment. Objectives more precisely focus on the determination of the mechanisms at the origin of Transient Luminous Events (TLEs), Terrestrial Gamma-ray Flashes (TGFs) and on their effects on the Earth environment. The scientific objectives of the TARANIS mission fall into three broad categories: ul

- Advance physical understanding of the links between TLEs, TGFs and environmental conditions.
- Identify other potential signatures of impulsive transfers of energy and provide inputs to test generation mechanisms.
- Provide inputs for the modelling of the effects of TLEs, TGFs and bursts of precipitated and accelerated electrons on the Earth's atmosphere. /ul
- To reach these objectives, the TARANIS scientific payload is composed of six scientific instruments: ul
- MCP : optical sensors,
- XGRE : X and gamma ray sensor,
- IDEE : high energy electrons sensor,
- IME-BF : low frequency electric field antenna,
- IME-HF : high frequency electric field antenna,
- IMM : 3 axis magnetic field search coil, /ul
- The total mass of the spacecraft will be around 185 kg and its volume less than 1 m^3.
- TARANIS will be the first space mission fully dedicated to the detection and observations from space with a complete range of scientific captors (optical, radiation, electro magnetism) of the TLE and TGF phenomena.
- The satellite is planned to be launched in the spring of 2020 from Kourou (French Guyana) on a VEGA launcher.

Maritime Applications for Small Sats: Observations of ocean waves, currents, tides, and navigational hazards

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Small satellites are ideal platforms for ocean observations due to their high pixel resolution (~meters), and high revisit frequency (~hours). The paper will discuss three Maritime applications: (1) Ocean wave spectra from weather to sub-seasonal temporal scales. (2) Nearshore bathymetry and navigational hazards. (3) Internal waves, currents, and tides.

Both single pushbroom images and framing video systems can be used. We focus on video because of its relative novelty on commercial space systems. Four enterprises have deployed video in Earth orbit: Skybox Imaging (2013-2015), Urthecast (2015-2017, Earth-I (2017-), and Planet (2017-).

Video has clear advantages in Maritime observations. Video enables space-time processing methods that invert wave celerity into depth (up to about 20 m), and map surface currents and tides. Or the ocean waves can be filtered out to enhance visibility of navigational hazards below the surface. From motion of surf one can infer changes in the beach morphology. These applications have been implemented with traditional high resolution satellites (WorldView, Sentinel 2). Small sats will enable better temporal sampling of ocean phenomena and at locations further from land. Examples will be presented with video from Skybox Imaging and Urthecast.

The paper will discuss trade-off between resolution, footprint size, image compression, and frame rate; 1-3 fps (vs. 30 fps typical) is adequate in most applications. We explain how and where color bands are useful.

This paper is an update of "Urthecast video imaging from Earth orbit: a new tool for mapping coastal bathymetry," presented at Coastal GeoTools 2017.

MICROCARB PROJECT: ATMOSPHERIC CO2 MONITORING WITH A MICROSATELLITE

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The continuous increase of greenhouse gases in the atmosphere due to human activities since the beginning of the industrial era, is clearly identified as the origin of the climate change. Carbon Dioxide is the most impacting greenhouse gas, but exchange processes from sources and sinks are complex and still poorly known. A continuous monitoring of CO2 atmospheric concentration is therefore necessary to improve our understanding of the carbon cycle. A space system can provide a global coverage with a unique instrument.

MicroCarb, first European satellite mission dedicated to CO2, aims at demonstrating the feasibility of a future low-cost operational fleet of small satellites. It will measure CO2 atmospheric concentration all around the world from a low Earth orbit, allowing to estimate the sources and sinks, with a high level of performances.

MicroCarb microsatellite (200kg) is based on the generic CNES Myriade platform, with enhanced capacities, and uses a very compact high resolution spectrometer that measures the sunlight reflected by the Earth in 4 SWIR O2 and CO2 absorption bands. It allows a wide range of viewing strategies including many calibration modes.

The development is conducted by CNES with European partners (UKSA, EUMETSAT, AERIS atmospheric pole) and the launch is targeted for 2021.

The presentation will describe the scientific objectives, the organization and actors of the program, a technical overview of the satellite with a focus on the original and innovative aspects, and will conclude with a project progress status.

Stray light solution for Ghgsat nanosatellite

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GHGSat is world's first nanosatellite dedicated for monitoring greenhouse gas (GHG) and air quality gas (AQG) emissions from any industrial site in the world. The satellite was designed and constructed by MPB Communications to monitor carbon dioxide (CO2) and methane (CH4) from a low earth orbit (about 500 km).

To reach the designated resolution of less than 50 meters and high precision of greenhouse gases monitoring, the nanosatellite has large aperture in order to collect enough optical signal. The aperture of about 10cm causes significant stray light issues with limited solution options without adding too much weight to the light weight satellite.

As the stray light was the main concern in this project, many precautions was taken. As a solution for blocking unwanted light, baffle with many vanes was used. However, having the vanes is not optimal solution without high absorbing coating applied on it. The coating requirements was low reflectance, no outgassing in space environment and long life stability, being a satellite inaccessible for maintenance.

The chosen coating for stray light elimination was Acktar Vacuum Black™. Hemispherical reflectance and BRDF data was examined before making the choice.

The satellite was launched in June 2016 and the images was analyzed to ensure the aimed resolution and precision of the optical system. After almost two years of activity, no visible changes was discovered in image quality nor stray light issues detected.

The Snipe Mission for Observing Small Scale Ionospheric and Magnetospheric Plasma Phenomena

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SNIPE mission consisted of four nanosatellites will do ambitious scientific observations with formation flying changing each satellite distance from 10 km to several hundred km. With such a unique operation, we can measure the spatial and temporal variation of near-earth space plasma phenomena. The SNIPE mission will be launched into a polar orbit of the altitude of ~600 km in 2021. The SNIPE mission is equipped with scientific payloads which can measure the following geophysical parameters: density/temperature of cold ionospheric plasmas, energetic electron flux, and magnetic fields. In addition, this mission has enhanced communication equipment, UHF up/downlink, S-band up/downlink and Iridium module. For the attitude control, this mission will use three-axis reaction wheels with sun sensor, gyro, and star tracker. KASI, KARI and Yonsei university cooperate for this mission, and lots of domestic companies provide subsystems on the SNIPE mission. The SNIPE mission will pave way for the next generation CubeSat missions in Korea.

using the Miniature X-ray Solar Spectrometer (MinXSS) CubeSats to Probe HOT plasma in the atmosphere of a COOL star

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The Sun is the closest star to Earth and hence provides a unique opportunity to study numerous stellar phenomena in detail unprecedented to other stars. One such phenomena, which is a longstanding mystery, is coronal heating of low mass stars. The solar corona contains plasma in excess of 1 MK at all times, strong concentrations of magnetic field called active region contain plasma at least up to 3 MK, and large flares heat plasma above 10 MK. Solar flares accelerate particles into the solar atmosphere and into interplanetary space and emit copious high energy electromagnetic radiation, such as soft X-rays (sxr). Hence sxr measurements provide an early warning for any pending geomagnetic affects as a result of solar flares. Additionally, the detection of sxr from the Sun provide direct information on coronal plasma of temperatures in excess of ~1 MK, but there have been relatively few solar spectrally resolved measurements from 0.5 – 10. keV. CubeSats can be a low-cost alternative to rapidly fill astrophysical observation gaps, that large missions are currently missing. The twin **Mi**niature **X**-ray **S**olar **S**pectrometer (MinXSS) CubeSats are the first solar science oriented CubeSat missions flown for the NASA Science Mission Directorate. The twin MinXSS have provided measurements from 0.8 -12 keV, with resolving power ~40 at 5.9 keV, at a nominal ~10 second time cadence. have proven to be consistent with numerous solar observations, proving the scientific capability of CubeSats.

SOLAR BRAGG SPECTROMETRY - NEW OPPORTUNITIES WITH MICRO-SATELLITES

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Solar X-ray spectra are am unique source of information crucial to explore the physics of the solar coronal plasma. Spectrometry allows determining basic plasma parameters, and thus to investigate coronal-heating mechanisms, physics of flares and space weather.

In the past, large satellites were using the Brag spectrometers to observe the X-ray spectra. The best spectra were obtained from the XRP instrument on board Solar Maximum Mission. Our team from Polish Space Research Centre used the experience of XRP to develop two follow-on Bragg spectrometers, RESIK and DIOGENESS, which successfully observed the solar spectra in 2001. Currently, we are working on two novel spectrometers: SolpeX and ChemiX for International Space Station and Interhelioprobe respectively. However the future of solar X-ray spectroscopy lays in using micro-satellites to carry the instruments. In my presentation, a description of CubeSats designed to observe the X-ray spectra of the Sun will be given.

A New Type of Neutral Atom Imaging and its Application in Space Weather Monitoring

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At present, the monitoring methods for extreme space weather phenomena such as magnetic storms are still based on the in-situ detection of physical parameters such as space energy particles and magnetic fields by a single satellite or a constellation of a limited number of satellites. Due to the lack of panoramic monitoring data, it is difficult to directly obtain the spatio-temporal evolution information of spatial particles and global energy continuum. Energy neutral atom imaging technology is a new kind of panoramic remote sensing imaging technology for space energy particles. It can effectively acquire the composition of space energy particles and its high temporal-spatial resolution panoramic remote sensing imaging data. It is of great significance for improving the ability of monitoring and forecasting extreme space weather phenomena such as magnetic storms. This paper mainly introduces the development progress of a new type of energy neutral atom imager, and the ongoing small satellite constellation for space weather monitoring based on neutral atom multi-perspective panoramic imaging programme.

The Atmospheric Effects of Precipitation through Energetic X-rays (AEPEX) CubeSat mission

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Precipitation into the upper atmosphere is one of the primary loss mechanisms for radiation belt electrons, particularly during the decay phase following geomagnetic storm enhancements. These particles go on to impact the upper atmosphere through ionization, which leads to a chemical response that increases NOx and HOx and destroys ozone. Quantifying both the loss from the radiation belts and the impact on the atmosphere requires an accurate estimate of the flux, energy spectrum, and spatial and temporal scales of precipitation. However, such assessments are particularly difficult due to limitations of most measurement techniques.

The AEPEX CubeSat is designed to quantify these parameters of radiation belt precipitation by measuring the bremsstrahlung X-rays created during the precipitation process. AEPEX will image the X-ray fluxes produced by the atmosphere, providing measurements of spatial scales, along with the X-ray flux and spectrum. A solid-state energetic particle detector will measure the precipitating electron energy spectrum, which is used to constrain the inversion of X-ray fluxes to electron fluxes. We show in this talk and in Xu and Marshall [2019] that the combined particle and X-ray measurements can be used to accurately measure the precipitating electron flux and the atmospheric ionization response. We present the science goals of the AEPEX mission, the mission design, and the spacecraft and instrument designs.

Understanding the ionosphere and thermosphere

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In this talk we discuss the most important questions in understanding the ionosphere/thermosphere and how they can be addressed with small satellites. The ionosphere is created by the solar radiation and the precipitation of energetic magnetospheric electrons and ions and by the ionization of meteoritic material. This last component has not attracted much attention lately but it plays a significant role, through the creation of the sporadic E-region, in limiting the performance of some of technological systems. The ionosphere is also driven from below by the creation of lower atmosphere tides and atmospheric gravity waves. We also note that transient phenomena, such as tropospheric storms and earthquakes and missile launches, produce an ionospheric signature. One particularly fascinating conjecture is that there may even be an ionospheric precursor signature that heralds earthquakes. There are still many mysteries to be addressed. Small satellites can address the ionospheric space weather by either providing a number of in situ measurements (we will briefly describe some new ideas); by imaging some of the drivers or the response (AGWs or the aurora); or by radio techniques. The key to understanding the global behavior of the ionosphere is to unravel the many different factors that influence its behavior – to achieve that goal we must make many, many observations. Only by achieving an international collaboration of many kinds of instruments (ground- and space-based) and models can we truly make progress.

Small Scale Radioisotope Thermoelectric Generators (RTGs) and Heater Units (RHUs): Enabling Technologies for Deep Space and Planetary Surface Missions

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Radioisotope thermoelectric generators (RTG) are under development in Europe as part of a European Space Agency (ESA) funded programme. Aimed at enabling or significantly enhancing challenging space science missions to solar system bodies and in deep space, this programme relies on the cost effective production of americium-241 as the radiogenic heat source and an iterative engineering approach to developing the systems which include isotope containment architectures and in the case of RTG systems bismuth telluride based thermoelectric generators. The RTG containment systems rely on the use of inner platinum-rhodium alloy cladding, insulation layers and carbon-carbon composite outer aeroshells. The RTG heat source configuration is designed to deliver 200 W. The modularity of the RTG design allows the 200 W heat source to build scalable RTG systems with electrical power outputs ranging between 10 W and 50 W per RTG unit. In addition, radioisotope heater units (RHUs) are being developed for thermal management applications. These are designed to deliver 3 W of thermal power per unit. This paper describes the most recent updates in system designs and provides further insight into recent laboratory prototype test campaigns of RTG and RHU systems.

CNES perspectives for affordable missions to Deep Space

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French involvement in affordable deep space missions has been illustrated over the last few years by the accomplishments of the Philae lander in 2014, and by the mission of the Mascot lander, developed with DLR, which was dropped in October 2018 by JAXA's Hayabusa 2 probe on asteroid Ryugu. The value of CNES dedicated engineering skills, such as mission analysis for the descent to small bodies, and of French laboratories know how in the development of high performance – miniaturised instruments, has been demonstrated on both missions. It will be put into practice again through our contribution to JAXA's MMX mission to Phobos in 2024, and more mission concepts are also being defined in partnership with major Space Agencies.

In the cases above, cubesats or small lander / rovers depend on a larger spacecraft for deployment and other resources, such as telecommunication relay or propulsion. Under other circumstances, teams of cubesats can also be deployed and perform advanced tasks such as telecommunication relay or distributed scientific measurements. This may involve surface networks, constellations of orbiters, or a combination of both.

After giving an overview of the French involvement on small deep space spacecraft, we will identify the science goals and investigations where cubesats and smallsats can make a unique contribution as science enablers and enhancers. The second part of the presentation will elaborate on mission architectures for the most promising concepts where cubesat size devices offer an advantage in terms of affordability, efficiency, and capacity to take risks.

A RECONFIGURABLE ENERGETIC PARTICLE DETECTOR FOR PLANETARY EXPLORATION

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We present a reconfigurable energetic particle instrument with a low energy threshold in order to study plasma populations in the thermal energy range. The instrument is intended to measure electrons from 10 keV to 1 MeV and ions from 10 keV to 10 MeV in various planetary environments. This instrument is based on a silicon detector with an ultra-thin entrance window. In front of the detector, a filter wheel allows to place either a thick foil, a pinhole or an obturator to allow the reconfiguration to various scientific modes to measure the combined spectra of electrons and ions, to measure the electron spectrum, to protect the detector from sunlight and to avoid saturation of the detector. The signal is processed by a reconfigurable Digital Pulse Processor implemented in a System on Chip which filters and shapes the pulses and creates energy spectra, allowing to optimize the tradeoff between energy resolution and maximum counting rate. The majority of the necessary building blocks are commercially available and some are even flight proven. The instrument fits in a 1U volume (10 cm x 10 cm x10 cm) and its power consumption is 2W. It is suitable to be flown on a 3U CubeSat or as a standalone instrument on a larger spacecraft.

Performance and supersonic ion beams of the ALPHIE (Alternative Low Power Hybrid Ion Engine) plasma thruster.

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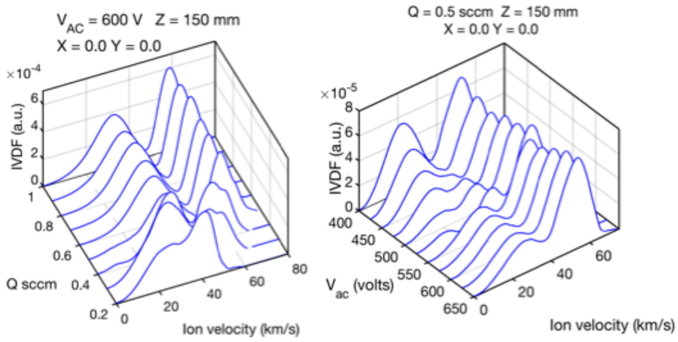
The Alternative Low Power Hybrid Ion Engine (ALPHIE) is a newly patented throttleable gridded plasma thruster [1]. Its design is small in size and different from the classical gridded configuration (Kauffman) and shares elements of Hall effect and Multi-Cusped field thrusters [1,2].

The thruster performance will be discussed on the basis of laboratory experiments [2] and PIC simulations [3]. The supersonic ion beams in its plasma plume exhaust have been characterized by means of movable electric probes [3]. Figures show the ion velocity distribution functions (IVDFs) at a fixed point along the plasma plume symmetry axis. The two-peaked IVDFs show the mesothermal plasma flow where fast (supersonic) ions move at 40-60 km/s speeds. These are controlled by the throttle potential V_{AC} and the propellant gas flor rate Q. Numerical calculations show that suprathermal ion beam formation depends on both Q and V_{AC}. Finally, the thrust levels, specific impulses and ion production rates will be discussed on the basis of laboratory tests.



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MarCo Spacecraft: Study and Analysis for Developing Communication Infrastructure for Manned Mission to Mars

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Distance between Earth and Mars ranges from between 55 million kilometres and 400 million, that is between 140 to 1,025 times further that the distance from the Earth to the Moon. This means that it could take as long as 20 minutes to send a message travelling at the speed of light one-way between the two planets. So for launching a manned mission communication infrastructure is required to be prepared for dealing with any emergency communication.

Recent mission launched by NASA of Insight Lander on Mars along with two cubesats named Mars Cube One(MarCo) could be a stepping stone for developing a fleet of satellites and building a communication infrastructure for manned mission to Mars. MarCo radio provide both UHF and X-band functions and capable of immediately relaying information, whereas earlier launched Mars Reconnaissance Orbiter (MRO) is able to transmit information in X-band but can’t simultaneously transmit and receive information. This paper deals with the detailed study and analysis of MarCO spacecraft functioning and further possible designs of a proposed communication infrastructure in future manned missions to Mars.

Dynamical aspects of the spatial gravity assists using for the forming high inclined orbits in the planetary missions

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Low-cost interplanetary tours with the high inclined orbit`s formation in the Solar system using gravity assists near its planets are considered with the accurate ephemeris using. Limited dynamic opportunities of their use require multiple passes near them. Topicality of the regular creation of optimum scenarios sequences of cranking passing of celestial bodies is obvious. This work is devoted to the description of required features of trajectory`s beams for the creation of such chains. Previously a comparative analysis of various modern astrodynamics studies of the 3D implementation of the gravity assists taking into account accurate ephemerides was performed [1]. Improved analytical formulas for the change of the inclination as a result of 3D gravity assist [1] were obtained and realistic results of the computation of parameters of the spacecraft`s orbit inclination changes at the Solar system bodies were presented. The Labunsky estimate of the admissible inclination variations and the corresponding graphs for the single gravity assist [2] somewhat differ from the more accurate presented calculations. The algorithms for designing multi-pass chains of multiply gravity assists are described that result in the energy-efficient increase of the inclination of the SC orbit to the ecliptic plane. Applications for the modern projects mission design are given.

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A study of students' perceptions of the role and value of a space science program for sustainable development

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Space science and engineering (SSE) education is becoming increasingly important for a nation's economic growth. It is deemed to play an important role in most societies in that, it contributes to national and economic growth. The aim of space science and engineering education is fostering and building a scientific space-educated society. Although views on space education vary from one definition to the other, most importantly, it includes the ability to solve problems and apply evidence-based decisions. This study explores students' perceptions of the value, role, and establishment of space science and engineering program in a technological research-intensive university. Given the dearth of previous empirical research, an exploratory approached is used. Focus groups are carried out to develop a nuanced understanding of the students' views of institutionalizing an SSE program. Relations between perceptions of teaching and learning of space science, intrinsic motivation and engagement is investigated. Implications for SSE curriculum development include ensuring progressive development from first to the fourth year, a need for enhanced focus on scientific and engineering applications for the sustainability of the SSE program, career opportunities after the establishment of the program. A framework for progressive curriculum development is recommended. Findings suggest that students are keen to undertake an SSE program provided it is offered in the university as it will provide a gateway for sustained interest in space science and development of a space workforce. The study concludes with suggestions on how to use SSE education to inspire learning and to encourage take-up of space-related subjects to help forge and spark interest in space-related fields.

SPACEPHARMA'S SATELLITES FOR MICROGRAVITY RESEARCH AND DEVELOPMENT

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Many chemical and biological processes are affected by the gravity field and proceed differently in micro-gravity environment. Going to orbit is the only means of providing a micro-gravity environment for any significant length of time. Space Pharma provides microgravity laboratories on its free-flying family of 3U and 6U DIDO CubeSats, enabling the mixing of fluids and the visual observation of the results using a light microscope and a spectrometer. The laboratory is suitable for chemical and biochemical reactions to study colloidal systems, self-assembly of polymers and macromolecules, bacterial growth rate, antibiotic effect and more.

The DIDO-3 satellite carries the SPMG-2 laboratory, a sealed system containing all the reagents for the experiments in a liquid-handling system hermetically sealed in an atmospheric box that has controlled temperature and environment. The laboratory also includes a suit of sensors to provide the observations and results reading of the experiments. This satellite platform provides the lab with power for the sensors, liquid handling and environment control, communication, and attitude control for proper function of the communication system and solar panels, and to ensure that no significant centrifugal fields interfere with the micro-gravity environment. The biological and bio-chemical materials involved in the experiments are quite sensitive to extremes of temperature and have severe degradation in their activity when stored for a long time. Due to this, it is important to load the reagents into the lab as late as possible (as close to the launch as possible).

Space science and engineering education at Nanyang Technological University through the SCOOBI mission

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The Satellite Research Centre (SaRC) at Singapore's Nanyang Technological University (NTU) has rapidly made strides in space technologies with 9 satellite developed and in operation since 2011. SaRC has initiated an educational program called 'NTU Student Satellite Series' (S^3) to enable satellite building capabilities and space science and engineering education in Singapore. Under this student-run program, S^3-I or SCOOBI is the first 3U Nanosatellite being built by a group of high school, undergraduate, graduate, and research scholars. The main mission objective of SCOOBI is to provide hands-on experience in satellite development and technology. As part of space science education in Singapore, SCOOBI is being designed to measure solar irradiance in Visible, Near Infra-Red (NIR) and Ultra Violet (UV) range using multispectral sensors along with a commercial off the shelf (COTS) camera for imaging purpose. Another payload is an IoT receiver to demonstrate the technology to receive and forward data from remote terrestrial IoT terminals. SCOOBI also demonstrates passive magnetic attitude control (PMAC) using permanent magnets. This paper explains how a tiered educational system incorporating students at multiple levels is being structured into a program to create a workforce for the emerging '*Newspace*' industry. A secondary benefit of the program is the indigenous development of cubesat subsystems. SCOOBI is scheduled for launch to a 550km circular orbit with a 5 degree inclination in Q4 of 2020.

INSPIRE: International Space Weather Research Using CubeSat Platforms

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The International Satellite Program in Research and Education (INSPIRE) grew out of courses at the University of Colorado to teach aspiring students not only about the design and development of small spacecraft, but to be immersed in the outstanding science that can be accomplished with such missions. INSPIRE today has five small satellite missions in development funded by four countries comprising mission objectives ranging from studying ionospheric dynamics to mesosphere and lower thermosphere wind and temperature observations, and solar observations in mid- and far-ultraviolet wavelengths. It is also developing a versatile University small satellite platform capable of carrying a variety of payloads ranging from plasma instruments to ultraviolet and infrared imagers. A network of four S-band stations and eight UHF ground stations enables high data downlink from these platforms. In this presentation, we describe INSPIRESat-1 & 2 science objectives in making simultaneous measurements of ion densities, velocities and temperature from two different altitudes and a range of local times to characterize plasma bubbles and traveling ionospheric disturbances. INSPIRESat-3 carrying a UV instrument is designed to make solar observations in the mid- and far-UV extending the SORCE observations beyond 2019 as well as occultation measurements of the thermosphere to derive gravity wave effects in thermospheric temperatures in the high latitudes in both hemispheres. INSPIRESat-4 is carrying a spatial heterodyne interferometer to make MLT temperature measurements and a hall effect thruster to lower its altitude to make in-situ plasma measurements at very low Earth orbits. The INSPIRE small satellite bus is a ring-deployed satellite that mounts on the launch vehicle payload fairing. The spacecraft bus is configurable to carry a variety of instruments. However, the different subsystems and card stacks conform to the cubesat standard and hence can be used in standard cubesat configuration as well. We contend that such small satellite missions can play a huge role in space weather programs around the world and can do so in an affordable and prudent way.

IDEASSat – A 3U CubeSat for Ionospheric Science and Capacity Building

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Building on the heritage of in-situ ionospheric sensors developed at National Central University (NCU) in Taiwan, we present the ongoing development of the Ionospheric Dynamics Exploration and Attitude Subsystem Satellite (IDEASSat) – a 3U CubeSat currently in the fabrication stage, with expected launch in 2020. IDEASSat carries the Compact Ionosphere Probe (CIP) – an all-in-one in-situ plasma sensor with flight heritage from the Advanced Ionosphere Probe (AIP) currently functioning aboard FORMOSAT-5, and will provide measurements of ionospheric structure and variability from a nominal 500 km Sun-synchronous orbit. The spacecraft subsystems are a combination of commercial off the shelf (COTS) and self-developed components designed in collaboration with partners from the International Satellite Program in Research and Education (INSPIRE). Key challenges include high precision pointing requirements of CIP, limited power and downlinkable data volume, as well as developing the necessary fabrication and integration capacity using university resources. We present the concept of operations, design, as well as lessons learned in the development, fabrication, and integration of IDEASSat. In conjunction with INSPIRESat-1 – a 9U SmallSat with the same payload, ionospheric measurements from IDEASSat will extend the coverage of in-situ ionospheric observations from the FORMOSAT-5, further enhancing our observational coverage of ionospheric variability and irregularities. Development of IDEASSat is also serving to build spacecraft design and operations capacity at NCU, providing students with a better appreciation of the relation between space physics and the spacecraft operational environment, as well as the technical, regulatory and management challenges inherent to building a functional spacecraft.

New Mexico Tech Student Satellite (NMTSat)

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NMTSat was conceived as a student satellite experiment on a minimal budget. NMTSat was funded a combined $50K from the New Mexico Tech administration and from the New Mexico NASA/EPSCoR program. That budget had to cover off-the-shelf components, in-house instruments, meetings, supplies, testing, and travel. Over several years and by a large number of volunteer students, primarily undergraduates, NMTSat was designed, built, tested, and delivered for launch. NMTSat is a 3U cubesat with five instruments, a plasma probe, two magnetometers, a optical beacon instrument, and a GPS occultation experiment. The last two instruments were supplied by outside collaborators (Los Alamos National Laboratory and ASTRA). We will provide an overview of the NMTSat project and discuss the challenge and lessons learned from managing such a project on a small budget with an all-volunteer undergraduate workforce.

Multiples satellite observations of "Wind Pump" impacts on marine systems

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This paper introduces new studies -- multiples satellite observations of "Wind Pump" impacts on marine systems. "Wind Pump" is defined as a series of processes driven by wind (include typhoon, monsoon and local strong wind) that influence on the states and movement of the upper ocean waters. Multiples small satellite may provide new data for this new study. "Wind Pump" response of environment changes, and subsequently affect the marine ecological status, it is expected to change the transport of nutrients, promote the cycling of major elements in the ocean, thus drive primary productions and marine ecosystem, and affect carbon fixation and fishery resources. This study examined the effects of Tropical Cyclones "Wind pump" on phytoplankton blooms, marine primary production, dissolved oxygen (DO) , CO_2 and fishery in the South China Sea and the Indian Ocean. Results suggested the formation mechanism and the effects of wind pumping, including upwelling, vertical mixing and cold eddy. We then characterized the impact of changes in wind speed, direction, location, strength, and frequency on the area and strength of wind pumping, as well as the ocean ecological systems. In the future, applying multiples satellite data, we will try to reveal how global climate change affects SST, and subsequently the impact to wind pumping and the associated propagation of energy.

Tropika equatorial constellation for Weather and Space Weather Forecasting

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The Tropika equatorial constellation of six 27U staellites aims to take advantage of Singapore's expertise in small satellite technology to build a small satellite platform capable of delivering vertical profiles of temperature and water vapor with the Global Navigation Satellite System (GNSS) radio occultation (RO) technique, ocean wind and moisture and flood inundation information from GNSS reflection (GNSS-R) signals, and in-situ ionospheric plasma density measurements from Low Earth Orbit (LEO). We aim to develop advanced techniques for assimilating GNSS RO and GNSS-R data into the regional SINGV Numerical Weather Prediction (NWP) model to improve regional weather forecasting and rainfall prediction. This project shall also develop a data-assimilation system combining satellite and ground-based measurements for monitoring space-weather conditions in South-East Asia and establish useful now-cast and forecast products that can be used to mitigate space weather impacts on communication and positioning systems in the region. We shall work with the Singapore Land Authority (SLA) to assimilate the data to improve the Singapore Satellite Positioning Reference Network (SiReNT), which is a nation-wide GNSS reference station network used for the purpose of high precision and accuracy positioning, navigation and monitoring. Thus not only does the project develop a small satellite platform capable of providing cutting edge weather and space-weather data, it will also develop downstream analytics platforms, working with local agencies, to utilize the data for Singapore`s national needs. The Satellite research centre at Nanyang Technological University will develeop the 27U satellites in collaboration with GeoOptics and Thales.

MERLIN: A franco-german MISSION to perform an innovative spaceborne measurement of ATMOSPHERIC methane

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Methane is a potent greenhouse gas. The MEthane Remote sensing LIdar missioN (MERLIN) will demonstrate the first active measurement of atmospheric methane from space.
The main scientific objective of MERLIN is the delivery of methane dry-air mixing ratio columns (XCH4) for all latitudes and throughout the year, with unprecedented small systematic errors. This will significantly improve surface methane flux estimates and the identification of methane sources on global and regional scales.

MERLIN is a joint French and German space mission, with a launch currently scheduled for mid-2024.
DLR-RFM is responsible for the design and development of the payload, an IPDA (Integrated Path Differential Absorption) LIDAR (LIght Detecting And Ranging). CNES is responsible for the overall mission system and for the design and the integration of the satellite. The platform is based on the new MYRIADE Evolutions product line for small satellites, an enhanced version of the MYRIADE platform used on a wide range of scientific and institutional missions. CNES, with DLR-RFM contribution, is also responsible for system performances and for the development of the mission ground segment in charge of scientific product generation and distribution, while expertise is shared between French and German centers.

The presentation will highlight the scientific objectives of the MERLIN mission and their significance in the current global warming context. It will detail the project organization and satellite key aspects, as well as the target performances and associated challenges. A focus will then be made on the current development status and expected mission schedule.

Constellation of small spacecraft for radio occultation probing of ionosphere and atmosphere

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The technique of radio occultation probing of the ionosphere and the atmosphere of the Earth is based on radio probing at “satellite-satellite” routes. As the satellites orbit, the propagation line of radio waves scans the ionosphere and atmosphere along the altitude of the radio transmitter beam. Analysis of the signal transmitted through the atmospheric slice provides insight on the state of the environment such as data on the electron content, temperature, density, pressure, humidity and movement of atmospheric slices. The environment parameters recovery (the inverse solution) is solved by variations of the signal amplitude and phase while passing through the atmospheric environment.

Meteorologists set the requirement to measure the atmosphere parameters of the land area 500 × 500 km for a reliable forecast. Given that the geosphere surface area is approximately 500 · 106 km^2, we can take that there are about 2,000 such areas. Estimates show that the number of radio occultation measurements of one SS of GNSS GLONASS and GPS is 1300–1400 daily. Hence, if the interval between measurements in each area of 500 × 500 km should be 3 hours (i.e., the measurement rate is 8 times per calendar day), the radio-occultation probing sessions requirement will be at least 16,000 per day. In this scenario, a constellation of at least 12 SS is required.

We offer the constellation of 18 small satellites to guaranteed solve the problem of observation of the ionosphere and atmosphere

ANGELS nanosatellite, from a successful CDR up to its launch

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Since the end of the 90's, there is a strong worldwide interest in the Cubesat & Nanosatellite objects, with pedagogical, technological, then scientific and more recently applicative goals.

This trend in miniaturization is associated with the emergence of innovative design, challenging development, manufacturing and testing methods, as well as product assurance approaches in order to favor the unveiling of new ideas and low cost missions.

Since around 15 years, CNES started to support academic initiatives followed by various R&D projects to support the emergence of Cubesat equipment, then nanosatellite applicative programs with the industrial development of: ul

- some platform equipment (S-band modem, X-band emitter, On Board Computer, Power Conditioning and Distribution Unit),
- a miniaturized ARGOS instrument developed by Thales Alenia Space and Syrlinks,
- a 12U nanosatellite project (ANGELS for ARGOS Neo on a Generic, Economical and Light Satellite), as a precursor of an industrial nanosatellites product line. Its development is conducted by a consortium led by NEXEYA and will carry the ARGOS Neo instrument. /ul
- After a self-compatibility EMC/RFC test of a complete satellite engineering model and a successful CDR, the flight model has entered in its manufacturing and testing phase based on a proto-flight testing approach. The launch is planned mid-October 2019, followed by an in-orbit validation phase. Based on a short mission duration (2 years), a challenging development time, a low harsh environment, a reasonable performance mission and a medium authorized risk level, this project will open the way to more demanding missions and especially operational constellations.

SandPIPR+ (Structure and Propagation of Ionospheric Patches in the polar Region) mission

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The SandPIPR+ multi-CubeSat mission will address the formation, structure, and evolution of ionospheric polar cap patches. Polar cap patches are referred to as plasma density enhancements in the F-region polar ionosphere, typically formed as a series of islands. Those density irregularities can cause signal scintillation. Therefore, understanding the formation and evolution and propagation of patches is key to forecasting space weather. The importance of polar cap patches is further highlighted from the fact that they directly substantiate the coupled dynamics of Earth's magnetosphere, ionosphere, and atmosphere, which is dependent on external and internal conditions. One important parameter in regulating the patch dynamics is the interaction and feedback between ions and neutrals occurring at altitudes less than ~400 km. This is, however, poorly understood due to the lack of appropriate measurements taken during different epochs in the evolution of a patch from the dayside to the nightside. SandPIPR+ mission will overcome these observational challenges to produce the first multipoint measurements of plasma structures in the polar cap and the associated interactions with the neutral gas that are responsible for the generation of plasma structure and the modification of the ion-drag force. SandPIPR+ directly addresses NASA's Heliophysics Science Strategic Objective "to understand the Sun and its interactions with Earth and the solar system, including space weather". Additionally, SandPIPR+ will provide preliminary measurements for the upcoming GDC mission, giving important implications for the instrument/spacecraft design and performance requirements.

Small Satellites for Next Generation Space Weather Measurements

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NASA Heliophysics Living With a Star program focuses on the science necessary to understand aspects of the Sun and Earth`s space environment that affect life and society. The goal is to provide the comprehensive research needed to understand the many factors affecting the Sun-Earth system and thus provide the information necessary for improved forecasting of space weather. In the past, in situ heliophysics observations have been obtained from flagship missions carrying comprehensive instrument suites and significant budgets; however, these high-cost missions still supply only localized measurement sets that are difficult to use to characterize the global response of the system. Because of this, the promise of small satellites as an affordable option for in situ measurements of relevant space plasma parameters makes these platforms an ideal candidate to obtain the outstanding observations necessary to advance space weather operations. The near-Earth vicinity of the Deep Space Gateway (DSG) could represent the first step in formulation of the next-generation space weather system concept, potentially providing a broad range of infrastructure (e.g., telemetry, launch capabilities) to enable a paradigm-shifting, more systemic approach to how space-based measurements are made. The location is ideal to launch small satellites (6U) that carry both remote sensing and in-situ sensors to cover the near-Earth environment from the magnetosphere to upstream of the Earth’s bow shock. In addition, the DSG can also provide a data relay function to pass real-time space weather measurement down to Earth or the Orion crew.

petitSat - A 6U CubeSat to examine ionospheric plasma density irregularities

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The mid- and low-latitude ionosphere is home to a variety of plasma density irregularities, including depletions (bubbles), enhancements (blobs), and small-scale scintillation, which result in the distortion of radio wave propagation. Recent observations from the C/NOFS satellite suggest that multiple mechanisms are responsible for forming plasma density enhancements, with wave action in the thermosphere as a significant driver of the enhanced densities. Indeed, statistical analysis of enhancements observed from satellites resembles the statistics of Medium-Scale Traveling Ionosphere Disturbances (MSTIDs) with respect to seasonal variability and solar activity. In order to investigate the link between these two phenomena, both in-situ data of the plasma enhancement and remote data of the MSTID at the magnetic footpoint are required. petitSat is a CubeSat mission designed to provide in situ measurements of the plasma density, 3D ion drift, as well as ion and neutral composition. The instrument suite includes a combined retarding potential analyzer and cross-track drift meter and a neutral mass spectrometer. This instrument suite will provide comprehensive information about the fluctuations in plasma, as well as changes in the neutral profile. petitSat will launch into a 51 deg inclination orbit at 400 km (consistent with an International Space Station deployment), allowing for numerous conjunctions with the Boston University All-Sky Imager network and GPS receivers from the International Global Navigation Satellite Systems (GNSS) Service (IGS) network over the mission lifetime.

ENERGETIC ELECTRON PRECIPITATION RESEARCH WITH NANOSATELLITES OF MOSCOW UNIVERSITY

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Small satellites are very useful for studying different kinds of physical phenomena, which can affect dangerously on spacecraft components and biological objects. Magnetosphere electrons flux dynamics is a very important factor of natural hazards in the near-Earth space. These phenomena will be observed during the space experiment with number of instruments on board nanosatellites of CubeSat form-factor elaborated Lomonosov Moscow State University. These satellites should be launched onto the solar-synchronous orbits with relatively low altitude (500…800 km) that provides the favourable conditions for the study of space radiation in different areas of the near-Erath space including trapped radiation, as well as electron precipitation from the Earth radiation belts.

The scientific concept and mission setup of the CubeSat-based experiment for medium-term and long-term dynamics monitoring of the high-energy charged particle fluxes spatial distribution in large areas of the Earth radiation belts for space weather forecast will be presented. This includes, among others, the estimation of the general scientific concept of small-sat experiment, the determination of optimal orbits and orientations of spacecraft, the verification of technical requirements and specifications for measuring instruments (spectrometers of energetic protons and electrons), requirements for satellite platform and its components, ground segment, general mathematical modeling of the mission.

The Climatology of Anthropogenic and Natural VLF wave Activity in Space (CANVAS) CubeSat mission

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Powerful Very-low-frequency (VLF) waves are radiated from the Earth's surface by lightning and ground-based transmitters. A significant fraction of the radiated wave power propagates through the ionosphere and into the inner magnetosphere, where it provides a source of energy to the plasmasphere and to radiation belt electrons. Past work has sought to quantify the scattering of radiation belt electrons by lightning-generated whistler waves, and the impact these waves on radiation belt precipitation. More recently, it has been suggested that ground-based VLF transmitters may have a significant role in scattering ultra-relativistic radiation belt electrons into the loss cone, thus constituting an anthropogenic mechanism of radiation belt modification. However, quantification of the effect of these waves on radiation belt populations requires an accurate quantitative assessment of the population of these waves.

The CANVAS mission is a 3U CubeSat designed to measure the climatology and wave properties of whistlers injected into space by both lightning and VLF transmitters. The spacecraft will measure three components of the wave magnetic field and two components of the wave electric field between ~1 kHz and 40 kHz. With five wave components we can determine wave properties including the Poynting flux and wave normal angles, which will inform the ultimate destination of these waves in the inner magnetosphere. The magnetic field components will be measured by a three-axis search coil (TASC) deployed on a 1-meter carbon-fiber boom. The electric field components will be measured by deployed dipole antennas ~70 cm in length. Accurate position and attitude knowledge, provided by the Blue Canyon Technologies XACT system, will enable assessment of the local B-field direction and thus wave normal angles. In this talk we will provide an overview of the science and mission goals, the science instruments, the spacecraft and subsystems design, and the mission design and concept of operations.

Low energy transfer to earth-moon DRO via Lunar Gravity Assists

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This paper discusses an approach to design transfer trajectories to a lunar distant retrograde orbit (DRO) from a low-altitude Earth parking orbit by using one lunar gravity assist or two lunar gravity assists. The spacecraft is placed on the Earth-Moon free return orbit by the first impulse, which is assumed parallel to the velocity of the parking orbit. Later, the second impulse, which is again parallel to the velocity of the spacecraft, enable the spacecraft to arrive at perilune. Thus, the third impulse applied at the perilune achieves a powered lunar gravity assist and promotes the spacecraft to fly to the lunar DRO. Finally, the spacecraft enters DRO by the last impulse whose direction is not restricted. However, the lunar gravity assist associated with the third impulse can place the spacecraft into a transfer orbit having the apogee distance more than two Earth–Moon distances. In this case, it is possible that the small third impulse, combined with the perturbation of the Sun, result the spacecraft to approach the Moon again from the exterior. So that the second lunar gravity assist is possible, which is also achieved by one impulse, and take the spacecraft enters DRO by another impulse. The total delta-v and flight time required to transfer from LEO to various phase points in a certain DRO was examined in both cases. The results showed that certain regions where the delta-v is low exists; and the flight time varies considerably depending on the targeted DRO phase point and the aforementioned two case. The transfer orbit using two lunar gravities needs lower cost (the total delta-v is less than 100m/s except the first impulse) but longer time. An applicable launch window with these features was proposed, which showed the potential to widen the option to transfer to a DRO.

Interplanetary by INPPS flagship and orbiting satellite.

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The International Nuclear Power and Propulsion System (INPPS) flagship for Mars and Europa flights will be introduced from space system and sub-system point of views. It will be described the INPPS flagship orbiting satellite, which will fulfill UN regulations for nuclear power sources (NPS) in space. Insofar the orbiting small satellite will be equipped with MEDIPIX / TIMEPIX detectors to measure in real time particle radiation. Moreover the orbiting satellite delivers real time video from INPPS flagship during interplanetary cruise and may be equipped with scientific payload as well.

MarCO: Trailblazing Interplanetary Small Science

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Launched May 5th, 2018, the MarCO spacecraft have demonstrated that small spacecraft (even CubeSats) can viably operate in the deep space environment. After successful reception of telemetry and achieving commandability, both spacecraft transitioned to nominal mode to begin checkout operations. Subsequent passes demonstrated 62.5 - 16000 bps one-way and two-way communications, ranging, Delta-DOR tracking, and multiple spacecraft per aperture operations with the DSN. All four antennas (UHF, low gain, medium gain, and high gain) performed well and were characterized in flight. The spacecraft successfully performed multiple trajectory correction maneuvers to achieve its flyby of Mars, and autonomously oriented itself for imaging, solar-radiation-pressure reduction, and charging.

On November 26, 2018, the MarCO spacecraft successfully flew by Mars while relaying entry-descent-and-landing telemetry for the InSight vehicle. Both spacecraft performed beyond expectations and were able to provide a real-time link for the so-called "seven minutes of terror". In addition, once InSight safely landed, it transmitted its first image of the Martian surface through MarCO. Over the following weeks, images of Mars and Phobos, performance and health information of the spacecraft, and historical data were all downlinked.

Many lessons have been derived from the MarCO mission and the operation of the first two CubeSats to leave Earth orbit. From planetary protection to low cost ops, MarCO is trailblazing a new generation of explorers.

JUPITER EXPLORATION MISSION CONCEPT : REMOTE SENSING STUDIES OF THE PLANET

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This work proposes mission to Jupiter and its moons. The primary mission will consist of a spacecraft that will deploy a small-satellite and a CubeSat constellation that shall explore the gas giant planet and its moons for its atmospheric composition and surface mapping. Trade studies on the payload shall be done. Optimal mission trajectory shall be designed from launch to orbital insertion of the satellite. Through this mission, our knowledge and understanding of the planet and the formation of Jupiter's moons will be increased. Before the end of life of each CubeSat, it shall be de-orbited into the atmosphere of Jupiter at a specifically selected site of interest and relay images and other data of the atmosphere. The same process shall be carried out with all the other CubeSat in the same location after a gap of several weeks so as to achieve the data of the same location with a certain interval of time and come up with geodetic framework. This shall help us compare and analyze the previous data. With the help of the CubeSat constellation, a geodetic framework can be made and various process and phenomena can be monitored. This paper will cover all areas of exploration mission design.Efforts are being made to reduce the mission costs and if implemented, it shall yield positive results and expand our understanding of the solar system and formation of the multi-moon system.

Mini Array satellites to reach and explore and harbor nearby trough going icy asteroid

Daniele Fargion, Daniele Fargion

Background: Mini Array satellites could be able to reach and explore near by icy asteroid while being in orbiting and in soft landing on ice surface, testing the
composition , its depth, tunneling under ice for biological test and potential bio-candidature ecosystem. Landing on near objects as incoming icy asteroid might be
a pioneering way to harbor living platform, comunication systems; if the test landing are succesfull they may offer the future human stations in space. Mini nano array of satellites might probe the ice nature, its depth size, the asteroid solidity by sonar and electromagnetic test. Results: The very small asteroid gravity may allow to land mini satellites ball-like by their slow rolling and by external spherical elestic material. The tagged asteroid migh be in future digged and exploted by larger size array satellites able (by nuclear engine power) to form inner and larger tunnel to protect (from cosmic rays): bio-sample, vegetal and even and animal ecosystem.
Human might better land, survive and live using icy asteroids as intermediate space stations. The ability to dig and expell by nuclear tractor engines, by coordinate array jets the external icy skin water (as a propeller) may be the way to deflect and drive in space the same visiting asteroid trajectory. Conclusion: Mini satellite landing on near object asteroid of icy nature may be the first step to a safe space station chain, able to harbor life as well as to become the future space ship for human planetray flight.

NEOShare: A Smallsat Mission to Explore the Diversity of Near-Earth Asteroids

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Presently, 20,000 near-Earth objects (NEOs) have known orbital characteristics. About 10% are characterized as Potentially Hazardous Objects (PHOs) that approach within about 20 Earth-Moon distances. Some of these NEOs have undergone additional characterization (*e.g.*,colors, spectra), a small number have had their shapes and other properties determined by Goldstone and Arecibo radar, and five have been visited by robotic missions (Eros, Itokawa, Toutatis, Ryugu, Bennu). Given the broad range of known sizes and colors/spectra (and thus compositions) as well as inferred densities, porosities, binarity, family membership, and hazard potential, there is clearly a need for additional up-close study of the diversity of this population. Indeed, the need to more fully characterize this diversity was part of the justification for listing NEO missions as of high interest in the currently-active NASA Planetary Decadal Survey.

To that end, the MILO Space Science Institute, a non-profit deep space mission collaboration between Arizona State University, Lockheed Martin, and GEOShare, is planning a mission called NEOShare. This mission would launch (in 2023) a cluster of six smallsats that would each perform a close flyby of a different NEO relatively close to Earth. Each smallsat would be equipped with cameras, spectrometers, and potentially other high-heritage instrumentation. Because some of the smallsats can be directed to flyby multiple objects, we plan to characterize at least eight new NEOs during the mission. NEOShare will be conducted by a consortium of U.S. and international universities and space agencies that join the MILO Institute`s membership-based model for deep space exploration.

Samara University Scientific-Educational Nanosatellite Program to study high atmosphere

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Creation of nanosatellites is the dominant trend in the development of space education, science and technology at the present time. Since 2014, the Samara University (SU) has been developing the scientific and educational aerodynamically stabilized nanosatellites (ASNS), which can be used in different proposes, in particular to study the upper atmosphere and ionosphere. The emergence of nanosatellites (CubeSats) requires revision of the fundamentals of their dynamics and motion control and construction principals. The latter depend on a number of features resulting from the totality of such factors as geometric dimensions, parallelepiped shape factor, mass and inertial characteristics, putting into orbit (low orbits with the dominating influence of aerodynamic forces), the conditions for launching into orbit as secondary payloads on launch vehicles (large angular velocities after CubeSats leave their launch containers). In the frame of SU Scientific-Educational Nanosatellite Program the first nanosatellite SamSat-218D was designed to hold the technology demonstration of the ASNS with a large static stability margin. The second nanosatellite SamSat-QB50 had transformable construction for creation aerodynamical stabilization after launching and was designed like a part of the international project QB50 to study the Earth's troposphere.At the initiative of the Samara University, a consortium to create a group of nanosatellites to study the ionosphere was established in 2018. The consortium joins nine Russian universities and two academic institutions. Currently, Samara University is creating a nanosatellite SamSat-ION as an element of the future grouping.

This work was supported by the Russian Science Foundation, project no. 17-79-20215

SPACE HAUC: An undergraduate CubeSat mission to demonstrate high bandwidth communication using a X-Band phased-array system

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We describe SPACE HAUC (Science Program Around Communication Engineering with High Achieving Undergraduate Cadres), a 3U CubeSat project selected by NASA for flight in 2020. It is part of the NASA Undergraduate Student Instrumentation Program (USIP), that is designed to provide hands-on training in spaceflight missions to multidisciplinary teams of undergraduate students with a goal of developing future space explorers.

SPACE HAUC will demonstrate high rate data transmission (up to 100 Mbps) which is essential for imaging applications that dominate nanosatellite missions. It operates in the X-band (7.2 - 8.3 GHz) and uses a 16 element (4 X 4) patch antenna array. The phased array will create a 25°(FWHM) beam and will also demonstrate beam steering over ± 45°with less than 5°error.

The X-Band communication system consists of Commercial off-the-self (COTS) transceiver and student-designed patch antennae array, RF Front-end for signal processing and a beam steering system. The entire communication module occupies a 1.5U volume and weight less than 1 Kg. Its transmitter and receiver consume approximately 9W power each; its radiated power is 1.6 W with a receiver sensitivity of -115 dBm.

If successful, SPACE HAUC will introduce an important new tool to the CubeSat community developed by undergraduate students.

Scientific and educational satellites SiriusSat in the CubeSat 1U format

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Two scientific and educational satellites SiriusSat-1 and SiriusSat-2, made in the CubeSat 1U format were launched 15.08,2018 from the ISS. Satellite manufacturing started in July 2017 during the project session in the educational camp Sirius (Sochi, Russia) with the participation of talented schoolchildren. Technical support of the project is provided by the Institute of Nuclear Physics of the Moscow State University (development of the payload, setting scientific tasks) and the Russian company Sputniks (development and manufacturing of the platform). The SiriusSat satellite payload is a detector of charged particles and gamma radiation in the energy release range 0.3 - 3 MeV. The satellites were launched into an orbit with inclination of 52°. The main scientific goals are the study of fast variations of electron fluxes in the slot between the radiation belts as well as the study of the dynamics of particle and gamma-ray fluxes at very low orbits in dependence on geomagnetic conditions. The transmitter at a frequency of ~ 435 MHz is used. The daily data amount is ~ 200 kB. To solve scientific problems, both monitoring data (count rates of particles every second) and detailed data on all interactions in the detector with a time resolution of 20 μs are transmitted, accumulated in the payload memory by a command that determines the time interesting to the researcher. The data are stored on SINP MSU server. They are available via web interface for students for the educational practice in space data analysis and for the scientific research

METASAT: AN OPEN METADATA SCHEMA FOR CUBESAT MISSIONS/h3

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The variety of small satellite missions range from high school science programs [1] to support for interplanetary communication [2] and the ways people document their missions are as diverse as the missions themselves. MetaSat, an open metadata schema in development, will function as a common way of describing hardware, software, and data specifications across missions to improve interoperability between them. This new digital infrastructure will allow ground station networks to better support the plethora of missions to be launched in coming years, 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. The MetaSat team will also be refining their design by piloting an implementation of the schema on an open network of ground stations called SatNOGS [3] and installing ground stations at public libraries across the globe. Feedback from people in those library communities will supplement input from experts to help lower the barrier for entry to using the schema and SatNOGS tools for satellite operations.

This project has been made possible through funding from the Alfred P. Sloan Foundation and its success ultimately relies on the MetaSat team's ability to develop a schema that meets the small satellite community's needs.

[1] https://www.media.mit.edu/projects/cubesat/overview/

[2] https://www.jpl.nasa.gov/cubesat/missions/marco.php

[3] https://satnogs.org/

Space Weather Research Support at the National Science Foundation

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The National Science Foundation (NSF) is the only United States federal agency whose mission includes support for all fields of fundamental science and engineering, except for medical sciences. The Space Weather Research program at NSF is engaged in supporting advances and discoveries in geospace sciences. It does so by funding stimulating research in the development of integrative geospace system models, CubeSat-based science missions, extended network of observing capabilities, and targeted education and outreach activities. The program's overarching goal is to support fundamental research to meet societal needs for improved monitoring and prediction of space weather in support of the Nation's effort to develop effective preparedness strategies for space weather events. This presentation will provide an overview of current and planned programs pertaining to space weather research at NSF.

From a rocket experiment to a CubeSat constellation: A joint venture of scientists and university students building a remote sensing instrument for atmospheric research

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The starting point of this project was the vision to obtain previously unattainable data for atmospheric research using spatially distributed remote sensing instrumentation in space. Spatial Heterodyne Spectroscopy (SHS) is a promising technology to realize optical instrumentation at micro satellite scale. Starting with a handful of Bachelor, Master and PhD students, in less than 2 years, a prototype instrument was designed, built and first tested as part of a Rocket Experiment for University Students (REXUS) campaign. Within only a few seconds in space, the basic functionality of the instrument could be shown. The instrument concept raised considerable interest in the scientific community and the team was invited to fly the spectrometer on a Chinese technology demonstration satellite. With largely new students and within less than 10 months, a satellite payload with an improved version of the initial instrument was set-up. A particular challenge were cultural and language differences between the European payload- and the Chinese satellite-team, which was handled by the students. The in-orbit demonstration was successful and only a few months later, the team was asked to fly the instrument on two more missions. These missions will bring together students from Germany, USA, India, Singapore, and further countries. In between these missions, the instrument and related processes are continuously improved. Finally, it will be only a small step toward a micro-satellite constellation. The general approach of this development is typical for ‘New Space’ and gives students, particularly when combined with high vertical integration, fantastic holistic insights into space projects.

Multispectral Arrays UV - LWIR

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Multispectral arrays have long been a key contributor to earth observation and remote sensing satellites Helping to reduce SWAP, increase resolution and overall performance. Previously much of the focus here was in the VIS & NIR wavelength regions. Leaving UV, SWIR, MWIR & LWIR wavelength to require discrete filtering. With superior capabilities across all wavelengths in design, deposition, sizing, assembly, LAS, ghosting, R%, stray light management, and channel to channel cross talk. Materion can offer MS arrays with superior performance from UV (as low as 220nm) through the LWIR (as high as 15.8um). This paper intends to summarize these capabilities and present the expanding demand for this technology.

Using SWARM satellite mission to study the effects of large tropical cyclones on the ionosphere

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Now it is known that the power phenomena occurring in the system of the geospheres can influence on the Earth`s ionosphere. In our work, the largest (more 4th category on the Saffir – Simpson scale, total - 19 cases) tropical cyclons (TC) with warm core in 2014 were considered.

We create original methods for analyzing SWARM plasma electron density data. The essence of the first method is to consider the ionospheric response corresponding to the characteristic wave disturbances in the atmosphere associated with the TCs. The second approach uses the capabilities of the positioning system of the SWARM satellites for estimation of the electron density spatial derivatives.

Some results. Our consideration has shown that in the periods of development of powerful TCs, various manifestations of atmospheric-ionospheric connections are observed (total statistics - above 100 cases). First, we recorded wave-like oscillations of the electron density in the frequency band of 10...200s with localization and characteristic of AGW - see fig.1. The relative magnitude of the disturbance reaches to 10% in the selected frequency band. Second, in some cases, we identify areas that can be explained by electric field perturbation transfer to ionosphere.

Conclusions**.** Our results can be considered as illustration of the complex system of transmitting disturbances of different scales from the lower atmosphere to ionospheric heights. Highly likely, this mechanisms are more complicated.

The study was done in the framework of the state scientific task of MSU and SRI RAS and partial supported by the RFBR projects 19-05-00941 and 18-05-00108.

ONEWEB SATELLITES; REVOLUTIONIZING THE ECONOMICS OF SPACE THROUGH INDUSTRIALIZATION

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The commercial "New Space" revolution has fueled the creation of an industry poised to enable applications never before imagined. Recent developments in small satellite technologies and modeling techniques are enabling a new class of cost effective, space-based capability. When combined with principles of mass production, these developments offer the ability to explore the Earth and the solar system around us in ways not achievable by large satellites.

Successful implementation of small satellite mass production is not as simple as an assembly line of workers installing standardized products. While high-volume production might offer the ability to create low-cost vehicles; design flaws, lack of quality control, and loss of configuration management become catastrophic when cascaded across the development of a constellation. OneWeb Satellites, Inc. (OWS) is the first serial producer of satellites revolutionizing the industry through high quality, cost predictable, rapidly developed small satellite platforms.

The Southwest Research Institute® (SwRI) is one of the oldest and largest independent, nonprofit, applied research and development organizations in the United States. With its world renowned commitment to space-based science over the past four decades, SwRI recognized early the impact of small satellites on space-based science. This commitment was most recently demonstrated by its CYGNSS constellation. To bring the full impact of the New Space revolution to space-based science, SwRI has joined forces with OWS. This alliance enables prototype small satellite missions that can be transitioned to operational constellations. We discuss how this is achieved in our COSPAR 2019 presentation.

AMICal Sat, ATISE and WFAI: three space instruments for auroral monitoring

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A lack of observable quantities renders it generally difficult to confront models of Space Weather with experimental data and drastically reduces the forecast accuracy. This is especially true for the region of Earth's atmosphere between altitudes of 90 km and 300 km, which is practically inaccessible, except by means of remote sensing techniques. This paper describes two space missions, AMICal Sat and ATISE. These satellites will perform measurements of auroral emissions in order to reconstruct the deposition of particle precipitations in auroral regions. ATISE is a 12U CubeSat with a spectrometer and imager payloads. The spectrometer is built using the micro-Spectrometer-On-a-Chip (µSPOC) technology. It will work in the 370–900 nm wavelength range and allow for short exposure times of around 1 s. The spectrometer will have six lines of sight. The joint imager is a miniaturized wide-field imager. Observation will be done at the limb and will enable reconstruction of the vertical profile of the auroral emissions. AMICal Sat is a 2U CubeSat that will embed the imager of ATISE and will observe the aurora both in limb and nadir configurations. As a follow up, we also develop an hyperspaectral instrument for the ESA D3S mission named Wide Field Auroral Imager. AMICal Sat launch is schedule for July 2019 and we hope to be able to present the first results of these measurements. ATISE will be launch in 2021.

Data interpretation will be done using the forward Transsolo code, a 1D kinetic code solving the Boltzmann equation along a local vertical and enabling simulation of the thermospheric and ionospheric emissions using precipitation data as input.

Research On Ionospheric Optical Remote Sensing Detection Technology Based On Micro-nano Satellite

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The ionosphere is closely related to human activities. Satellite communications, GPS positioning and navigation, and SAR imaging detection require for the fine detection of total ionospheric electron content (TEC) and F2 layer peak electron (NmF2).

There are two development trends in ionospheric optical remote sensing. First, large imaging spectrometer for multi-band and large field of view detection to obtain sufficient ionospheric information is developed; Second, miniaturized photometer design for ionospheric photometer is also developed. In terms of miniaturization, the ionospheric TEC and F2 layer peak electron density can be directly obtained by using an ionospheric photometer which detects the ionospheric nighttime OI135.6nm airglow intensity.An ionospheric photometer (IPM) carried aboard the FY3-D satellite which launched on November 11, 2017 has successfully obtained the fine structure changes and small changes in the ionosphere.Also, the high-sensitivity detection advantage of the IPM was fully realized.

In recent years, micro-nano satellite technology has developed rapidly, and there are already mature and stable optical micro-nano satellite platforms available. Micro-nano satellites are light in weight, small in size, low in cost, short in development cycle, high in functional density, fast and flexible. And multiple micro-nano satellites can be used to form a constellation or formation flight.

This report will introduce the design of the ionospheric optical remote sensing payload carried on the micro-nano satellite. Combined with the characteristics of the micro-nano satellite such as "small /fast/flexible", easy formation or networking, the revisit period of the ionospheric environment detection can be greatly shortened while obtaining high-sensitivity ionospheric detection results. In addition, combined detection of micro-nano photometers in different observation bands can achieve all weather observation capability of the ionospheric environment.

AERO & VISTA: Demonstrating HF Radio Interferometry with Vector Sensors

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The Auroral Emission Radio Observer (AERO) and Vector Interferometry Space Technology using AERO (VISTA) are twin 3U CubeSats, funded by NASA's H-TIDeS program, that will study radio emissions of Earth's aurora from a polar low earth orbit. Each CubeSat carries a radio science payload featuring a deployable vector sensor antenna that measures the electric and magnetic field in each of three orthogonal directions. The six electromagnetic field values are processed to estimate the angle of arrival and polarization of incoming signals from 100 kHz to 15 MHz to better than 10 degrees. This localization capability will enable AERO and VISTA to answer fundamental questions about the nature of auroral energy production and dissipation through refinement of source spatial distribution and physical mechanisms for auroral kilometric radiation (AKR), mid frequency bursts (MFB), and auroral roar and hiss phenomena.

Together, AERO and VISTA will also demonstrate low frequency interferometry to further improve radio localization ability by a factor of 10. A key goal is to validate theoretical modeling that shows interferometric arrays composed of vector sensors will be able to maintain sensitivity even in the presence of terrestrial interference. This capability would relax the requirement that space-based low frequency interferometers be placed far from the Earth in GEO or lunar orbits, significantly increasing the data volume returned from such a telescope. The interferometry demonstration, to be performed at 10-20 km separation between the spacecraft, requires high fidelity knowledge of relative position and timing, and will use differential drag to control spacecraft separation.

The enhanced Ion and Neutral Mass Spectrometer for the PetitSat CubeSat mission

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There is great need for in situ measurements of atmospheric ion and neutral composition and density due to a dearth of measurements since the DE satellite mission ~30 years ago. The Ion and Neutral Mass Spectrometer (INMS) seeks to fill this void while achieving several measurement firsts and enabling new scientific studies, including constellation missions. INMS is a tiny, versatile time of flight spectrometer that measures atmospheric composition within a 1.1 U volume, approximately 0.5 kg and 1.8 W nominal power. INMS is based on front-end optics including thermionic emission ionization, pre-acceleration, gated time of flight (TOF), electrostatic analyzer (ESA) and channel electron multiplier (CEM) detectors. The compact sensor has a dual symmetric configuration with sensor heads on opposite sides of shared electronics. INMS measures in situ ions and neutrals (H, He, N, O, N2, O2) with M/dM of approximately 12 and has been successfully demonstrated in space as part of the ExoCube and Dellingr CubeSat missions. An upgraded version of the instrument has been delivered for flight on the ExoCube2 mission in late 2019 and an instrument with two redundant neutral apertures will be flown on the PetitSat mission in 2020. This presentation will provide a description of the INMS design, including upgrades for upcoming missions.

A microsatellite for solar wind monitoring

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Solar wind monitoring at the upstream L1 location is an essential part of the space weather observation system. Such modern spacecraft are relatively large and carry diverse science instruments. We suggest the concept of the microsatellite-scale monitor, having onboard only the essential instrument set. Such a spacecraft may solve a task of multipoint measurement in order to capture slanted or spatially localized structures. We discuss an optimal instrument set, radio-communication and attitude control systems as well as economical ways of launch and transfer trajectory.

ICEYE's MICRO-SATELLITE SAR CONSTELLATION: NEAR-REAL TIME SATELLITE DATA FOR EARTH OBSERVATION

Penelope Kourkouli, Pekka Laurila, Rafal Modrzewski
-, *ICEYE Ltd, Espoo, Finland*

Small satellites have paved the ground for new opportunities aiming to understand the Earth's surface processes and bring new services to EO community. The first wave of new, smaller EO satellites were built by private sector to enable real-time imaging with optical instruments; however, microwave remote sensing has been following rapidly the same development. New instruments provide already significantly improved monitoring capability, as microwave data can be acquired in nearly all weather, lighting and seasonal conditions, including during polar night and constant cloud cover.

In the beginning of 2018, the Finnish Earth Observation company ICEYE demonstrated feasibility of the first commercial SAR micro-satellite, ICEYE-X1, with successful stripmap-imaging results. In December 2018, the second satellite ICEYE-X2 was launched successfully, imaging with a resolution of 3x3 meters.

Over the next 3 years, ICEYE's goal is to build the world's first and largest commercial constellation of SAR micro-satellites, i.e. 18 SAR micro-satellites by the end of 2020, providing access to timely and reliable radar images up to tens of accesses per day at any location on Earth. High temporal resolution data will assist on Earth's real-time monitoring, introduce novel approaches and services, and complementing the already existing well-established methods.

Here, we show the potential of imagery acquired by the ICEYE-X1 & X2 sensors in several EO application scenarios, focusing on change detection methodologies. We concentrate on several potential applications such as urban, agricultural, hazards, forest monitoring, and vessel tracking.

Novel technological advances in the form of near-real-time data provided by ICEYE's future constellations will lead to possibility of continuous high-revisit monitoring for wide areas and hence support decision-makers to plan and respond faster.

RainCube: Radar Weather Observations from a Sustainable, Small Satellite Platform

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RainCube (Radar in a CubeSat) is a technology demonstration mission to enable Ka-band precipitation radar technologies on a low-cost, quick-turnaround platform. The RainCube 6U CubeSat features two new technologies: the miniaturized Ka-band atmospheric radar (miniKaAR) and the half-meter Ka-band deployable parabolic antenna (KaPDA), and it is the first precipitation radar designed to fit within a CubeSat volume. Shortly after one month of operations, RainCube commissioned the spacecraft and radar, deployed the radar antenna, and collected the first observation of rainfall. RainCube has completed its baseline mission in demonstrating on-orbit a precipitation radar on a 6U CubeSat, and RainCube has successfully demonstrated the first radar instrument on a CubeSat platform. RainCube is currently in extended operations.

This paper will focus on the RainCube on-orbit observations and the demonstrated capability of the new radar technologies. The paper will also address the implications for future Earth Science missions, including a sustainable approach for weather satellite constellations to provide a new paradigm in observing temporal variations of weather systems.

CloudCT: Spaceborne scattering tomography by a large formation of small satellites for improving climate predictions

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The response of small convective clouds to changes of environmental conditions is a major source of uncertainty in climate predictions. Current satellites yield retrievals of cloud-tops via coarse 2D data, and cloud microphysics based on a 1D radiative model. This is incompatible with the 3D heterogeneous nature of small clouds. Observing and quantifying the microphysics of small clouds require a tomographic setup and a volumetric retrieval model based on 3D radiative transfer. Observations should be both multi-angular and simultaneous, because these clouds have a few minutes lifetime, and their morphology changes during advection. This joint requirement is inconsistent with common observational satellites, which are bulky, expensive and have a solitude viewpoint at any time. To meet the needs, we report on a new spaceborne mission, `CloudCT` funded by the European Research Council (ERC). The enabling technology for a tomography setup is state-of-the-art nanosatellites. CloudCT will comprise a formation of 10 nanosatellites tailored for the mission. Carrying multi-band cameras, they will coordinate to image cloud fields simultaneously from multiple directions. The satellite formation will autonomously self-organize its topology for best data acquisition and use advanced pointing to aim at the same clouds. The formation is planned to launch and start data collection in 2022. The data will be used for 3D scattering tomography, which we devise. We present initial simulations of cloud tomography, based on initial specifications of an orbit, formation, platforms and cameras.

SmallSat Constellations for Earth Science – it's about Timing

Anthony Freeman

Constellations of SmallSats or CubeSats open up the fourth dimension – time – for scientists to remotely measure quantities of interest from space. As a striking (and ground-breaking) example, NASA's CyGNSS 'string of pearls' constellation, led by University of Michigan PI Chris Ruf, tracks the variations in surface winds under tropical cyclones over short timescales. Similar concepts under development by NASA include TEMPEST (U. CO/JPL) which targets the time evolution of clouds, and TROPICS (MIT/LL), for time-resolved observations of precipitation structure and storm intensity. All three address the time-derivative of quantities of interest to Earth System scientists.

The National Academy's 2017 Decadal Survey for NASA Earth Science calls for high temporal revisit frequency to address several challenges. Planet's commercial satellite constellation is out in front, providing daily, global high-spatial resolution maps for a few spectral bands in the Visible and Near-IR, which scientists have begun to make use of. The author has conceived of an S-Band SmallSat SAR constellation to satisfy NASA's need for rapid revisit surface deformation measurements. Others are studying SmallSat constellations to monitor volcanic hotspots using Thermal IR bands, 3-D Winds in the atmosphere, and variations in the Earth's gravity field at higher temporal resolution than NASA/DLR's GRACE missions.

The common thread for each of these SmallSat constellations is the importance of time sensitivity. Scientists may be willing to sacrifice spatial resolution, spatial coverage, and radiometric sensitivity for temporal resolution. The implication is that SmallSat and CubeSat instruments without large apertures can provide scientifically compelling measurements. SmallSat developers should therefore be encouraged to pursue methods to improve time sensitivity, resolution and even latency – for example through compact GPS, chip-scale clocks, retroreflectors, VLBI or other methods for precision orbit determination, and linking up with ComSat networks such as Oneweb, GlobalStar and Iridium to get data down quickly.

SMALL SATELLITES FOR SUSTAINABLE SCIENCE AND DEVELOPMENT IN AFRICA; POLICY PERSPECTIVES

Peter Ekweozoh, Anietie Ekanem
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Policy inconsistency coupled with gross policy implementation challenges constitute a brick wall to Africa's progress in achieving sustainable and development through adoption of Small Satellites programme. This hydra-headed monster explains the inability of Africa to innovate and utilize her best skills in competing for much desired niche in the ever changing global cutting-edge science and technology space. Africa is highly blessed with vibrant youthful population and mineral resources that require innovation and cutting-edge technological tools and processes to expand value-chain deliverables in human skills and material resources. Africa as a developing continent has a significant socio-economic growth potential compared to developed regions of the world. The growth potential can be sustained through policy formulation and institutional reforms that will support the adoption of small satellite programmes, that will provide an ideal platform for the development of a knowledge based-economy. However, reforms in institutions and policy formulation must be contextualized, the research paper seeks to address the policy inconsistency and factors that affects the implementation of existing policies. The study will proffer solutions to the policy inconsistency and also come up with recommendations by which existing policies can be implemented to promote human capital development and the managing of Africa's natural resources in a sustainable manner through the adoption of small satellite programmes. The research will address the policy inconsistency through critical analysis to see whether the current policy direction, planning, prioritization, budgeting, implementation and monitoring processes are consistent with national development outcomes.

Small Ultraviolet Payloads for Astronomy

, Jayant Murthy
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Although ultraviolet astronomy was the first major astronomy program from space, there are still many problems that are available to small satellites, for the same reasons as the earlier payloads. The sky is dark in the ultraviolet with few competing sources and we can reach down to the darkest regions of the sky with small payloads. I will describe our program at IIA in building small payloads whcih are intended for space flight. I will also describe our spectrograph which was selected for flight on the Chinese Space Station.

Lunar exploration with cubesats: the challenges and the rewards

Ana Gomez De Castro
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There is a growing interest in Lunar exploration fed by the perception that the Moon can be made accessible to low-cost missions in the next decade. The on-going projects to set a communications relay in Lunar orbit, the deep space Gateway proposal, as well as the spreading of commercial-of-the shelf (COTS) technology for small space platforms such as the cubesats contribute to this perception. Small, cubesat size satellites orbiting the Moon offer ample opportunities to study the Moon and enjoy an advantage point to monitor the Solar System and the large scale interaction between the Earth and the Solar wind. A review of teh current status on Lunar cubesat research will be presented, including the Earth ASAP proposal designed to monitor hydrated rock reservoirs in the Lunar poles and to study the interaction between the large Earth`s exosphere and the solar wind in preparation for future exoplanetary missions.

An Energetic Particle Monitor for Ice Giant Atmospheric Probes

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The Voyager 2 flybys of Uranus and Neptune provided limited measurements of energetic particles in the magnetospheres of the planets. The energetic particle instrument onboard the spacecraft detected significant fluxes of energetic electrons and protons in the regions of their magnetosphere where these particles could be stably trapped. We will review these observations and discuss the need for a more detailed modeling of the energetic particle environment of these two planets in the context of their future exploration.

An Ice Giant Atmospheric Probe will provide a unique platform in order to measure energetic particles in the innermost regions of the magnetospheres of Uranus and Neptune – within a few radii of the cloud tops – and into the upper atmosphere, as was done with the Galileo Probe EPI instrument at Jupiter or during the Cassini Grand Finale at Saturn.

We will propose an instrument onboard an Ice Giant Atmospheric Probe in order to provide omnidirectional as well as sectored measurements of electrons (30 keV – 1 MeV) and ions (30 keV – 6 MeV) in the magnetospheres of Uranus and Neptune. The foreseen instrument will operate during the pre-entry phase of the Ice Giant Atmospheric Probe and provide unique measurements in order to understand the innermost magnetospheric structure, dynamics, and electrodynamical coupling between the dust, rings, moons, and atmosphere of Uranus and Neptune that can not be achieved with an orbiter.

GEO-X : GEOSPACE X-RAY IMAGER

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GEO-X (GEOspace X-ray imager) is a Japanese CubeSat project to be injected in the vicinity of the Moon. GEO-X aims X-ray imaging of the Earth’s dayside magnetospheric structures including cusps and magneto-sheaths. From past X-ray astronomy observations, charge exchange X-ray emission is observed between solar wind heavy ions (O^{7+}, N^{5+}, …) and neutrals in the Earth’s exosphere. Observational and simulation results strongly suggest that X-rays can be used for imaging of the Earth’s magnetosphere. For this purpose, a 12U CubeSat GEO-X is planned. It will carry a wide field of view X-ray imaging spectrometer composed of an ultra light-weight X-ray telescope and a high-speed Si sensor (Ezoe et al. 2018 J. Astron. Telescope Instrum., 4, 0406001). To observe the X-ray emission from the Earth’s magnetosphere, the satellite will be injected into a high Earth orbit. A launch time will be around the next solar maximum 2022-25.

NanoGam - a non-uniform voxel pattern for monitoring and localizing gamma-ray transients

Lee Yacobi, Ehud Behar, Shlomit Tarem, Roi Rahin
Physics, Technion, Haifa, Israel

Following the recent discoveries by the LIGO-VIRGO gravitational wave (GW) observatories, astronomers aim to observe the entire sky at once with increasing sensitivity. Continuous monitoring the soft gamma-ray skies is crucial in order to increase the sample of joint observations of gravitational and electromagnetic waves, for a deeper understanding of the underlying phenomena involved in the mergers of neutron stars and black holes and their associated GWs. The ability to localize those transients will accelerate their followup at longer wavebands.

In this talk we will present NanoGam – a proposed constellation of nanosatellites for monitoring the gamma-ray sky. The proposed detection unit is a three dimensional non-uniform pattern of gamma-ray-detecting-voxels based on small scintillators with SiPM light-sensors. Using small voxels maximizes the effective area projected at any point in the sky to an area equivalent to the area achieved in large detectors such as Fermi-GBM, but on a platform as small as a 3U-6U CubeSat. The non-uniform pattern utilizes the occultation between voxels to provide angular sensitivity, in order to reconstruct the transient positon.

We will show the recent advancements in designing the readout hardware to simultaneously read tens of voxels, and a preliminary voxel patterns which we simulated and tested in our lab.

ELFIN mission overview and first results.

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The Electron Loss and Fields Investigation with a Spatio-Temporal Ambiguity-Resolving option (ELFIN-STAR, or ELFIN*) mission, comprised of two 3U CubeSats, was launched in September 2018 to explore the mechanisms responsible for relativistic electron loss during magnetic storms. It is currently in commissioning phase, with all instruments and spacecraft functioning nominally as verified by data collections that will be presented in this talk. Nominal science operations is expected to commence in June 2019, and is expected to yield at least one complete scan of the radiation belt L-shells once per orbit (90 min period) from each satellite (up to four possible, limited only by downlink capability). Pitch-angle resolved energy spectra of ions and electrons between 50-5000keV are routinely measured, as well as the local magnetic field and its variations in the electromagnetic ion cyclotron (EMIC) wave frequency range (at the equator), in order to determine the role of EMIC waves in causing relativistic electron precipitation. Survey mode allows after-the-fact selection for downlink of interesting periods, based on local activity and quality of conjunctions with THEMIS and other equatorial satellites, using on quick-look data. Satellite separations enable resolution of spatial from temporal variations to determine definitively the latitudinal extent and temporal evolution of the precipitation. We describe the technical mission implementation and show how the first results guarantee a rich dataset with high scientific potential to be collected over the ~6months of remaining mission lifetime.

Flight demonstration of a mini Ion and Neutral Mass Spectrometer onboard the Exocube an Dellingr CubeSat missions.

Nikolaos Paschalidis, Sarah Jones, Marcello Rodriguez, Paulo Uribe, Tim Cameron, Dennis Chornay, Ed Sittler, Alex Glocer
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A mini time of flight Ion and Neutral Mass Spectrometer (INMS) has been developed for in situ measurements of ionospheric ion and neutral densities and composition. The INMS is designed for a mass range of ~40 amu and a mass resolution M/dM ~ 12. It occupies a small volume of 10cm x 10 cm x 11cm, weighs ~560 grams and dissipates ~1.8Wtts of peak power. The mini - INMS has flown on the NSF Exocube and on the NASA Dellingr CubeSat missions both on LEO orbits. Improved versions are scheduled to fly on other near feature missions. This presentation will report on initial flight measurements from several orbits and the challenges for delivering science data from a small instrument on small satellites. The demonstration is critical for future small satellite constellation missions.

Constellation of Satellites to study Solar Dynamics and to provide ground work in order to prevent black outs caused by Coronal Mass Ejections

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The Sun is the dynamo of the biological diversity and life on the Earth. With the increase in the technological advancement in scientific community, our reliance on the electronics devices has increased. A majority of our lives now revolves on the data provided from the Satellites around the Earth. On March 13, 1989 the entire province of Quebec, Canada suffered an electrical power blackout. Hundreds of blackouts occur in some part or the other of the World but the 1989 Quebec blackout was different, as this was caused by Coronal Mass Ejection. This paper presents a sustainable approach to study the Solar Dynamics through a constellation of CubeSats, strategically placed at L1. The CubeSat will have adaptive Machine Learning capabilities to autonomously deploy solar reflective array that would enable the satellite to reflect most of the Solar Radiation, to maintain the optimal working temperature of the electronics onboard. The mission architecture proposed through the paper has been designed to maximize the observable data from the Sun. A detailed description of the reflective array actuated from Machine Learning Algorithm will be included. Tables will also be given to depict the amount of time that will pass at each mode of launch and more importantly, some idea on the cost in terms of energy, as well as money, will be discussed within today's context. Even though the possibility of such a mission is probably non-existent for this decade, it is essential to do these exercises so that mankind's troubleshooting post Coronal Mass Ejections could be increased. In addition, this paper hopes to underline few ground work required in order to prevent the black outs caused due to CMEs on the Earth.

The SoSWEET-SOUP (SOlar, Space Weather Extreme EvenTs and Stratospheric Ozone Ultimate Profiles) Constellation Mission

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SoSWEET-SOUP is an innovative small satellites constellation which aims to measure on complementary platforms the solar influence on climate and the Earth radiation budget, with a particular focus on UV spectrum and ozone layer, which are most sensitive to solar variability. Another major scientific and operational objective is Space Weather extreme events detection in Lyman Alpha, 3 orders of magnitude more sensitive than H Alpha and with high resolution and contrast (to He II 304). Previsions are possible hours in advance (flux rope deformation).

The mission combine the scientific advantages of associating a constellation of 12 nanosatellites (20-30 kg, 12 to 24 "U") on equatorial orbits (+/- 20°) to a small polar satellite of 100-120 kg on a OneWeb Arrow like platform for an almost continuous solar viewing (including arctic and antarctic regions).

SoSWEET-SOUP model payload definition is still open but will include, on the polar satellite, SUAVE (*Solar Ultraviolet Advanced Variability Experiment*), an optimized heavy-duty thermally stable SiC telescope for FUV (Lyman-Alpha) and MUV (200–220 nm) imaging (sources of variability, extreme events), and SOLSIM (*SOLar Spectral Irradiance Monitor*), a newly designed UV double-monochromator covering 170-340 nm. Other instruments include a small coronagraph, new UVC detectors (for Herzberg continuum), ozone radiometers, Earth radiative budget, Electron-Proton detectors and vector magnetometer. Constellation satellites include: precise ozone profiles (miniGOMOS with dual Sun and stars occultations), temperature and detailed energy radiative budget monitors (miniSCARAB evolved type). Science objectives, mission profiles and payload will be presented and opportunities of missions and potential collaborations discussed.

NASA's Earth Science Technology Validation on CubeSats and its impact in building future missions

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With the advent of increased CubeSat and SmallSat constellation deployments by both Governments and Commercial entities, there is a need to assess the technology maturity and their impact on scientific research. Since 2012 the NASA Earth Science Technology Office has been running a research program focused on technology validation in space, In-Space Validation of Earth Science Technologies (InVEST). This program encourages flying new technologies and new measurement concepts on CubeSat platforms. The basic premise of the program is to validate new technologies before they are implimented on CubeSat constellations or small satellites. The technology validated under this program was instrumental in future CubeSat constellation architectures such as TROPICS and TWICE. Recently three CubeSats, under the InVEST program, were launched from International Space Station. Two of these CubeSats have started returning valuable data on hurricanes and storms. Some of the successful instruments like IceCube have produced the first ever global atmospheric cloud ice map at 883-GHz band. Similarly RainCube and TEMPEST-D are producing valuable data from near-overlapping observations of typhoons and hurricanes.
This talk will provide an overview of instruments and measurement concepts deployed on CubeSats being funded by NASA's Earth Science Technology Office and their contribution to address some of the technical challenges with future science missions.

HyTI: high spectral resolution thermal imaging from a 6U CubeSat platform

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The HyTI (Hyperspectral Thermal Imager) mission, funded by NASA’s Earth Science Technology Office InVEST (In-Space Validation of Earth Science Technologies) program, will demonstrate how high spectral and spatial long-wave infrared image data can be acquired from a 6U CubeSat platform. The mission will use a spatially modulated interferometric imaging technique to produce spectro-radiometrically calibrated image cubes, with 25 channels between 8-10.7 microns, at a ground sample distance of ~70 m. The HyTI performance model indicates narrow band NEDTs of 0.3 K. The small form factor of HyTI is made possible via the use of a no-moving-parts Fabry-Perot interferometer, and JPL’s cryogenically-cooled BIRD FPA technology. Launch is scheduled for no earlier than October 2020. The value of HyTI to Earth scientists will be demonstrated via on-board processing of the raw instrument data to generate L1 and L2 products, with a focus on rapid delivery of precision agriculture metrics.

TGF and TLE observations from Small Satellite Constellation

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Small satellites may be used effectively for Earth observations, in particular Atmosphere transient phenomena, such as Terrestrial Gamma-ray Flashes (TGFs) and Transient Luminous Events (TLEs). In the frame of Universat-SOCRAT multi-satellite project these phenomena will be observed with number of instruments on board small satellites. Full-blown constellation should be consisted from three basic small spacecraft, added by complementary satellites of Cubesat type. It is planned that one of them will be a joint development of Lomonosov Moscow State University and Aserbaijshan National Aviation Academy. The most of constellation satellites should be launched on solar-synchronous low altitude orbits (400-600 km) that provides the favourable conditions for the study of TGFs and TLEs from different areas of the Earth Atmosphere including near Equatorial and Polar regions.

Study of TGFs and TLEs still remains very important despite a lot of data obtained about such phenomena in recent time. The main reason is the absence of sufficiently complete theoretical understating of physical nature of high energy processes in the Earth atmosphere. The complex observations in different electromagnetic wave bands with good accuracy of event source localization are necessary. Just, the satellite constellation is quite appropriate for the last. Advanced instruments for observations of TGFs and TLEs will be also presented.

A GNSS PAYLOAD WITH COMMERCIAL-OFF-THE-SHELF RECEIVERS FOR CUBESAT PRECISE ORBIT DETERMINATION

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Global Navigation Satellite Systems (GNSS) have been used as a key technology for satellite orbit determination since many years ago. In view of the increasing popularity of miniaturized satellites (e.g. CubeSats), we developed a small-sized versatile GNSS payload board for orbit determination using commercial-off-the-shelf single-frequency GNSS receivers with extremely small weight, size and power consumption. The board features two separate antenna connectors and four GNSS receivers—two per antenna. This redundancy lowers the risk of total payload failure in case one receiver malfunctions.

Two prototypes of the GNSS positioning board have been successfully launched onboard the Astrocast-01 and -02 3-unit cube satellites with altitudes of 575 and 505 km, respectively. The multi-GNSS receivers are capable of tracking the GNSS satellites from four major systems, i.e., GPS, GLONASS, BeiDou and Galileo. In addition, both satellites are equipped with an array of three laser retroreflectors enabling orbit validation with satellite laser ranging (SLR).

First real-time orbit results using GPS only indicate that the receivers perform very well on both satellites. The RMS of the 1-day orbit fits is at the level of 2-5 meters after removing a few outliers despite errors caused by the ionosphere and the orbit model. In the next few months, we will compare the accuracy of the real-time orbits derived using different GNSS, download raw code and phase measurements for post-processing using the graphics linear combination (sub-meter accuracy expected) and validate the orbits with SLR. The results achieved in these experiments will be shown.

Solar Neutron and Gamma-ray Spectrrocopic Mission

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Solar neutron observations are very important on understanding of particle acceleration mechanism in the Sun. However, previous ground-based observations with large area telescope (~10 m2)at high latitude are not sensitive to solar neutrons due to attenuation in the earth atomsphere and roughly 10 detection since its discovery in 1980 (Chupp et al. 1982). From space, the SEDA-AP instrument with much smaller area (100 cm2) onboard the International Space Station (ISS) monitored solar neutrons including charged particles, and successfully detected more than 30 detection since its launch in 2009 (Muraki et al. 2014). Unfortunately the SEDA-AP operation was stopped on March 2018. To overcome situation for no mission dedicated for solar neutrons, we have designed and developed a solar neutron and gamma-ray detector for a 3U cubesat with a size of 30x10x10 cm. Actually we launched the 50-kg class ChubuSat-2 satellite for solar neutron observations on February 2016 (Yamaoka et al. 2016), and have now been modifying it to a 3U cubesat application. The solar neutron and gamma-ray detector consists of multi-layered plastic scintillator bars, and GAGG(Ce) scintillator array, and both of them are read out with silicon photo-multipliers (Si PMs). More than 600 signals from Si PMs are processed by IDEAS ASICs. In this paper, we will describe details of the detector and performance of its breadboard model (BBM).

DSL: Interferometric Imaging with Linear microsatellite Array in Lunar Orbit

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Low frequency sky map and global spectrum are basically unexplored domain. It is of significant importance to understand early universe, such as the universe Dark Ages and cosmic dawn. Many ground experiments are implemented in order to reveal the mystery of low frequency universe, but ground observations are hardly convincible because of the ionospheric blockage and man-made low frequency interferences.

A space mission is proposed by NSSC to map low frequency sky and measure global spectrum since 2014, soon later proposed to the CAS-ESA space science joint mission as Discovering the Sky at Longest wavelength (DSL). The concept is composed of a mother satellite and 8 daughter satellites forming a linear array around the lunar low orbit. Taking the advantages of Moon shielding, the space array receives only cosmic radiation from the sky without radio interferences from the Earth. Longest baseline of 100km is selected to produce low frequency sky at an angular resolution of 0.1 degree, which almost the recognized size of a point radiation sources, taking into account the scattering by the inter-galaxies medium. A pathfinder microsatellite Longjiang-2 is already in the lunar orbit piggybacking on Chinese ChangE-4 program in 21st May, 2018. Continuously spectrum from 1-30MHz is retrieved in 3 orthogonal polarizations. Further study on phase A/B is already supported by the Strategic Priority Program on Space Science, Chinese Academy of Science.

Status of the PolarLight X-ray polarimeter in space

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PolarLight is a compact X-ray polarimeter on a CubeSat, which was launched into a low-Earth orbit in October 2018. In the first three months, the detector was briefly powered on for functional test. With successful upgrades of the satellite software, which enables accurate attitude control and continuous operation of the payload, PolarLight is now in the full commissioning phase, and keeps observing scientific objects including the Crab nebula and Sco X-1. Here we will describe the status of the instrument in space and show some preliminary results. We will also show simulation designs for a thicker polarimeter that can suit a future CubeSat with higher detection efficiency.

Development of advance micropropulsion system fot cubesats and nanosats

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The use of CubeSats or nanosats is increasing in the space industry. These are inexpensive and easily disposable satellites when compared to conventional satellites. These CubeSats or nanosats can orbit in constellation formation can be used for several short-term missions like military spy applications or weather data gathering. Although they seem to be very pragmatic both technically and economically there exist a limitation of keeping them in desired orbit or movement of these Cubesats or nanosats about any of their axis. This limitation directly affects satellite productivity and capability of performing various tasks. These limits can be overcome by the implementation and development of micro-propulsion systems. The implementation and deployment of a micro-propulsion system include the fabrication of micro or nano-sized nozzles, fuel or thrust generating source and a control unit. The source for thrust can range from water to several complex fuels such as inert gases (in cold gas thrusters). A self-oxidizing fuel with low or controlled calorific value and energy output is preferred. There must be at least 3 micro-propulsion nozzles in a CubeSat or nanosat so that movement can be done about any of the 3 axes. Various parameters for different fuels are analysed in this paper like ease of storage, density of fuel to be carried, thrust per unit mass of different fuel and complexity of injection system

IONOGLOW: new insight for ionospheric detection of tsunamis by airglow camera from space

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Detection of ionospheric anomalies following the Sumatra and Tohoku earthquakes (*e.g.*, Occhipinti 2015) demonstrated that ionosphere is sensitive to tsunami propagation: oceanic vertical displacement induces internal gravity waves propagating within the neutral atmosphere and detectable in the ionosphere. Observations supported by modelling proved that ionospheric anomalies related to tsunamis are deterministic and reproducible by numerical modeling via the ocean/neutral-atmosphere/ionosphere coupling mechanism (Occhipinti et al., 2008).

During Tohoku event, in 2011, new exciting measurements were performed by airglow cameras in Hawaii: those measurements show the propagation of the internal gravity waves induced by the Tohoku tsunami in the Pacific Ocean and modifying the airglow emission at 630nm mostly located at 250 km of altitude (Makela et al., 2011; Occhipinti et al., 2011). This revolutionary imaging technique is today supported by two new observations of moderate tsunamis: Queen Charlotte, M: 7.7, 27 October, 2013, and Chile, M: 8.2, 16 September 2015 (Grawe & Makela, 2015, 2017).

The potential idea to put an airglow camera on a satellite opens new exciting perspectives for tsunami detection. In this talk we present all this new tsunami observations by airglow camera, and we explore and detail the new perspective, and the technical and the physical constrains, to use an on-boarded airglow camera. We explored the orbit possibilities, as well as the effect of magnetic field and the propagation geometry, and the quantification of the observable airglow emission from space to maximize the observation of the tsunami signal by on-boarded airglow camera and to improve the oceanic monitoring and future tsunami warning system.

All ref. here @ www.ipgp.fr/~ninto

Close up imaging simulation of low-altitude ENA emission during geomagnetic substorm

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The low altitude ENA emission generated by the precipitation ions of the ring current located at magnetic latitude 50 °~60 °, 1500~3000 km altitude. Low-orbit sun-synchronous satellites are the closest spacecraft to the ENA emission sources. Utilizing sun-synchronous orbit satellite on boat of a two-dimensional neutral atom-coded aperture imager was simulated, which can realize all-weather and all-orbital conjugate continuous monitoring of low-altitude ENA radiation sources without dead angles. Simulation studies show that: (1) The low orbit the sun synchronous satellite can approach ENA emission source on both inside and outside of radiation belts, remote sensing of neutral atoms image with the temporal resolution about 5s, it helps to analyze precipitation and injection of energetic ions of the ring current, and the causal sequence with the environment field, identify if “the energetic ions come from the solar wind”; (2)Using the high-energy particle spectrum data of the semiconductor detector to confirm the causal sequence between the changes of ion flux in the inner radiation belt and cosmic rays, as well as the corresponding solar proton events, so as to provide the exploration basis for solving the mystery of "particle source in the inner radiation belt"; (3)Due to the north-south conjugate imaging and monitoring characteristics of the neutral atom imager on the low-orbit satellite, it can realize the south and north comparative observation of the ion flux distribution in the South Atlantic anomaly, providing the exploration basis for the study of "the south Atlantic anomaly" ; (4)Due to proximity to ENA emission source, the neutral atom imager will respond to medium-and small-magnitude signals of geomagnetic substorm activity, which will help realize continuous collection and statistical analysis of massive data of geomagnetic activity without missing, and provide important data support for the creation of new space-based weather forecasts.

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Optimal design of an ideal instrumentation package for high-resolution characterization of wildfires from small-satellite constellations

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Wildfires and other types of biomass burning are estimated to consume biomass containing 2–5 petagrams of carbon globally every year, generating intense heat energy, transforming the landscape, and emitting smoke plumes that comprise different species of aerosols and trace gases, which can have adverse effects on human health, air quality, and environmental processes. Existing spaceborne systems observe fires at coarse spatial resolutions (0.33–4 km) and saturate at 325–700K brightness temperatures, whereas vegetation fire scene components can range from surface background (~300K) to smoldering (600–800K) and flaming (1000–1500K) temperatures. Current uncertainties associated with fire emissions are ~100%. With recent technological advancements, it is becoming increasingly possible to raise sensor saturation levels to accommodate background to flaming temperatures at high spatial resolutions. By leveraging new technologies in compact optical and detector-array designs, low power electronics, and low power active cooling systems, we have designed a small fire-science instrument package that can measure fire temperatures of up to 1500K at ~50-m spatial resolution. This instrument can be built to fit in a 12U (20×20×30 cm) or smaller form factor for easy adaptability either as a free-flying CubeSat or as a hosted payload on other small or large spacecraft. It is anticipated that the completion and launch of this optimal instrumentation package would offer unprecedented advancement in our ability to determine fire intensity, emissivity, and flaming/smoldering properties in detail and with high accuracy, thereby providing significantly improved capacity for fire disaster preparedness and emissions characterization.

on the need of the use of data from small satellites in elucidating ionospheric phenomena during very intense geomagnetic storms

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A study to clarify the mechanisms responsible for the pre-storm and main phase ionospheric phenomena during November 20-21, 2003, is presented using heliophysical, interplanetary, geomagnetic, and global ionospheric data. The results show that the ionospheric responses in the main phase do not indicate prompt penetration electric fields as the main ionospheric driver. The results also show that the prestorm phenomena do not originate from a local time effect. The simultaneous occurrence of foF2 enhancements at two widely separated longitudinal zones appeared to suggest a role played by the magnetospheric electric field. However, the analysis of *hmF2* at the stations could not confirm the notion that these fields are the main drivers of pre-storm phenomena. An investigation of flare effects on the pre-storm phenomena also revealed that solar flares are not the main drivers. The present results appear to suggest that pre-storm ionospheric phenomena could be a result of some underlying mechanisms that are working together with varying degree of importance. The present results further intend to show that the mechanisms that are responsible for the pre-storm phenomena could only be largely explained by the use of data from small satellites, given that small-satellite missions by filling gaps in time or coverage, can provide valuable measurements that would help answer important outstanding science questions in space weather.

Keywords: geomagnetic storm, solar X-rays, solar wind, shock gas, ionosphere, pre-storm phenomena.

Orbiting Nano-satellites for Earthquake Prediction (ONSEP)

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The ONSEP mission is a proposed nano-satellite constellation mission, which is intended to perform measurements in the VLF and HF-frequency bands in the Low Earth Orbit to understand the pre-seismic anomalies (seismic-electromagnetic mechanisms) occurring in the ionosphere, which will help predict earthquakes.

Over the last 25 years, ground-based and satellite-based observations have been carried out to understand precursory signatures that could help reliably predict earthquakes. The characteristics of the ionosphere have been highly unpredictable due to its dependence on various phenomena such as solar activity, thunderstorms, earthquakes, volcanic eruptions, and man-made noise. The seismic-electromagnetic process prior to an earthquake has proven to be a reliable pre-seismic phenomenon for short-term prediction of earthquakes. The plate tectonics close to the epicenter of an earthquake lead to the compression and expansion of the rocks, causing a piezoelectric effect. As a result of this triboelectric effect, and rising warm gases, the Earth's surface potential around the epicenter changes, which creates anomalies in the Earth's electric field and subsequently the ion density in the ionosphere. The associated anomalies have been observed over a wide frequency range from DC to VHF.

The observations made by the DEMETER mission (launched in 2004) have confirmed these anomalies. The results and observations made by the ICE (Instrument Champ Electrique) instrument onboard the DEMETER mission is used as a case-study to derive the mission requirements for the ONSEP mission. The primary mission objective of ONSEP is to perform active/passive observations in the VLF and HF bands to record the anomalies during pre-seismic activities, at the time of an earthquake and post-seismic activities to develop better correlate ionospheric anomalies to geo-hazards and manmade noise.

In summary, this paper provides a feasibility study of using a constellation of nano-satellites to perform active/passive ionospheric measurements, that could help better understand pre-seismic signatures.

CYGNSS SMALLSAT CONSTELLATION FOR SEVERE STORM AND HYDROLOGIC SCIENCE APPLICATIONS

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The NASA Cyclone Global Navigation Satellite System (CYGNSS) mission consists of a constellation of eight microsatellites successfully launched into low Earth orbit on 15 December 2016. Each observatory carries a radar receiver to measure GPS signals scattered by the Earth surface. Over ocean, the reflected GPS signals are used to estimate surface wind speed and air-sea latent heat flux. Over land, estimates of near-surface soil moisture, wetland extents, and imaging of flood inundation are possible. The measurements are able to penetrate through all levels of precipitation and heavy vegetation due to the GPS frequency of operation. The density and revisit time of sampling afforded by the number of satellites in the constellation makes possible reliable detection of short time scale weather events such as flood inundation dynamics immediately after a tropical cyclone landfall and rapid soil moisture dry down immediately after major precipitation events. Engineering commissioning of the constellation was completed in March 2017 and the mission is currently in its extended science operations phase.

Science data products are being generated for ocean surface scattering cross section, near surface (10 m referenced) ocean wind speed and mean square slope. The impact of CYGNSS wind speed data assimilation into hurricane weather prediction model is being investigated. Measurements over land are used for terrestrial science applications, including near-surface soil moisture content and flood inundation extent.

The COSPAR 2019 presentation will include an overview, current mission status, and highlights of scientific applications related to its ocean wind and terrestrial water cycle measurements.

New Small Satellite Passive Microwave Radiometer Technology for Future Constellation Missions

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The advent of small satellites and miniaturized instrument technology enables a new paradigm for observation from Low Earth Orbit (LEO). Passive microwave radiometer systems, such as SSM/I, AMSR-E, AMSU, ATMS, WindSat and GMI, have been providing important Earth observations for over 30 years, including but not limited to surface wind vector, atmospheric and surface temperature, water vapor, clouds, precipitation, snow and sea ice.

In this presentation, we will discuss three small satellite technology demonstration sensors that span the capability currently offered by the existing fleet of microwave environmental sensors and a follow-on system currently in development. These systems are COWVR, a low-frequency fully-polarimetric conical imager, TEMPEST-D, a mm-wave cross-track imager/sounder and TWICE, a conical sub-mm wave imager/sounder. Combined, these systems offer the potential to image the Earth from 6-800 GHz. When deployed in a constellation, they enable new observations of dynamic physical processes and coupling between land, ocean, atmosphere and cryosphere.

We will describe unique observations enabled by these systems when used in constellations, including time resolved measurements of dynamic atmospheric processes (e.g. developing convection) simultaneously with surface and atmospheric fluxes. We will show measured performance comparisons between these new small-sat sensors to the equivalent operational sensor, giving examples of on-orbit comparisons for TEMPEST-D and pre-launch measured data from COWVR and TWICE. We will discuss new mission concepts enabled by constellation sensor trains and distributed constellations, particularly as it relates to the observation goals identified in the US NRC Decadal Survey. We will highlight the potential for multi-sensor small-satellite constellations, showing recently acquired passive microwave and precipitation radar data from TEMPEST-D and RainCube. Finally, we will describe a new ESPA-class conical imager concept currently in development that leverages these prior small radiometers.

Theremospheric variations from GNSS and accelerometer observations on GRACE and Swarm

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The upper layer of the Earth’s atmosphere is highly variable in space and time due to anacoustic dynamics actions through the collisions between the ionospheric plasma and the neutrals. Monitoring and understanding thermospheric air mass density variations are important for the orbital decay and space physics. In the last half century, thermospheric air mass density variations and climatology have been studied and modelled, but were subject to large uncertainty due to using empirical models and less observations. Nowadays, the GPS precise orbit determination and accelerometers on satellites provide a unique opportunity to estimate and study air density variations with unprecedented accuracy. In this paper, the recent results and advances in the theremospheric variations are presented from GPS POD and accelerometer data on GRACE and Swarm satellites as well as future challenges and perspective.

SigNals Of Opportunity: P-band Investigation (SNOOPI)

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SigNals Of Opportunity: P-band Investigation (SNOOPI) will demonstrate remote sensing using Signals of Opportunity (SoOp) in the frequency range from 240-380 MHz. This technique shows promise for measuring root-zone soil moisture (RZSM) and snow water equivalent (SWE) from space. Both variables were identified in the 2017-2027 Decadal Survey (ESAS 2017). P-band observations are required to penetrate into the root zone. SWE is proportional to the reflected signal phase and the longer wavelength at P-band increases intervals between phase wrapping.

Funded under the NASA In-Space Validation of Earth Science Technologies (InVEST) program, SNOOPI will verify important assumptions about reflected signal coherence, robustness to the RFI environment, and our ability to capture and process the transmitted signal from orbit. This is a necessary risk-reduction step on the path to a science mission.

The SNOOPI instrument consists of three subsystems: 1) Low Noise Front End (LNFE), developed from an airborne demonstration instrument and later redesigned in a CubeSat form factor; 2) Digital Back End (DBE), a modification of the Cion GNSS instrument flying on CICERO and 3) Commercial (COTS) antennas.

Success with SNOOPI will retire critical risks associated with a P-band SoOp satellite instrument. In addition to enabling direct measurements of RZSM and SWE, which are not presently possible, this instrument will be orders of magnitude lower in size weight, power and cost than comparable monostatic radars due to the re-utilization of powerful anthropogenic signals.

SMALL SATELLITE ENABLED SOLUTION FOR CLOUD CHARACTERIZATION AND WEATHER IMAGING

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Two of the largest weather gaps are the need for cloud characterization (CC) and situational weather imaging (SWI). Recent developments in small satellite and instrument technologies combined with advanced analytics have enabled a distributed low earth orbit (LEO) constellation of visible, near-infrared (NIR), shortwave infrared (SWIR), and mid-wave infrared (MWIR) imagers that offers a cost effective and rapid response for providing CC and SWI. Historical efforts have combined visible, NIR, SWIR, and MWIR imagers into one “exquisite” instrument thus increasing the size, weight, power, and cost while driving instrument complexity and delivery time beyond acceptable limits. Separating the imagers into three different high-performing instruments and flying them on a small satellite constellation allows us to meet weather priorities, while providing accelerated responsiveness and resiliency.

By combining Southwest Research Institute’s capability for space-flight instrumentation with commercially available low cost small satellite platforms, we are able to offer an innovative constellation for weather monitoring known as the Pleiades Suite. The constellation provides data in the visible, near infra-red, short-wave infra-red, and mid-wave infra-wavelengths. The instruments and their host small satellite platforms are distributed into clusters that fly in synchronized formation, simultaneously observing the same scene and provide: detection of clouds, thin cirrus over bright targets, deserts, smoke, sand, and dust; differentiation between liquid/ice, low/high, polar/maritime, mixed-phase clouds, and snow; and cloud top temperature, pressure, and optical properties. Our COSPAR 2019 presentation will provide information regarding the implementation and benefits of our Pleiades approach.

The CubeSat Radiometer Radio Frequency Interference Technology (CubeRRT) Validation Mission: First Ever Space-borne Demonstration of Real-Time Interference Filtering

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The CubeSat Radio Frequency Interference Technology (CubeRRT) Validation mission is the first ever technology demonstrator to detect and filter out radio-frequency interference (RFI) over a wide-bandwidth onboard the spacecraft. CubeRRT represents a technological advancement to counter the increased crowding of spectrum allocations, and preserve the integrity of passive microwave observations against RFI.

Currently, nearly 90% of the bandwidth between 6 to 40 GHz is allocated for non-Earth exploration use. Earth observation satellite systems have a limited spectrum to operate in. RFI has resulted in increased noise and bias in geophysical science retrievals from passive microwave measurements. An RFI detection algorithm is harder to implement at wide measurement bandwidths that exist at higher microwave observations, and resulting in extremely high data downlink rates. The CubeRRT mission was designed to filter out RFI signals and salvage any remaining clean signals using advanced statistical techniques over a much wider bandwidth and performs RFI detection onboard the spacecraft.

The CubeRRT mission can ingest 1 GHz of radiometric measurement bandwidths at microwave frequencies from 6 to 40 GHz and perform onboard filtering. CubeRRT successfully demonstrated and validated the onboard operation of complex RFI filtering algorithms. The backend has collected more than 300 hours of data. In the figure, blue plot represents the on-board filtered signal and the red plot represents the RFI corrupted signal.

Science prospects of the improved X-ray Detector iXRD on 3U CubeSat Sharjah-Sat-1

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Nanosatellites with science payloads have entered the high energy astrophysics domain and expected to contribute to high-quality science together with the conventional large observatories. Small satellites focus on science that deemed as poor use of large observatories (surveys, background observations, extremely long observations of bright objects), yet, such long observations are very valuable to uncover the nature of interesting X-ray sources such as black holes and neutron stars. Given that large observatories can only be built by developed countries with strong economical, scientific and technological establishment, nanosatellites pave the way for developing countries to strengthen their experience in space technology as well as contributing to world-class science. Our group has been working on CdZnTe based detector systems to be utilized in small satellites. Our first detector XRD is in orbit on the 2U BeEagleSat CubeSat with the main aim of measuring hard X-ray background at low Earth orbit and to catch gamma-ray bursts. Currently, we have been working an improved version of this system (iXRD) with a larger collecting area and detector thickness, a collimator to limit the field of view, and improved electronic design. We are planning to test the iXRD on 3U CubeSat Sharjah-Sat-1. The science prospects of the iXRD are very long observations of bright compact objects, solar observations, and cosmic hard X-ray background. In this work, we will describe the iXRD and discuss the functional requirements of the subsystems for each of the science prospects.

Directed Energy Propulsion - The Path to Radical Advancement

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High power directed energy solutions offer a radically different approach to both space propulsion and long range power applications. While chemistry will get us to Mars it will not allow rapid interplanetary nor interstellar capability. None of our current propulsion systems, including nuclear, are capable of the ultra high speeds needed for rapidly exploring the solar system and for the future capability of relativistic flight to enable interstellar exploration. However, recent advances in photonics and directed energy systems now allow us to realize the ability to project the high power over vast distances that is needed for space applications. When operated in direct drive photon momentum exchange, extremely high speeds including relativistic flight become possible. When used in indirect drive mode where the beamed power is converted to electrical power to drive high I_{sp} ion engines, we can realize high mass missions in our solar system at vastly higher speeds and shorter mission times than chemistry. The same core technology can be used for many other purposes including planetary defense, stand-off asteroid composition analysis, space debris mitigation, power beaming to long range spacecraft and other distant assets, LEO and GEO power beaming from Earth and space among many others applications. We are currently in three Phase II NASA NIAC R&D programs. We will discuss the roadmap ahead and both the short term and long term milestones that allow for a logical and cost effective approach.

Calibration and Validation for Small Satellites

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he satellites launched for NASA’s Earth Science Division (ESD) to address research and applications in Earth System Science historically have had extensive calibration/validation (cal/val) programs, including both pre-launch and post-launch, for the latter including both on-board and vicarious calibration. With the advent of small satellites, many of which have come from technology-focused and/or cost constrained/capped programs, while others have come from commercial satellite programs, the availability of resources, both in terms of orbital area/volume and cost to support these activities. In this talk a review of how cal/val goals were implemented and achieved in ESD’s small satellite missions will be provided, and the implications of these choices on potential data utilization will be addressed. A brief summary of related insight from the Commercial Satellite Pilot Data Buy program will also be provided.

Applications of PlanetScope Constellation Dove CubeSats for Hazards and Climate Monitoring

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Planet, Inc`s PlanetScope constellation consists of over 120 currently operating nanosatellites (3U CubeSats) are taking multi-spectral images of the Earth every half a second, and is capable of near daily monitoring of the global Earth surface in between 81.5 or 52 degree latitude bounds despite of cloud cover or weather, and at 3-5 m ground sample distance (GSD) or spatial resolution. This presentation highlights the ongoing research and applications for Earth sciences, as well as applications like natural hazards and environmental monitoring and climate change studies. Timely monitoring of natural hazards such as storms, cyclones, flood, drought, harmful algael bloom in freshwater water bodies or coastal oceans, and other disasters enables rapid hazards response and management. Here, we present examples using the PlanetScope Dove images to detect flash floods in semi-arid regions, cyclone-induced floods and debris in mega cities, and harmful algal blooms in fresh water lakes; and other applications such as water resources management, crop classification, and sensing of energy resources.

Studying Earth landscapes from space with high resolution using small satellite constellations

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Studies of land-cover and land-use change (LCLUC) on a global scale became possible when the first satellite of Landsat series was launched about 47 years ago. Since then land-change science has been rapidly developing to answer the questions on where changes are occurring, what is their extent and over what time scale, what are their causes, their consequences for ecosystems and human societies, their feedbacks with climate change, and what changes are expected in the future. LCLUC studies use a combination of space observations, in situ measurements, process studies and numerical modeling. To get the most out of current remote sensing capabilities with moderate spatial resolution (at 20-30 m) researchers strive to utilize different freely accessible remote sensing data sources from NASA-USGS Landsat and ESA Sentinel Programs. A synergistic use of these data increases frequency of observations, which is important for a number of science questions and applications, especially in the regions with frequent clouds. To enhance the capability of monitoring the Earth at a higher spatial resolution the NASA LCLUC program scientists include data with meter spatial resolution (5m) from satellite constellations operated by Planet Lab and Digital Globe. This presentation will briefly summarize significant results on improving our potential in landscape monitoring by synergistic use of mid- and high-resolution observations of natural vegetation, agriculture and urban areas. The issues and advantages of using high-resolution data in studying landscapes will be discussed.

IAI's Image analytics tools for Space imagery

Tal Feingersh

R&D, IAI, Israel

In recent years IAI concentrated R&D efforts to automate and facilitate some of the main the image-to-information processing chains for their customers. The result if a set of pioneering image analytics tools for remote sensing space missions.

This presentation will scan through two of them, Eoview© for spectral analytics and BetterView© for EO/SAR fusion analytics.

EOview is an automated interpretation tool designed for non-experts, which facilitates remote-sensing data-to-Information production. It specializes in Multispectral (MS) and Hyperspectral (HS) Electro-Optical (EO) images, and provides fused information layers (vector & raster maps) from Panchromatic, MS and HS images. It runs cutting-edge processing algorithms for automated radiometric, atmospheric & geomteric correction, automated interpretation and production into added-value information products suitable as up-to-date spatial inputs for Geographic Information Systems (GIS).

EOview supports multiple commerical spaceborne sensors, and allows flexible addition of new emerging ones. It is optimized for human visual interpretation, based on surface properties, target materials and detection of change between images. *EOview* supports insertion of new algorithms via a dedicated friendly user interface.

Better*View* is an integration tool for Electro-Optical (EO) and Synthetic-Aperture Radar (SAR) images, that provides fused information layers. It runs cutting-edge image processing algorithms for automated geomteric matching and fusion of such images, into added-value information products.

Fusion in Better*View* is optimized for human visual interpretation, based on surface properties, objects and infrastructures in the images. It works in an adaptive manner, fitting its processes to input image statistics.

Better*View* products are synergetic and value-added in the sense that the combine the best of both worlds: SAR's day-and-night observation capability in all weather conditions, and EO's color and spectral information, preserving its intuitive visual quality.

Crop RS-Met: A soil water content model for crop fields driven by high temporal satellite vegetation index

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Yield production of rainfed crops in dryland regions is mostly determined by the available water in the soil, which may vary greatly across the field area and along the season. Thus, continuous spatial and temporal estimations of soil water content are essential for irrigation management and proper decision making in these fields. In-situ measurements of soil water content lack this spatial dimension, while interpolating techniques may result in large uncertainties. Here, we use a biophysical model combining remote sensing and meteorological information (Crop RS-Met) to assess root-zone soil water content across wheat fields. The model, which is based on the dual FAO56 formulation uses a water deficit factor calculated from rainfall and atmospheric demand information to constrain actual evapotranspiration and soil water content in crops growing under dry conditions. Crop RS-Met spatial assessment is driven by the spatial resolution of the remote sensing spectral-based information. In this study, we test Crop RS-Met with spectral-based vegetation index derived from different satellite platforms, including the recently lunched Israeli-French Vegetation and Environment monitoring on a New Micro-Satellite (VENµS) and Sentinel2. Results are compared with Crop RS-Met using proximal sensing and in-situ soil water content measurements in a dryland experimental wheat field. Correlations with grain yield will be tested after harvest, followed by a comparison between the spatial and temporal advantages of the different platforms.

Global Observations from a Science-Quality Passive Millimeter-wave Atmospheric Sounder on a CubeSat: Temporal Experiment for Storms and Tropical Systems Demonstration (TEMPEST-D)

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Global observations of clouds and precipitation processes are essential to improve prediction of tropical cyclones and severe storms with substantial impacts on human life and property. To improve understanding of convective processes, global observations with rapid revisit times are necessary. Geostationary satellites provide visible and infrared measurements every few minutes. However, passive microwave measurements provide greater contributions to forecast skill, since they penetrate inside the storm where processes leading to precipitation occur.

To address this critical observational need, the Temporal Experiment for Storms and Tropical Systems (TEMPEST) mission deploys a closely-spaced train of 6U CubeSats with identical low-mass, low-power millimeter-wave radiometers. The TEMPEST train samples rapid changes in convection and water vapor by observing every 3-4 minutes for up to 30 minutes. TEMPEST millimeter-wave radiometers at 87 to 181 GHz provide soundings of mid-tropospheric water vapor to improve understanding of its role in convection. TEMPEST fills a critical observational gap and complements existing and future satellite missions, e.g. TROPICS and GPM.

The TEMPEST Demonstration (TEMPEST-D) mission is a partnership among Colorado State University, NASA/Caltech Jet Propulsion Laboratory and Blue Canyon Technologies. The TEMPEST-D 6U CubeSat was launched to the ISS on May 21, 2018 and deployed on July 13, 2018, into a 400-km orbit with 51.6° inclination. The TEMPEST-D mission met its mission success criteria in the first 90 days. Global brightness temperature measurements by TEMPEST-D have been compared to well-calibrated, on-orbit reference sensors, demonstrating that TEMPEST-D is well-calibrated and highly stable, compared to much larger, more expensive operational instruments.

Space Weather Research Missions with Small Satellites in China

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Recent advances in technology miniaturization have enabled building small spacecraft (less than 1000kg) and micro- and nano-satellites, for low cost and with decent reliability. Small-satellite missions can both complement larger missions by filling gaps in time and/or coverage, and constitute stand-alone missions with specific scientific and application targets. Constellations of dozens, hundreds, maybe even more small satellites could provide the information needed to monitor the vast space weather environment. This talk will introduce the space weather research missions with small satellites in China, including Advanced Space-based Solar Observatory (ASO-S), ESA-CAS Solar Wind Magnetosphere Ionosphere Link Explorer (SMILE), and Self-Adaptive Magnetic Reconnection Explorer (SAME). ASO-S will reveal the multiple relationships between solar magnetic field, solar flares, and Coronal Mass Ejections (CMEs). SMILE will carry out global imaging of the interaction between solar wind and magnetosphere for the first time. SAME aims to make simultaneous and self-adaptive measurements of plasmas at electron-ion-macro scales with a fleet of 12+ cubesats and one mother satellite.

The possibility to measure the plasma density and its fluctuations in the ionosphere on cubsats using radiophysical techniques

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The principal possibility to measure the plasma density and its fluctuations in the ionosphere on ultra-small space vehicles using radiophysical methods is shown. These methods allow to determine the characteristics of the medium by the properties of the received radiation. It is assumed that each small spacecraft has a satellite navigation receiver as well as a device for emitting and detecting a signal at two multiple frequencies in the radio band. In this approach, information on plasma density is contained in the received phase difference. Radio receivers and radio transmitters on satellites constantly exchange radio signals and then it is possible to determine the plasma density and its fluctuations from the phase shift. Numerical estimates are also made to determine the maximum distance between satellites where one can reliably receive a radio signal. The proposed approaches in the present work can be used to study ionospheric irregularities not only of natural origin but also of artificial ionospheric turbulence.

The work of Chugunin D.V. and Chernyshov A.A. was supported by Russian Science Foundation (the project №17-77-20009).

Advanced miniaturised sensors for commercial and scientific nanosatellite missions

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Nano-satellites, particularly in the CubeSat form factor, have attracted a lot of interest worldwide. With their rapid turn-around and low cost, they lend themselves particularly well to education. However, exploiting advances in miniaturisation, nanosatellites are increasingly being employed in commercial and scientific arenas. In some domains internationally competitive science can also be performed and several current CubeSat missions are targeted at science applications, especially at studies that can be carried out at Low-Earth Orbits or through piggy-back opportunities. A particular area that benefits is applications requiring constellation missions. Low resource miniaturised instrumentation with a high degree of integration is a key enabling technology required for maximising exploitation of such mission opportunities.

The Mullard Space Science Laboratory (MSSL) has an ongoing development programme aimed at highly miniaturised in-situ space sensor systems and integrated satellite electronics. The laboratory is developing/has delivered several sensors suitable for nanosatellite missions (UK TechDemoSat and the EU QB50 and DISCOVERER missions) and has also built and launched an educational CubeSat. This paper will present an overview of the development programme, discuss some of the sensors launched and under development, discuss data from one of the QB50 sensors, discuss some of the proposed science mission ideas and present a roadmap of the programme vision.

The Development of a Low-Voltage, Ultra-Compact Plasma Spectrometer

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Instrumentation is needed to support the increased demand for low-cost, small satellites to support research and space weather monitoring. Such instrumentation is also needed for constellation missions envisioned by space agencies, such as in the NASA Heliophysics Roadmap. We are developing a low-voltage, ultra-compact plasma spectrometer that is designed to meet these requirements. The collimator and electrostatic analyzer elements are etched into a single silicon wafer to enable manufacturability of large quantities. The instrument is capable of measuring ions or electrons at a discrete set of energies without the requirement to sweep voltages. The energy range measured will depend upon the detector used; for example, solid state detectors can be used for energies greater than ~ 1 keV. We are developing a concept micro-faraday cup for lower energies. We will present the instrument design, test results of the collimator-analyzer layer, as well as initial test results of the micro-faraday cup.

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Spatial - temporal study of plasma-waves and ionospheric parameters using microsatellites.

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The implementation of microsatellites (MS) *Kolibri-2000* (2002) [1] and *Chibis-M* (2012-2014) [2] showed that the electromagnetic monitoring of the ionosphere can be successfully carried out with the help of MS that are integrated into the Infrastructure of the Russian segment of the International space station (ISS RS) and the release from the cargo ship *Progress* in autonomous orbit with altitude of 500-600 km.

The method of ionosphere research using (Fig. 1) simultaneously release two copies of MS *Trabant* (weight of each ~60 kg., 2020-2024) to study:

- mechanisms of occurrence and dynamics of ionosphere inhomogeneties of different scales depending on the active processes in the Sun and on the Earth - space weather;

- regularities of changes in plasma-wave and electromagnetic parameters in the ionosphere of natural and technogenic character in a wide dynamic and frequency ranges;

In the monitoring mode (time resolution of tens of seconds), long series of the same type of data reflecting the "correct" statistics of observations are recorded. High-frequency modes (wave form) are included in some parts of the orbit, creating the most effective diagnosis of events — this is the implementation of the idea of "case study", but the price for the high information content of this mode is the loss of the picture of phenomena as a whole.

Multiparameter plasma-wave studies on a wide range of ionosphere deterministic spatial parameters (~ 0.1-100 km) will be carried out in a bundle of two MS *Trabants*.

Fig. 1. The output circuit from the *Progress* of the *Trabant-A* and *Trabant-B* for autonomous orbits.

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Small satellite for studying cosmic radiation environment in space

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CubeSats are built from a modular structure of 10x10x10cm cubes, and a wide range of commercially available electronic and electromechanical components which can match the structure with suitable design concepts. The satellite costs orders of magnitude less than large-scale satellites. CubeSat idea can be used as a mini research satellite to study specific variation of cosmic ray protons and heavy ions and the impact of solar activity on the radiation environment for planetary missions. It is planned to develop such a small satellite in about 3 years time which would be launched as a subsidiary payload with ISRO"s PSLV facility from India.

The scientific investigation of the mission would include simultaneous observations of primary cosmic ray protons and Fe ions using the satellite sensors /detectors and data from operating ground based cosmic ray neutron monitors. The new and continuous observations would help characterising the prolonged effect of low solar activity on high levels of cosmic ray energetic heavy ion fluxes during the current solar cycle 24 and the future cycle 25. This would help estimate the radiation doses that the astronaut would experience while on a long duration mission or evaluate the risks that the robots have to be safeguarded from single event effects during workouts on Martian surface.

The detector system would include pure silicon carbide sensors for charged particle flux measurements in an elliptical orbit of 400-80000 km so that its variation due to earth`s magnetic field can also be studied.

SMALL SATELLITES FOR EARTH OBSERVATION: A PERSPECTIVE FROM JPL/NASA

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In the cost-constrained environment of NASA, the need for an acceptable compromise between science objectives and mission affordability is informing the decadal surveys. The rising credibility of SmallSats and CubeSats as science platforms has changed significantly in the last few years while access to space and the ability to deploy multiple spacecraft have inspired people to develop mission concepts that exploit the new capability. Interestingly, new scientific observations are possible, via constellations, formation flying, and sensor disaggregation. This talk reviews ongoing missions such as CYGNSS, and technology demonstration experiments such as RainCube and TEMPEST-D, and discusses the value added to Earth science measurements by single smallsats and constellations. As general characteristics of smallsat constellations, instrument resolution (strength, direction) is dictated by spatial sampling in the measurement, and high sensitivity in the frequency band of interest is dictated by temporal sampling, leading to novel requirements in instrument bandwidth. Exploiting such richness in spatial and/or temporal sampling allows for observations of physical processes thus far precluded, such as highly dynamic changes needing high resolution, as in the case of seismic event detection. Additionally, the talk discusses new concepts rapidly emerging as part of the Designated Observables architecture studies following the Decadal Survey report of 2018, which calls for smallsats as part of the NASA observation strategy in the next decade.

Exploration of Enceladus through constellation of CubeSats

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The desire for a better understanding of the Universe has been the dynamo of our civilization. Ever since the discoveries made by the Cassini spacecraft, human fascination has only increased about Enceladus. This paper presents a sustainable approach to study more about Enceladus through constellation of satellites. The mission architecture proposed through the paper has been designed to maximize the scientific data from the Enceladus surface. Various trade studies will be included at the architectural and system levels to demonstrate the compliance of the science instruments for a complete optimization. Detailed in-orbit observations and communication plans for the constellation of satellites and their transmission to the Earth will be showcased. Comprehensive tables and graphs will be given to illustrate the compliance of the functionality of the constellation of satellites. Tables will also be given to depict the amount of time that will pass at each mode of travel and more importantly, some idea on the cost in terms of energy, as well as money, will be discussed within today's context. Even though the possibility of such a mission is probably non-existent for this decade, it is essential to do these exercises so that mankind's understanding of Enceladus will be increased. Enceladus discoveries have changed the direction of planetary science, this mission hopes to establish some general guidelines for such an exploratory mission.

QCM SENSORS FOR CONTAMINATION MONITORING IN SUPPORT TO NEXT CUBESATS AND SMALL SATELLITES MISSIONS

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Quartz Crystal Microbalance (QCM) based sensors were applied in the past on-board small satellite missions, e.g. SMART-1, SDS-4 missions (Paita 2012, Nakamura 2013) to monitor the molecular contamination coming from outgassing sources of spacecraft materials that can degrade critical spacecraft surfaces, such as optical systems, solar panels, thermal radiators and thermal management systems (Benner 1998, Wood 1996).

Thus, QCM sensors are suitable instruments to monitor step by step these degradation processes which occur in space conditions and to characterize the deposited compounds by using the Thermogravimetric Analysis (Dirri 2016).

In the past years, an Italian Institutes Consortium developed CAM (Contamination Assessment Microbalance), for monitoring in-orbit contamination of sensitive surfaces and payloads on ESA`s future satellites, and recently developed CAM-LAB i.e., for ESA laboratory applications. These devices are low mass (100 grams for the sensor head), low volume (smaller than 5x5x5 cm3) and low power consumption (less than 1.5 W) sensors.

The device is composed by: 1) Sensor Head, containing a sensing crystal (which measures the deposited contaminant mass), a reference crystal (reference), their related Proximity Electronics (PE) and Temperature Control System (TCS); 2) Main Electronics Unit (MEU); 3) Harness; 4) User Interface (UI). The main innovations of CAM and CAMLAB are to measure directly the crystal temperature (better than 0.1°C), larger measurable mass range (up to 700 µg/cm2) and larger operative temperature range (from -80°C to 130°C) compared with previous QCM devices and the possibility to easily change the sensitive elements (i.e. crystals). The instruments concept and performance are presented.

Democratizing Solar System Exploration, Using Low-cost Interplanetary Explorers

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This paper presents a low-cost, small satellite inter-planetary explorer for solar system exploration. In contrat to the existing NASA program models such as Discovery (~500M$) and New Frontiers (~ 1B$) this class of Explorers (~ 50M$) is designed for the more eager and broader exploration of the solar system, as well as more responsive to recent discoveries and more inclusive of a broader set of space explorers, including private companies, universities and other government and private institutions. The Expansive Common Low-cost Inter-Planetary Science Explorer (ECLIPSE) is a proposed small satellite class, low-cost, multi-use spacecraft platform concept to conduct such multi-destination science across the solar system. We describe a canonical spacecraft bus for deep space exploration based on existing and emerging Solar Electric Propulsion (SEP) subsystem, and a set of existing scientific payload. The spacecraft is in the small satellite (200 – 250 kg) category and carrying 25-50 kg of scientific payload. Six key measurement areas were identified including: electric field, magnetic field, planetary imaging and spectral signature, D/H ratio, ionizing radiation, and more. Measuring these quantities in a consistent manner at a large number of locations (i.e. at interplanetary distances) will significantly expand our knowledge of the history and makeup of the solar system and further democratize and broaden the scientific access to the this exciting scientific destination. The paper also presents several mission concepts for the broad exploration of the population of asteroids and commets, among other applications.

Achievements and Future Plan of JAXA's Interplanetary CubeSats and Micro-sats

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The University of Tokyo and Japan Aerospace Exploration Agency (JAXA) developed the world's first deep space micro-spacecraft PROCYON. Its mission objective is to demonstrate a micro-spacecraft bus technology for deep space exploration and proximity flyby to asteroids performing optical measurements. PROCYON was launched into the Earth departure trajectory on December 3, 2014, together with Japanese asteroid sample return mission Hayabusa-2. PROCYON completed the bus system demonstration mission in its interplanetary flight.

Currently, Japan is not only pursuing the improvement and utilization of the demonstrated micro-sat deep space bus system with a weight of tens of kg or more, but also trying to develop smaller spacecraft with a weight of less than tens of kg, namely CubeSats, for deep space exploration. We are developing two self-contained 6U CubeSats for the rideshare opportunity on the USA's SLS EM-1 mission, one of which (EQUULEUS) will fly to a libration orbit around Earth—Moon L2 point and perform scientific observations of the Earth and the Moon, and the other (OMOTENASHI) is planning to perform "semi-hard" landing on the moon by using a solid rocket motor onboard.

We are also seeking the possibility of CubeSats which is carried by a larger spacecraft to the destination and supports the mission by taking advantage of its low-cost and risk-tolerable feature. We are studying several other CubeSat and Mirco-sat deep space missions in Japan, and this paper overviews the Japanese achievements and future plans of CubeSats and Micro-Sats for deep space exploration.

Exploration of Titan by small planetary satellite

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Ever since the discovery of the universe, deep space operations and explorations to identify human presence and conditions of their existence, have interested entire human race. With an increase in population, resources are being utilized explicitly which leads Earth towards a catastrophic future. Therefore, human colonization is not just key to exploration, but it is crucial to human survival. This paper is dedicated to exploring the possibility of life sustenance on Titan. The futurology of this paper lies in simulating a small planetary satellite, which is a space probe entering a planetary atmosphere. The probe consists of an aero-braking heat shield and a parachute which will be deployed at a certain altitude. The simulating space probe is an Arduino based satellite which is powered by an electric power source and equipped with an accelerometer, gyroscope, real-time clock, GPS, temperature, and altitude measuring sensors along with a camera pointing towards the Nadir direction to the satellite. The live and continuous data captured by the satellite will be received by the ground station (Graphical User Interface) and will be analyzed further for deeply understanding the targeted destination. This incremental step towards the exploration of Titan would mark the beginning of Human Colonisation in outer space.

Update of CSES Mission

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China Seismo-Electromagnetic Test Satellite (CSES) mission, being one of the China National Geophysical Fields detecting satellite missions, was proposed in the beginning of 2003 and cooperated with Italian Limadou mission.

The main objectives of CSES are:1) global geomagnetical field, its temporal-spatial distribution acquirement and related scientific issues research, 2) Ionospheric plasma environment and ionospheric response to natural and artificial events both from above and below, and 3) research of the mechanisms among Lithosphere-Atmosphere-Ionosphere Coupling as well as integrate research on Earth System science. The main CSES observing content include: Geomagnetical Fields and low frequency EM waves, In-situ ionospheric parameters and Ionospheric plasma tomography.

In the beginning of 2018, the CSES-01 launched in orbit successfully, which is due to flying onboard for 5 years in a solar synchronization circle orbit and carrying on 8 payloads. Since the launching event, CSES-01 sounded nice performance in-orbit accompanying with a large amount of data acquired and preliminary processing and application.

In the end of April of 2018, CSES-02 proved by China government following the CNSA-ASI MoU on CSES-02 signed in the Later of March of 2019. According to the draft scheme, CSES-02 will fly on the same orbit with CSES-01 but additional 1 payload than the 1st one. CSES-02 was planned to be launched before the end of 2021 and about 2years onboard overlap with CSES-01.

Monitoring the Earth's magnetic field and ionosphere with LEO nanosatellites: the NanoMagSat project

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The geomagnetic field has been continuously monitored from LEO orbits since 2000, complementing ground-based observatory data by providing accurately calibrated scalar and vector measurements with global planetary coverage. The successful three-satellite ESA Swarm constellation is planned to remain in operation up to hopefully 2024. Further monitoring the field from space with absolute magnetometry beyond that date is of critical importance for improving our understanding of the dynamics of the various components of this field. Here, we will report on our ongoing efforts to design and launch "NanoMagSat" nanosatellites, carrying an advanced miniaturized absolute scalar and self-calibrated vector ASM magnetometer (based on a concept successfully tested on Swarm), allowing 400 Hz scalar and calibrated 1 Hz vector data to simultaneously be acquired. Attitude restitution would be achieved thanks to a set of star trackers. A Zero Field Magnetometer (ZFM, with many sub-systems similar to those of the ASM) allowing additional much lower noise vector data to be acquired at even higher rates (400 Hz), is also under development/consideration. This core payload would be complemented by a dual frequency GNSS receiver and a Langmuir probe, to enhance the possibility to address space weather related issues. A first (possibly multiple satellites) launch is currently considered at a ~60° inclination LEO orbit complementing the orbits of the Swarm constellation, which could be followed (possibly simultaneously) by launches on additional orbits to quickly form the basis of a future constellation of nanosatellites for permanent monitoring of the geomagnetic field and ionospheric environment from space.

Spherical picosatellite for monitoring of high atmosphere density

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The lower thermosphere (between 100 and 250 km in height) and many of the processes developing there are still rather badly known. Active satellites are scarce in these regions as drag would cause its re-entry in a matter of days or weeks.

Two types of low mass spherical satellites are being developed to determine the density of the lower thermosphere by two methods: by directly measuring the drag by means of high-accuracy MEMS-accelerometers, and indirectly by analyzing the data of GNSS receivers. The ballistic coefficients are kept to very low values to maximize the deceleration caused by drag. The first kind of satellite will have a mass of no more than 100 grams and will be non-stabilized (V1), while the second is expected to have less than 1 kg and will be aerodynamically stabilized along 1 axis (V2). The diameter of each satellite model would be of 10 cm.

The accelerometers are the main sensor of the satellite and must be able to measure accelerations down to ~1 micro-g. A primary battery will feed all the electronic devices.

A complete mission would require a swarm of spherical satellites distributed in polar orbits along several orbital planes. While this would produce the highest scientific revenue, it would also call for dedicated launches.

As the residence time in orbit will be very limited, around one week depending on the ballistic coefficient, the satellite must be as simple and cheap as possible.

The Stratospheric Aerosol and Gas Experiment (SAGE) IV Pathfinder

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Atmospheric aerosols and ozone are designated as observing system priorities in the 2017 Decadal Survey Report. Accurate records of stratospheric aerosols are a vital piece of the puzzle regarding climate change. Stratospheric ozone has been the subject of observation and research for decades. Its importance is exhibited in the Clean Air Act, which mandates that NASA monitor atmospheric ozone. Satellites observed the initial decline of ozone in the late 1970s and early 1980s and supported the adoption of the Montreal Protocol. Current observations hint at a potential recovery. Adequate determination of that recovery requires continuous and, in the case of multiple instruments, overlapping data records. With SAGE III ISS currently entering its third year on orbit, and with most other current ozone monitoring orbital systems well beyond their expected lifetimes, we look towards the future of satellite observations of stratospheric ozone and aerosols to develop the Stratospheric Aerosol and Gas Experiment (SAGE) IV Pathfinder. Enabled by the Instrument Incubator Program and now in Project Year 3, the SAGE IV Pathfinder team is developing and validating a technology demonstration that will pave the way for a future SAGE IV spaceflight mission. Current technological advancements allow SAGE IV to fit within a CubeSat framework and make use of commercial hardware, significantly reducing the size and cost when compared to traditional missions and enabling sustainability of future measurements. SAGE IV will meet the definition of the newly-recommended Venture-Continuity missions by "bringing forward innovative approaches to sustain measurements at lower costs."

The integrated Standard Imager for Microsatellites (iSIM): An agile, high-resolution, multispectral EO camera for the new constellations of small satellites

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iSIM is a compact, robust binocular camera for Earth Observations (EO) developed by SATLANTIS providing diffraction-limited images from 450 nm to 1 micron. iSIM is currently the only EO imager that can continuously operate while the satellite moves both along and across its orbit, and it is best suited for tracking irregular linear structures from Low Earth Orbit (e.g., coastlines, borders or pipelines). iSIM-170 has an effective aperture of 150mm and a focal length of 1500mm. The electronics combine COTS CMOS detectors and components with SATLANTIS proprietary technology of on-board image processors to implement super-resolution and multi-spectral capabilities.

At 500km altitude, iSIM-170 will provide images in four bands (RGB+NIR) with a swath of 7.5km and GRD=1.1m at 600nm. The final spatial resolution after applying our super-resolution and multi-spectral techniques depends only on wavelength, i.e., it does not depend on the number of bands. The total mass is below 15kg, making iSIM-170 one of the smallest, most powerful cameras in the market for EO microsatellites. The Flight Model (FM) of iSIM-170 is currently scheduled to be launched to the ISS in Q1 2020. The Qualification Model (QM) of iSIM-170 performed functional, thermal-vacuum cycling, vibration tests during Q4 2018 while radiation tests have been performed during Q1 2019. The QM of iSIM-170 will be flown on-board a high-altitude airplane in Q3 2019 to demonstrate fully its agility, super-resolution and multi-spectral capabilities. In this paper we present the results of the QM tests, the airplane imaging campaign, and the preparations for launching the FM of iSIM-170 to the ISS.

BALKAN-MEDITERRANEAN REAL TIME SEVERE WEATHER SERVICE AND POSSIBLE SYNERGIES

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The BeRTISS (Balkan-Mediterranean Real Time Severe weather Service) is a project funded by the European Territorial Cooperation Programme “Interreg V-B Balkan-Mediterranean 2014-2020". Under the frames of this collaborative project a transnational operational service for monitoring severe weather events in the Balkan-Mediterranean area will be established by exploiting Global Navigation Satellite Systems (GNSS) tropospheric products. By exploiting the fact that GNSS signals transmitted from satellites to ground reference stations are delayed by water vapor in the troposphere we can estimate this tropospheric delay by incorporating surface pressure and temperature measurements. Using this tropospheric delay we can infer Precipitable Water Vapour (PWV) which is the most abundant greenhouse gas (accounting for ~70% of global warming). GNSS derived PWV has been utilized as an input to Numerical Weather Prediction (NWP) models to improve the forecasting accuracy. BeRTISS real-time service, which will comprise the extension of the existing European GNSS network of tropospheric products, will facilitate continuous PWV monitoring over Greece, Bulgaria and Cyprus using the GNSS derived tropospheric products over the region. Cloud information provided through projects such as C^3IEL (Cluster for Climate and Cloud Imaging of Evolution and Lightning) is considered as an important aspect that can be combined with GNSS meteorology services and enhance the information content that can be provided through the operational platform that is being developed under BeRTISS. /h5 /h5

FPGA implementation for high throughput small satellite applications

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Generally, various kinds of processors and microcontrollers with highly optimized software solutions are in practice in small satellites.But even with modern high speed signal processors, some intensive error correcting and digital filtering algorithms are too much for them. For that, ASIC solution has also been practiced, but comes with the cost of being non-reconfigurable and expensive. FPGAs on the other hand has least of these caveats. By computing such intensive tasks in parallel and pipelined fashion using every clock more efficiently we can significantly increase the throughput maintaining low power. Modern FPGAs also supports rapid dynamic partial reconfiguration which with careful design can even outperform ASICs in some cases. This poster illustrates the high performance, low power, high radiation tolerance property of FPGA to implement in any satellite requiring high throughput such as measuring high-resolution cloud dynamics.

"Italian assets for space science and exploration with Cubesats"

Maria Cristina Falvella, Alessandra Di Cecco, Marta Albano

Cubesats represent a revolution for space assets both for their low cost and time of realization. These small satellites are used for educational activites, as well as, for Earth observation, astrophysics investigation and fundamental physics experiments. Cubesats are also perfect benchmark to test new miniaturized technologies (i.e. MEMS), by opening interesting scenarios for industrial investments and technology transfer. Moreover, the affordable cost of Cubesats provides a unique opportunity to involve the emerging Countries in space activities and, in turn, to provide a new spin to their economy. In this scenario, the Italian Space Agency (ASI) has started several projects involving national and foreing Research Institutes, Universities and industries, as well as, by collaborating with other Space Agencies. We present the current National activities on cubesat missions, starting from academic collaborations and industrial involvements, up to scientific proposals and international projects.

Six years of stellar astrophysics with BRITE Constellation

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BRIght Target Explorer (BRITE) Constellation is an international nanosatellite space astronomy mission performing high-cadence, long-term, two-colour photometric monitoring of the brightest stars in the sky. The mission consists of six nanosatellites (hence "Constellation"): two from Austria, two from Canada, and two from Poland, launched in 2013 and 2014. Each 7 kg nanosat carries an optical telescope of aperture 3 cm feeding an uncooled CCD. One instrument in each pair is equipped with a blue filter, the other with a red filter. Each BRITE instrument has a wide field of view (~24 degrees) so up to about 30 stars can be observed simultaneously. The Constellation is supported by a network of three ground stations. The BRITE observational sample is dominated by the most intrinsically luminous stars: massive stars at all evolutionary stages, and lower-mass stars at the end of their nuclear burning phases. The goals of BRITE-Constellation are (1) to measure p- and g-mode pulsations to probe the interiors and ages of stars through asteroseismology; (2) to detect stellar surface and wind structures, and measure stellar rotation; (3) to investigate eclipses and tidal interaction in binary systems; and (4) to search for planetary transits. Following a brief overview of the basic characteristics of the Constellation and the construction of the nanosats, I will describe the key scientific results obtained during the last 6 years, and discuss synergies with the recent TESS mission.

The HERMES project (High Energy Rapid Modular Ensemble of Satellites): probing space-time quantum foam and hunting for gravitational wave electromagnetic counterparts.

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I discuss how several of the proposed models for space-time quantization predict an energy dependent speed for photons. Although the predicted discrepancies with the general speed of light are minuscule, I discuss how it is possible to detect this intriguing signature of space-time granularity with a new concept of modular observatory for photons in the energy band 10 keV − 30 MeV. This observatory may consist of a swarm of micro/nano-satellites on low orbits. Sub-microsecond time resolution and wide energy band allows to probe tiny energy dependent delays, expected to be the signature of the granular structure of space-time in several of the proposed theories of Quantum Gravity. Moreover this kind of experiment allows to perform temporal triangulation of high signal to noise impulsive events with positional accuracies of few arc-seconds, making an observatory like that a promising hunter for the elusive electromagnetic counterparts of Gravitational Waves.

Formations of Small Satellites to Characterize 3D Cloud Properties: TOM and CloudCT

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Clouds have significant impact at global scale on the Earth's energy balance through albedo as well as on water transport. Therefore, uncertainties in global climate models are significantly affected by our limited knowledge about cloud internal composition, in particular of shallow convective clouds. ***CloudCT*** is an ERC Synergy Grant to improve small cloud observations, using a distributed sensor network on small satellites. Crucial for such formations are a high accuracy attitude determination and pointing capacity, as well as self-organizing networked controls to position the satellites for appropriate observations. In the "***T***elematics earth ***O***bservation ***M***ission" TOM 3 Bavarian satellites will test 2021 this advanced small satellite technology in combination with photogrammetric methods for the observation of ash clouds. Here from different perspectives by sensor data fusion 3D images will generated. In CloudCT in 2022 by computed tomography methods the satellite measurements will be combined to derive even the cloud's internal 3D information. For this objective 10 pico-satellites flying in formation will use multipoint observations of backscattered light from the clouds to reconstruct their interior 3D properties by a computed tomography approach. The basic data processing principles have already been tested by Technion using airborne data. An appropriate test infrastructure based on high precision, high dynamics turntables has been established at ZfT to realize realistic experiments of the in-orbit situation. The new data will provide the input to tune cloud resolving models at Weizmann Institute and to better parametrize their sensitivities in climate models in order to improve longer term climate predictions.

Polarimetric Detection of Super-thin Clouds and Dust Using CubeSats

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Super-thin clouds with optical depths smaller than ~0.3 can seriously affect the remote sensing of aerosols, surface temperature, and the atmospheric composition gases. Without taking into account these clouds, the sea-surface temperature retrieved from satellite data could be ~5-10K lower than the actual values at tropical and midlatitude regions, where these clouds frequently exist [1, 2]. Super-thin clouds can consist of ice clouds at high altitudes and also water clouds at low altitudes. Detection of optically thin clouds at low altitudes from space is very difficult due to their partial transparency, land surface emission, and the fact that they are relatively warm [3]. Studies have shown that super-thin clouds can be detected by a polarimetric imager facing toward the backscattering direction of sunlight, exploiting a distinct, characterizing feature of the angle of linear polarization of the backscattered solar radiation [1, 2]. We are designing two CubeSats with polarimetric instrumentation to detect super-thin clouds, as well as dust aerosols that we anticipate will significantly improve environmental and climate modeling.

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Geometric aspects of stereoscopic spaceborne imaging of dynamic clouds in the CLOUD experiment

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There are gaps of knowledge regarding cloud dynamics. This is partly due to lack of global-scale high resolution data on three-dimensional flow fields, specifically updrafts that drive cloud convection. Such data can be inferred from tracking cloud-envelope evolution. Towards this, a dedicated CLOUD experiment is planned in the C3IEL mission (by the Israeli and French Space Agencies). CLOUD involves three or two small satellites at low earth orbit, hundreds of kilometers apart. As they overpass clouds, they will stereoscopically image clouds simultaneously, and track cloud evolution during four minutes. The planned nadir field of view is 80km, at 20m nadir resolution. The very large baseline, high off-nadir view angles involved during overpass, and Earth curvature deviate significantly from small-angle stereoscopy common in computer vision. Moreover, in these large angles, the appearance of cloud features vary significantly across viewpoints and time. These aspects challenge geometric self-calibration, stereo triangulation and ultimately estimation of cloud envelope flow. We present analysis of these challenges and simulations. Large eddy simulations create dynamic cloud fields. Through these clouds, radiative transfer is operated. The radiance is projected to perspective images, at perturbed platform poses in orbit, to challenge computer vision. Flow is then estimated based on non-rigid matching of estimated cloud envelopes.

VENµS mission overview

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VENµS (Vegetation and Environment New Micro-satellite) is a joint France-Israel space program. The satellite was launched in August 2017, the scientific mission started in march 2018 and will finish in August 2020.

VENµS is a dual mission that gathers both a scientific mission and a technological mission (IHET- ISRAELI Hall Effect Thruster).

The scientific mission is devoted to earth remote sensing in the visible part of the spectrum. It started on March 1st 2018, 6 months after launch. VENµS covers once every two days at least 123 sites representative of the main terrestrial and coastal ecosystems in the world. The 5 meters' resolution images are taken in 12 spectral bands in the visible and near-infrared ranges with a 27 km field of view. This scientific mission is scheduled for 30 months' operations. The CNES is in charge of this mission.

The technological mission is devoted to the qualification of an electric propulsion system. It started with a cycle of 2 days every month and will continue with a full 6 months' period to decrease the satellite altitude from 720 km to 410 km, and then will go on at this altitude during 1 year in order to qualify the propulsion system in low earth orbit conditions. The Israeli Space Agency is in charge of this mission.

The aim of this presentation is to introduce VENµS, its potential and to open the way to the other presentations that will show how the exploitation is managed, the first results and more, …

VENµS: SPECIFICITIES OF IMAGE QUALITY AND IN-ORBIT CALIBRATION MONITORING

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Earth observation satellites like Sentinel-2 or Landsat 8 have already demonstrated the importance of a global coverage associated with high resolution (about 10 m) for regional and country scales applications. These applications, such as detailed land-cover mapping, agri-environment policies, water management, vegetation primary productivity and yield estimates, are crucial for defining global change mitigation or adaptation policies. To prepare the future earth observations systems, users raised one question about the increasing of the revisit period in order to limit the impact of cloud-coverage on the applications and to capture rapid phenomena. In this context, VENµS products offer an undeniable added value to explore the benefit of expanding the time rate of high resolution acquisition in visible and near infrared spectral bands.

VENµS provides 5 and 10 m resolution images in 12 shortwave spectral bands every two days over a set of 123 scientific sites, with constant viewing angle and overpass time. Firstly, this article presents briefly the main characteristics of the mission and available products. Then, it explains the objectives and the activities of radiometric and geometric calibrations. A special focus is made on the different radiometric and geometric calibration methods and the associated calculated performances.

VENµS data are freely available to everybody for peaceful and non-commercial uses on the French Theia land data center: http://www.theia-land.fr. Continuous observations will be performed all along the scientific mission duration, until mid-2020.

Using Venus to Map Daily Evapotranspiration over Irrigated Agricultural in Arizona

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Sustainability of irrigated agriculture in the U.S. Southwest is threatened by water shortages and the challenge of managing salinity. One way to reduce the threat and improve crop water management is to use remote sensing observations to help map daily evapotranspiration (ET) at fine spatial scales. The maps, when combined with crop growth forecast models and local management expertise, can improve crop water management, ET forecasting, and irrigation scheduling. The Venus mission has capabilities to realize these improvements in three ways: 1) its high frequency observation periodicity enables nearly daily charting of crop cover and leaf area, 2) its high spatial resolution (5-10 m) provides detail that makes possible crop monitoring and management within fields, and 3) Venus' multispectral capability resolves canopy density variations not feasible with conventional NDVI-based mapping.

Since 2018 we have been using Venus to track crop growth and ET over crops grown in two significant irrigation districts in Arizona: Yuma, where over 80% of leafy greens are grown for North America during winter months, and in the Ak-Chin Indian Community, where long season crops such as cotton, alfalfa, corn and potato are grown. Differences between ET and cover mapping results using conventional and Venus satellite data will be shown.

The SkyHopper Space Telescope CubeSat

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The SkyHopper Space Telescope is an Australian-led international 12U CubeSat mission funded for detailed definition which aims at establishing a breakthrough in low-cost astronomical infrared observations from space. SkyHopper, expected to launch by late 2022, will carry an actively cooled four-channel camera covering the spectral range from 0.8 to 1.7 micron simultaneously, and be capable of autonomously pointing to new targets within two minutes. The combination of timeliness on target and low-noise infrared image quality from space will offer a facility unique in the world for multiple areas of astronomy, from discovery of potentially habitable Earth-size planets around nearby cool stars to rapid follow-up of astrophysical transients such as afterglows of Gamma Ray Burst explosions originating from the edge of the observable Universe. SkyHopper will be launched in a Sun-synchronous low-Earth orbit with an initial two-year long primary science mission. Here, we will provide an overview of the science case and of the spacecraft design focusing in particular on the thermal management of the telescope and camera and on solutions for low-latency, near 24/7 communications.

Novel solar soft X-ray imaging spectroscopy from a CubeSat platform

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We present a proposed small satellite pathfinder mission, the CubeSat Imaging X-ray Solar Spectrometer (CubIXSS), to measure spectrally-resolved, spatially-isolated soft X-rays (SXRs) from the quiescent and flaring Sun from a 6U CubeSat platform in low-Earth orbit during a nominal 1-year mission.

A critical observational gap exists from 0.2 to 3 keV (4–60 Å), where spectrally-resolved stellar observations are plentiful but have not been routinely made for the Sun in many decades. These SXR emissions provide crucial diagnostics of plasma temperature distributions, as well as elemental abundances that probe plasma origins over a wide range of temperatures, that are not available from observations at other wavelengths but are essential for understanding plasma heating, particle acceleration, and energy transport from magnetic reconnection processes in both solar flares and quiescent active regions.

The primary CubIXSS instrument is the Multi-Order X-ray Spectral Imager (MOXSI), a novel spectro-spatial imager utilizing a custom pinhole camera and Chandra-heritage X-ray transmission diffraction grating to provide full-Sun imaging spectroscopy. MOXSI covers the 0.2 to 10 keV (1–60 Å) passband with 0.25 Å FWHM spectral resolution and moderate spatial resolution of 25 arcsec FWHM, sufficient to isolate solar flares and active regions from their ambient surroundings. Additional pinholes with tailored filters provide non-dispersed images with coarse spectral information to seed analysis of the dispersed spectro-spatial images and for improved sensitivity to quiescent conditions. MOXSI’s unique capabilities enable SXR spectroscopy and corresponding temperature and elemental abundance diagnostics of individual flares and active regions over a spectral range never before accessed by any prior solar mission.

MOXSI is supported by low-noise, commercial off-the-shelf (COTS) SXR spectrometers enabling full-Sun SXR spectroscopy from 0.5 to 20 keV with 0.15 keV FWHM spectral resolution. Multiple detectors and tailored apertures provide sensitivity from deep solar minimum to X5 flares.

CubIXSS is a pathfinder for larger SmallSats with improved sensitivity and spatial and spectral resolutions.

Cubesats for UV astronomy

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II shall show that valuable science in the domain of ultraviolet astronomy can be obtained using cubesat platforms. I shall present conservative preliminary designs based on refractive optics and sized for a 3u platform, as well as a concept design based on easily-aligned deployable mirror petals. I suggest that one valuable astronomical goal of a cubesat mission could be the survey of the 217.4 nm extinction band. Another could be a pilot survey for transient events.

SEEJ: Smallsat Exploration of the Exospheres of Nearby Hot Jupiters

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The first detected exoplanets found were “Hot Jupiters”; these are large Jupiter-like planets in close orbits to their host star. The stars in these so-called “Hot Jupiter systems” can have significant X-ray emission and the X-ray flux likely changes the evolution of the overall star-planetary system in at least two ways:

(1) the intense high energy flux alters the structure of the upper atmosphere of the planet -- in some cases leading to significant mass loss;

(2) the angular momentum and magnetic field of the planet induces even more activity on the star, enhancing its X-rays, which are then subsequently absorbed by the planet.

If the alignment of the systems is appropriate, the planet will transit the host star. The resulting drop in flux from the star allows us to measure the distribution of the low density planetary atmosphere. We describe a science mission concept for a Smallsat Exploration of the Exospheres of hot Jupiters (SEEJ; pronounced “siege”). SEEJ will monitor the X-ray emission of nearby X-ray bright stars with transiting hot Jupiters in order to measure the lowest density portion of exoplanet atmospheres and the coronae of the exoplanet hosts. SEEJ will use revolutionary Miniature X-ray Optics (MiXO) and CMOS X-ray detectors to obtain good collecting area and high sensitivity in a low mass, small volume and low-cost package. SEEJ will observe scores of transits occurring on select systems to make detailed measurements of the transit depth and shape which can be compared to out-of-transit behavior of the target system. The depth and duration of the of the flux change will allow us to characterize the exospheres of multiple hot Jupiters in a single year. In addition, the long baselines (covering multiple stellar rotation periods) from the transit data will allow us to characterize the temperature, flux and flare rates of the exoplanet hosts at an unprecedented level. This, in turn, will provide valuable constraints for models of atmospheric loss.

C^{3}IEL : Cluster for Climate and Cloud Imaging of Evolution and Lightning, an innovative way to observe clouds and their environment

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The French-Israeli C^{3}IEL (Cluster for Climate and Cloud Imaging of Evolution and Lightning) is an innovative mission currently in the pre-formulation stage 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 the interactions with their environment at a high spatial and temporal resolutions of the scales of the individual convective updrafts. The C^{3}IEL coordinated train of nano-satellites will carry visible cameras measuring at a spatial resolution of ~20 meters, near-infrared imagers measuring in and near the water vapor absorption bands, and optical lightning sensors and photometers. The observations of these space-borne sensors will 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 C^{3}IEL mission will be introduced, and the nano-satellite train configuration, the observational strategy and the different sensors of the mission will be discussed. Finally, we will introduce the observations and products of the C^{3}IEL 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.

Maritime Aerosol Network as a component of AERONET – an opportunity for collaboration

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Maritime aerosol network as a component of AERONET was established in 2006.

MAN deploys hand-held sunphotometers (Microtops) aboard ships of opportunity.

Aerosol optical depth over oceans is a very important atmospheric parameter. The interest to the data is high in various scientific communities (ocean color, global aerosol transport modelling, satellite remote sensing). We provide instruments, calibration and processing. The major advantage of our activity is the fact that hand-held sunphotometer calibration and processing are tied to the AERONET standard.

We have been successful negotiating with various government agencies and institutions in the US, UK, Poland, Germany, France, Canada, Russia, Italy, South Africa, Spain, Australia, and New Zealand regarding the possibility of ship-borne measurements. Overall about 550 cruises have been completed and many are ongoing or planned.

The current status of the network can be found at
https://aeronet.gsfc.nasa.gov/new_web/maritime_aerosol_network.html

The data are in a public web-based archive and available for the scientific community at large. The collected data will make an important contribution, will enhance our knowledge and help the scientific community better understand aerosol optical properties over the oceans.

Being a component of AERONET, Maritime Aerosol Network provides an excellent opportunity for collaboration.

Using a single band Nano Satellite for Earth Observations (EO): Lessons learnt from BGUSAT

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EO missions using nano-satellites have been successfully launched and used in the past years. Forecasts for the upcoming years display an increase of such missions. BGUSAT is a remote sensing single band, SWIR sensor via a spatial resolution of 600 meters per pixel.

BGUSAT was launched as a secondary payload from India on the PSLV-37 on February 2017 as part of collaboration between the Israeli Aerospace Industries (MBT), Ben-Gurion University of the Negev and the Israeli Space Agency. As opposed to established and well known satellites and their EO sensors, the properties and the feasibility to conduct a scientific research using BGUSAT was yet unknown and was thus addressed in this research. Such a sensor upraises the question of tradeoff between spatial resolution and spectral coverage according to the scientific usage. Thus, the overall objective was to provide a study using a low spatial resolution imaging system at a wave length of approximately 1600 nm that might give way to mapping atmospheric and LULC phenomena`s. A comparison of BGUSAT images with other well established and known earth observation satellites was applied to investigate the potential contribution of single band images.

In the presentation, we intend to overview the satellite design and capabilities and present results of the ongoing research. A primary conclusion that we set to demonstrate is that in comparison to large known and widespread operational satellites, cubesats can achieve equivalent and improved results with the advantage of high temporal resolution and beneficial spatial resolution of LEO.

THE VENµS MISSION: A TOOL FOR THE SCIENTISTS, A CONTRIBUTION TO PREPARE THE NEXT GENERATION OF SENTINEL 2

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The VENµS mission is the result of cooperation between France and Israel. The satellite carries a super-spectral camera characterized by 12 narrow spectral bands ranging from 415 nm to 910 nm. The main features of VENµS are a 2-days revisit time, 27 km swath, a camera resolution of 5.3 m, and the capability to observe any site at constant view angle and local time.

VENµS mission was launched on August 1st, 2017, and the commissioning phase ended on March 2018.

We will first present a brief history of the mission concept and of its scientific motivations. We will then detail the scientific objectives and preliminary results. Briefly, the general objectives of the VENµS mission are the provision of data for scientific studies dealing with the monitoring, analysis, and modeling of land surface functioning under the influences of environmental factors as well as human activities.

The last part of the presentation will be devoted to the possible role of VENµS data for improving or validating the algorithms applied to Sentinel-2 data and especially the usefulness of VENµS for the preparation of the next generation of Sentinel-2. One of the questions raised by the users regarding Sentinel-2 is the possibility of increasing the revisit period in order to limit the impact of cloud-coverage on the applications and to capture rapid phenomena. VENµS is clearly the right tool to explore the benefit of an increased revisit of Sentinel-2 Next Generation.

LAND MONITORING ASPECTS BY SENTINEL-2 AND VENμS

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A joint JCT-IAI working group was established recently to demonstrate monitoring with the Venμs satellite of the ecological state of a typical mediterranean ecosystem using NPP as example. This presentation will give an overview of the status of this work and preliminary results. A comparison with equivalent S2 results will be discussed and insights for recommendations on similar future missions in terms of spatial, spectral and temporal resolutions in order to complement existing missions.

The ESA satellites Sentinel-2 (S2) and the joint French-Israeli microsatellite Venμs μare two of the most recent satellites put into orbit for land monitoring. Each satellite falls into a different mass category. With a launch mass of 1140 kg, S2 is a standard size satellite while Venμs with a launch mass of 265 kg, that is four times less, falls into the category of mini-satellites. While the observation of vegetation is the main objective of VENμS, S2 has broader mission applications but the observation of land biomass is one of its primary objectives. Those two missions have some commonalities, in particular in terms of spectral bands, and also some differences, for instance in terms of revisit and considering that the S2 are a series of satellite. In order to optimize the design of future sensors for land monitoring we analyze the advantages and limitations of each of these systems based on in-orbit imaging results and try to quantify the added value of larger satellites versus mini-satellites for such missions.

Monitoring Inland Waterbody from Multiple Remote Sensing Satellites: A Case Study in Tsengwen Reservoir, Taiwan

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Operational retrieval of water parameters over inland waterbodies usually requires solid infrastructure and costly maintenance. Owing to the increasing amount of satellite imageries with high spatial resolution, it becomes possible to obtain useful information for small waters in a regular manner. Tsengwen Reservoir, a major freshwater storage located in Chiayi county of Taiwan, is an important hydrological facility for irrigation and industrial water supply. However, due to the trends in weather extremes and uneven distribution of precipitation, Tsengwen Reservoir has experienced high variability of water storage between 1.2×10^8 m^3 and 5.1×10^8 m^3 in difference seasons. This study demonstrates a workflow to first reconstruct slope digital elevation model from a series of optical satellite images, including the Vegetation and Environment monitoring on a New Micro-Satellite (VENµS) mission, and then to track water level and water volume changes from a densified time series composed of multiple optical satellites. Our preliminary results show that an inclusion of VENµS images is able to increase water level accuracy from meter to decimeter level. The water volume estimates are in a range of 5%–10% when we add VENµS image sources in addition to other mid-resolution imageries, such as Landsat family and Sentinel-2 data. It is concluded that microsatellite missions are a network of supportive dataset which can help on decision making and planning in hydrological management.

ASSESSMENT OF CHICKPEA MORPHO-PHYSIOLOGICAL TRAITS BY VENµS ALL BANDS AND VEGETATION INDICES

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Chickpea (*Cicer arietinum*) is an important grain-legume worldwide and water-stress is a major constraint to its productivity. Area under chickpea cultivation is recently growing. Moreover, global climate change toward greater aridity resulted in higher fluctuation in precipitation. Thus, improved ability to spatially assess plants water status can promote more efficient irrigation. The current study aims to assess water potential, leaf area index, biomass and grain yield by VENµS (Vegetation and Environment monitoring on a New MicroSatellite). During the growing season of 2018-2019, field experiments were grown in three locations, representing different climatic conditions across Israel. Five irrigation regimes were applied: 50%, 75%, 100%, 125% and 150% of Penman-Monteith evapotranspiration were implemented in Giva'at Haim and Or HaNer. In Gilat the 75% and 125% treatments were applied in plots that are relevant to VENµS pixel size. Plants were characterized weekly for morpho-physiological traits, and yield data will be obtained in the end of the experiment. Preliminary results showed differences in vegetation indices values as well as in water potential, biomass and LAI values. We will discuss the potential of using VENµS data for assessment of morpho-physiological traits and yield components in chickpea.

VENμS observations over Israel

Arnon Karnieli

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Taking advantage of the tilting capabilities of the VENμS, the State of Israel is covered by 27 tiles of 27x27 km each within three long strips, 27-km swath each. The western strip, observed in forwarding view angle, starts north of Rosh Anikra, passes Haifa Bay and the Mediterranean coastal plain, and ends in the Nizzana sand dunes by the border with Egypt. The eastern strip starts north of the Hermon Mountain, passes Lake Kinneret, and ends south of Emek Beth Shean. The southern strip starts north of Perosdor Yerusalaim, passes the vicarious calibration site at Shizafon Playa, and ends in the Gulf of Eilat. The eastern and southern strips are observed in backward view angles. The location of the VENμS orbit and the view angles were determined in order to minimize sun glints from the Mediterranean and Lake Kinneret. The three strips were selected in order to optimize monitoring the agricultural areas of the country, the national reserved and parks, natural and planted forests, as well as the long-term ecological research (LTER) sites.

The VENμS scientific center was established at Sede Boker Campus of Ben Gurion University. This center coordinates the national activities that are derived from the VENμS scientific mission. Among these: receiving Level 0 and Level 1 images from CNES; convert Level 1 to Level 2 and Level 3; developing unique algorithms and applications for using the data; distribute images among certified end-users in Israel, and maintain the national archive for the VENμS images over Israel. In addition, the center will carry out the vicarious radiometric calibration activities in the Negev site. For the calibration and for accurate atmospheric correction, aerosol optical thickness and water vapor are monitored by sunphotometers in 5 designated locations across Israel: Eilat, Sede Boker, Rehovot, Haifa, and Kiryat Shemona.

CAMELOT: Cubesats Applied for MEasuring and LOcalising Transients - Mission Overview and In-Orbit Demonstration

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We will present the results of our feasibility study, and the progress towards building the in-orbit demonstration satellite, for the CAMELOT (Cubesats Applied for MEasuring and LOcalising Transients) mission, which will be a fleet of nano-satellites designed to perform an all-sky monitoring and timing based localisation of gamma-ray transients, some of which are the electromagnetic counterparts of gravitational waves (GW) detected by LIGO/Virgo. CAMELOT will measure the time difference between the arrival of the signal at the different satellites and determine the location of gamma-ray bursts (GRBs) in the sky by triangulation. The satellites will downlink the data about the detected transients within minutes. LIGO/Virgo have a modest localisation accuracy, limiting our knowledge about the events that produce GWs. Simultaneous detections of GWs and GRBs, with accurately measured locations, will therefore be important for enabling quick follow up observations, providing valuable multi-messenger information about these astrophysically important phenomena. They will also allow us to identify sub-threshold GW events, extending the sensitivity of LIGO/Virgo.

Currently, we are in the construction phase for a demonstration mission, which will validate the design of the detector system, as well as the time-stamping electronics, onboard processing, data handling and analysis. We will describe the detector development and testing on high-altitude balloon flights. We will also present the design of the in-orbit demonstration mission, which is scheduled to take place in the end of 2020.
The CAMELOT mission provides ample potential for international collaboration and we are communicating and cooperating with teams in several other countries.

INFRARED SMALLSAT FOR CLUSTER EVOLUTION ASTROPHYSICS (ISCEA)

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The proposed Infrared SmallSat for Cluster Evolution Astrophysics (ISCEA) mission will significantly advance our understanding of galaxy evolution through observations of galaxy clusters and their cosmic web environments. These observations will help us understand how galaxies evolved in the cosmic web of dark matter during the peak epoch of galaxy formation. ISCEA will conduct a complete census of the star formation activity in a large mass-limited sample of the earliest thermalized galaxy clusters by mapping the 3D distribution of galaxies down to a star formation rate limit of 5 $M_{\odot}$/yr out to a radius of 10 Mpc for all clusters more massive than 10^{14} $M_{\odot}$ at 1.6 z 2.4, while probing the cosmic structure surrounding each cluster as traced by emission line galaxies. These observations will permit a detailed study of the star formation activity as functions of cluster mass, radius and environmental density over the key Gyr in which clusters coalesced from the cosmic web, providing key insights into galaxy evolution during this critical epoch.

The ISCEA instrument is an innovative cost-effective multi-slit near-infrared spectrograph from Southwest Research Institute, with a field of view 200 times that of the Hubble Space Telescope; it is capable of observing 500 galaxies simultaneously over a range of 0.9 to 1.7 µm, a regime not accessible from the ground without large gaps in coverage. Pointing control of better than 2 arcseconds is provided by the Blue Canyon Technologies, Inc. high performance 150 kg class small satellite. The COSPAR 2019 presentation will provide an overview of the ISCEA science and information regarding the implementation of the ISCEA small satellite.

THESEUS: a candidate ESA M5 space mission

Enrico Bozzo
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THESEUS is a mission concept proposed in response to the ESA call for medium-size mission (M5) within the Cosmic Vision Programme and selected by ESA on 2018 May 7 to enter an assessment phase study. The mission is designed to vastly increase the discovery space of the high energy transient phenomena over the entirety of cosmic history. This is achieved via a unique payload providing an unprecedented combination of: 1) wide and deep sky monitoring in a broad energy band (0.3keV - 20 MeV); 2) focusing capabilities in the soft X-ray band providing large grasp and high angular resolution; and 3) on board near-IR capabilities for immediate transient identification and redshift determination.

In this contribution I will present the current status of the project about one year after the beginning of the phase A study coordinated by ESA.

High Performance Near and Far Ultraviolet Camera for Star Planet Activity Research CubeSat (SPARCS)

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Star-Planet Activity Research CubeSat (SPARCS) observatory is a funded mission by NASA's Astrophysics CubeSat Program. A 6U CubeSat led by Arizona State University, SPARCS objective is to provide the UV context for the atmospheric signatures of planets in the habitable zone of M dwarf stars. In depth characterization of the UV environments of M dwarf planets will be crucial to understanding the effects of the star activities on planet atmospheric composition and will help to delineate biological and abiotic sources for observed biosignatures. SPARCS is designed for observation of M stars in two spectral bands in the near ultraviolet (NUV, 260-300 nm) and far ultraviolet (FUV, 150-170 nm). NASA's Jet Propulsion Laboratory is responsible for delivery of the two channel UV camera, SPARCam.

Two 2D-doped CCDs optimized for NUV and FUV are the enabling technology of SPARCam. The NUV detector uses a custom antireflection (AR) coating to achieve ~ 70% external quantum efficiency (QE). The FUV detector incorporates an integrated filter and is designed to maximize the in-band FUV sensitivity (QE35%) and reduce the out of band detection (better than two orders of magnitude ≥OD2 red leak suppression). Comparing these detector performances with previously flown microchannel plate-based detectors, a factor of five improvement is achieved in the overall throughput of the system.

We will present a brief overview of SPARCS and the SPARCam architecture with focus on the high-performance UV detectors for the far ultraviolet and near ultraviolet channels.

GMOD: The Gamma-Ray Module on EIRSAT-1

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EIRSAT-1 (Educational Irish Research Satellite) is a 2U CubeSat developed by students at University College Dublin (UCD) as part of the European Space Agency’s (ESA) Fly Your Satellite! program. Upon launch, EIRSAT-1 will be Ireland`s first satellite and will feature a number of scientific payloads originally developed at UCD. This includes GMOD: a miniaturised gamma-ray detector to study high energy transients such as gamma-ray bursts (GRBs).

EIRSAT-1 will be the first spacecraft to incorporate OnSemiconductor (SensL) silicon photomultipliers (SiPMs) in a space-based gamma-ray instrument. It will feature an array of 16 SiPMs coupled to a 25x25x40mm Cerium Bromide crystal. The SiPM readout will be conducted by the SIPHRA application specific integrated circuit, designed by IDEAS Norway. A yield of 12 GRBs over 1 year with 10-sigma significance including 1 short GRB is expected from GMOD.

Other payloads include the ENBIO Module: an experiment to test ENBIO coatings to be used on ESA`s Solar Orbiter and Wave Based Control: a UCD developed control system for flexible spacecraft structures and under-actuated systems. These experiments, GMOD in particular, will further the applied sciences developed in UCD and will raise the TRL for future Irish space missions in larger CubeSats and constellations with the ultimate aim of localisation.

The EIRSAT-1 Engineering-Qualification Model is currently under development with environmental testing planned for the Autumn of 2019. Currently, the Flight Model is planned for delivery in mid 2020 with an expected launch to the ISS for deployment later in that year.

JM presenting on behalf of the EIRSAT-1 team.

Radiation belt monitoring in the Universat-SOCRAT multi-satellite mission

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D. V. Skobeltsyn Institute of Nuclear Physics of M. V. Lomonosov Moscow State University (SINP MSU) is developing the new project Universat-SOCRAT intended for monitoring of space factors being a threats space missions: ionizing space radiation, electromagnetic transient luminous events in the atmosphere, asteroids and space debris, and powerful gamma ray bursts in space. A system of small satellites will be launched into specially selected orbits crossing the wide range of magnetic drift shells at different altitudes. The primary scope for the project is the operational monitoring of near-Earth's radiation environment: fluxes of electrons and protons of Earth's radiation belts and energetic particles of solar galactic origin. The energetic particles are responsible for an enhanced radiation exposure, ionization effects, internal charging, single event effects and other hazards that can prevent human activity in spacecraft altitudes as well as in the upper and lower atmosphere and on-ground. These space factors also represent a significant health risk for manned spacecraft crew and passengers onboard aircraft. Activity in terms of Universat-SOCRAT project can address so far unanswered questions of detection and dosimetry of ionizing radiation both of cosmic and terrestrial origin and will contribute to the improvement of space weather models, air transport safety measures and global navigation systems reliability.

using Pairs of Cubesats

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It has long been recognized that an excellent way to study the fine structure of bursty energetic electron precipitation and, in particular, greatly aid in separating spatial and temporal variations would be use multiple satellites. The advent of Cubesat technology has permitted the fielding of satellite missions consisting of two satellites in close formation for an affordable cost. Two such missions are Aerocube-6 and FIREBIRD; these two LEO missions have returned a wealth of data over the last few years. Among the unexpected findings are the existence of "curtains" of precipitating energetic electrons that have latitudinal scale sizes of a few kilometers or less and can persist for a minute or more. The measurements have shown also that bursts of precipitation, viewed in the local bounce loss cone, often have different temporal intensities and spatial structures even with a satellite spacing of only a few kilometers. The high-altitude scattering process, presumably chorus, thus often creates finely structured precipitation patterns at the top of the atmosphere. Typical examples of these highly-structured observations will be shown and discussed.

The Low-Latitude Ionosphere/Thermosphere Enhancements in Density (LLITED) Mission

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The Low-Latitude Ionosphere/Thermosphere Enhancements in Density (LLITED) CubeSat mission is a funded mission through NASA HTIDs program. It is a 3-year grant with CubeSat delivery at 20 months and a 1-year on-orbit mission life. Currently, delivery of the spacecraft is scheduled for February 2020. The mission is to provide both ionosphere and thermosphere measurements related to the Equatorial Ionization Anomaly (EIA) and the Equatorial Temperature and Wind Anomaly (ETWA). The EIA and ETWA are two of the dominant ionosphere/thermosphere interactions on the low-latitude duskside. While the EIA has been extensively studied both observationally and with modeling, the ETWA is less well known since observations are infrequent due to a lack of suitably instrumented spacecraft at appropriate altitudes. LLITED will, for the first time, provide coincident high-resolution measurements of the duskside ionosphere/thermosphere at lower altitudes that will characterize and improve our understanding of the ETWA, provide insight into the coupling physics between the ETWA and EIA, and increase our knowledge of the duskside dynamics that may influence space weather.

The LLITED mission will consist of two 1.5U CubeSats in a high-inclination circular orbit, with an orbit altitude between 400 and 500 km. The CubeSats will maintain a 1/4 to 1/2 orbit separation to each other in order to observe any temporal changes as the ETWA evolves. The bus and subsystems are provided by The Aerospace Corporation. Both CubeSats will host three payloads: an ionization gauge (IG), planar ion probe (PIP), and GPS radio occultation sensor (GPSRO). The Aerospace Corporation is providing the IG and GPSRO sensors and Embry-Riddle is providing the PIP. The products provided are in-situ neutral pressure/density, in-situ plasma density, and slant TEC. The observations from LLITED will be combined with other available data to provide a comprehensive and compelling dataset of the ETWA.

IGOSat – a 3U educational CubeSat for measuring the ionospheric Total Electron Content and characterizing the radiation belts electrons and gamma-ray emission.

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IGOSat (Ionosphere and Gamma-ray Observations Satellite) is a nanosatellite aimed to measure the Total Electronic Content (TEC) and the Gamma-ray radiation at low Earth orbit and in Earth's ionosphere. Its areas of interest are the Aurora zones and the South Atlantic Anomaly (SAA).

The selected configuration consists of two small payloads: one based on a novel kind of scintillator, CeBr3 based, for radiation belts gamma-ray and electrons characterization; the other on a dual band GPS receiver for the measurement of the TEC (total electrons content) of the ionosphere, through occultation technics. These 2 payloads will be hosted on a 3U CubeSat platform, orbiting the Earth at an altitude of about 600 km and inclination of about 97°.

The project is supported by the French Space Agency (CNES) and the University Paris Diderot, in collaboration with three laboratories (APC, IPGP and AIM), gathered within the LabEx (Laboratory of Excellence) UnivEarthS. It has started in 2012, and is presently in phase D, where we are building the Qualification Model. The Flight Model construction and the satellite launch are planned for 2020. Beside its scientific interest, one main objective of IGOSat is educational and thus to give hands-on experience to students in a space project. More than 270 students have already worked for IGOSat

This paper will describe the scientific and educational objectives of IGOSat, the mission, the payloads and their associated technology.

Shields-1 Preliminary Radiation Shielding Dosimetry in Polar Low Earth Orbit

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NASA Langley Research Center Shields-1 has maintained operations in polar low earth orbit for over 6 months and continues taking radiation shielding dosimetry measurements with multiple dosimeters behind varying areal densities of radiation shielding from 1 to 6 g/cm2. On 16 December 2018, Rocket Lab USA successfully placed Shields-1, an Educational Launch of Nanosatellites (ELaNa) XIX payload, into polar low earth orbit. Shields-1, a 3U CubeSat, contains three experiments: a radiation shielding dosimetry experiment with an aluminum baseline and atomic number (Z)-radiation shielded electronics enclosure with dosimetry measurement, and resistance measurements on a charge dissipation film. Preliminary dosimetry data inside the spacecraft shows a significant reduction in total ionizing dose in comparison to Space Environment Information System (SPENVIS) Multi-Layered Shielding Simulation (MULASSIS) polar low earth orbit modeled total ionizing dose calculations. The Shields-1 dosimetry is also anticipated to provide radiation belt information, such as the South Atlantic Anomaly and other polar low earth orbital regions, for multiple particle energies based on the shielding thicknesses in front of the multiple dosimeters onboard Shields-1. These recent dosimetry measurements are anticipated to provide a range of particle belt energetic data in polar low earth orbit in support of space research and radiation effects on spacecraft.

The potential of LEO CubeSats for science, and radiation environment specification.

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Flights of small satellites in the lower-end of the Low-Earth Orbit (LEO) environment, at altitudes 400-800km, provide an opportunity to measure both precipitating and locally trapped particles. This can be accomplished with a simple one-directional narrow field of view detector, spinning fast (a few seconds) along and across the local magnetic field. The trapped particle fluxes at lower-end of LEO are close enough to those at the higher-end, 800-4000km, such that extrapolation using simple functional forms of flux variation with pitch-angle obtained from the lower-end can result in good specification of fluxes at the higher-end. Because the lower-end LEO environment (especially near 450km or below) does not suffer from radiation effects, highly capable CubeSats can now be launched at a low cost and in large numbers to achieve significant scientific returns even during their short lifetime (1-2 years to passive re-entry). Therefore, a new way of comprehensively exploring the complex space environment from lower-end LEO is now emerging. These can serve both as scientific trailblazers and space environment monitors. Cross-calibration and absolute calibration are both important, and current missions (e.g., POES) can be used to facilitate that. We discuss new science that has been obtained from such missions and provide ideas for future exploration with new concepts from that altitude.

ESTIMATION OF FUNCTIONAL AND STRUCTURAL TRAITS OF C3 AND C4 CROPS USING VENUS AND IN SITU REFLECTANCE DATA

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VENμS was designed to provide multi-temporal (ever 2 days), multi-spectral reflectance data for monitoring and analyzing land surfaces over selected sites. Here, we report on the comparison between VENμS reflectances to ground-based measured reflectances (4-band SKYE radiometers) at three AmeriFlux agricultural sites (maize and soybean), NE USA, and estimating crop structural and functional traits. Reflectances from four spectral Venus bands, similar to the Skye radiometer bands (green, red, red edge and NIR) from the 2018 growing season were compared showing good correspondence. Two traits of both crops, structural - green LAI, and functional - fraction of PAR absorbed by photosynthetically active vegetation ($fAPAR_{green}$), were estimated using VENμS and SKYE reflectances; Normalized Vegetation Index (NDVI), green NDVI (NDVIgreen), red-edge NDVI (NDVIred edge), the Wide Dynamic Range Vegetation Index (WDRVI), and the Chlorophyll Index (CIred edge) were used. The relationships between the VIs and the crop biophysical properties differed slightly but with similar trends. NDVI, NDVIred edge and WDRVI were highly correlated to LAIgreen for both satellite- and ground-based systems while NDVI, NDVIgreen, NDVIrededge and WDRVI were moderately correlated to fAPARgreen. Algorithms using VENμS red edge spectral bands allowed estimation of green LAI in both crops with no re-parameterization. Comparisons between satellite-based and ground-based reflectances and VIs through the growing season indicate the potential of VENμS spectral data for monitoring and analyzing land surface functioning. Comparisons will continue for the 2019 growing season; VI relationships will be applied to estimate crop biophysical properties and phenology.

MAPPING CROP PHENOLOGY USING VENµS OBSERVATIONS OVER MARYLAND EXPERIMENTAL SITES

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Crop growth stages are critical in scheduling irrigation, fertilization, and harvest operation. For decades remote sensing data have been used to extract vegetation phenology by utilizing mathematical functions to describe crop growth and development. However, results somewhat depend on the availability of earth observations, especially during critical growth stages. Vegetation phenology products, at kilometer resolutions, are commonly available today. Nevertheless, these resolutions are too coarse to monitor crop growth at the field scale and difficult to validate at such coarse resolutions. Moreover, remote sensing phenology and crop growth stages represent different crop properties so they are not interchangeable The VENµS observations with 2-day repeat and 5-m resolution provide an opportunity to map crop phenology at field scales since the fine spatial resolution is more suitable to be validated using ground observations and the PhenoCam photos. In this presentation, we demonstrate a near real-time algorithm for detecting crop emergent dates. Our results using VENµS images over the Choptank River watershed in Maryland, USA, show that crop emergence can be reliably mapped. Different green-up dates of the forest, corn, and soybeans match the PhenoCam observations and agree to the state-level crop progress reports from the USDA National Agricultural Statistics Service (NASS). Separating single and double-crop soybeans, which is a challenge in traditional crop classification, were differentiated in green-up dates. Based on these findings, this study indicates future opportunities to map crop growth stages at field scales using high temporal and spatial resolution remote sensing data.

THE EFFECT OF LESS THAN 2 MINUTES AND VIEWPOINT ON VEGETATION INDICES OBTAINED BY VENµS

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In Israel, Vegetation and Environment monitoring New Micro Satellite (VENµS) obtains 27 tiles in three strips: west (W), east (E), and south (S). The western strip is imaged first with forward view, then the eastern and southern strips are imaged with backward view. The focus of the current study is on ~320 km^2 in which tile S01 overlaps tile W08. This unique image acquisition allow exploring the combined effect of the time difference and view angle change on spectral data. Several locations with different vegetation types were chosen. Data analysis shows that the changes in vegetation indices values are in different trends for comparing the images of the different tiles on the same day. The trends are also changing for different vegetation types. This information will allow better understanding data analysis of VENµS data in Israel, in more locations, and might be useful for imagery obtained by other satellite-mounted sensors.

Impact of flux footprint heterogeneity of agricultural site on surface-atmosphere exchange

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Vegetation dynamics and characteristics in the changing area of footprints of eddy covariance sensors influence the measurements. The objective of the study is twofold: 1/ estimation of flux footprints variation and heterogeneity during the vegetation development using high spatial resolution satellite data; 2/evaluation the impact of land cover heterogeneity on the evapotranspiration (ET) and gross primary productivity (GPP) in the course of vegetation season of two crops. The study started in 2018 at field (cca 45 ha) seeded with cover crop of legume-cereals and clover (*Trifolium pratense*) - stable crop in 2019 season. The flux footprints of eddy covariance (EC) tower have been predicted using simple parametrization method (Kljun 2004) and calculation of the ET and GPP using standard ICOS protocols. We used the VNIR bands of the Venus and Sentinel-2. Moreover, we acquired airborne hyperspectral data (CASI, 1 m, 10 nm) at date of the satellite overpasses, resampled it to spatial and spectral resolution of each satellite data and estimated variation in satellite pixels. . Preliminary results display significant differences in footprint variability calculated from different data sources when using several vegetation indices (NDVI, EVI, RER) as a proxy of crop cover. This indicates an importance of precise information about the changes of footprint shape and size and their relation to changes in surface properties. More study is still needed in testing the procedure with other crops and focus should be paid to data preprocessing (atmospheric correction).

Crop stages and biophysical variables retrieval using VENµS observations

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The VENµS optical Earth observation mission is a unique opportunity to evaluate the contribution of dense temporal time series at high resolution to crop monitoring. VENµS' 5m-2day spatio-temporal resolution permits to characterize subtle changes in crop development.

To take advantage of these observations we aim to assimilate VENµS and Sentinel2 imaging into the SAFYE-CO2 crop model on the SUDOUE site in southern France. However, two steps are necessary to convert the VENµS reflectance data into suitable inputs for our model.

Firstly, we retrieve biophysical variables: LAI and FAPAR**.** These variables are obtained with the PROSAIL model through a LUT approach. This task also emphasizes the contribution of the B7 to B10 red-edge bands to the retrieval of LAI and FAPAR. Our preliminary results present a high correlation with Sentinel-2S SNAP LAI (RMSE=0.53 R2=0.85).

Secondly, crop calendars are retrieved per plot and main crop type. Our algorithms exploit both the temporal and spectral dimensions of the signal to detect events such as rapeseed flowering and harvest. The features of the VENµS mission increase the probability to detect such events, however this also increases the complexity of the signal compared to other optical missions. The detection of harvest exhibits a high accuracy when compared to expert readings of NDVI time series (80%).

This study will allow us to give an insight into the impact of observational density on the retrieval of crop variables such as yield and carbon storage and on the retrieval of variables and parameters used in crop monitoring.

The VENµS L2A and L3A surface reflectance products

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To allow a robust exploitation of the information provided by VENµS, users must have access to high quality time series of surface reflectance. It is therefore necessary to remove the disturbing effects of the atmosphere. This is the role of the Level 2A product, which includes an accurate and robust cloud detection, and corrects data from atmospheric effects due to variable aerosol content. Compared to classical processors based on multi-spectral relations to detect clouds and estimate aerosol content, the Maja processor - used for VENµS L2A computation - also involves multi-temporal criteria based on the fact that land surface reflectance tends to change slowly compared to the atmospheric contribution. A large scale validation effort has been done to measure the accuracy of the L2A products generated with MAJA, regarding cloud detection accuracy, validation of Aerosol optical thickness of surface reflectances.

But even with accurate surface reflectance and cloud masks, such products are still complicated to use for non specialists. The presence of clouds causes spatial and temporal data gaps in the time series and processing method must be robust to that, which is complex. Overcoming this difficulty is the role of the L3A product, which, for VENµS, provides a bi-monthly synthesis of cloud free surface reflectance.

Our presentation details the methods behind MAJA and L3A processors and details their validation results.

Prospects of the SmallSat Solar Activity/Axion X-ray Imager (SSAXI)

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Detection of soft X-rays from the Sun provides direct information on coronal plasma at temperatures in excess of ~1 MK. The **S**mallSat **S**olar **A**ctivity/**A**xion **X**-ray **I**mager (SSAXI) will combine Miniature lightweight Wolter-I focusing X-ray optics (MiXO) and monolithic CMOS X-ray sensors in a compact package to enable the capability to create solar spectral images from 0.6 – 6 keV. This spectral bandpass is key for observing diverse solar phenomena to constrain various components of coronal heating in the Quiet Sun (QS), Active Region (ARs), and microflares (*GOES* A and sub A level events). Furthermore, the spectral resolution (resolving power ~10 – 40) will allow determination of Fe, Mg, Ca, Si, S, O, and Ar abundances. Any excess in the Quiet Sun soft X-ray flux between 2 – 6 keV that cannot be described by traditional solar models, will be candidates for X-rays converted from axions in the solar magnetic field along the line of sight to the solar core. Thus, effectively imaging the solar core. Axions are a promising dark matter candidate as well as a solution to the strong charge-parity (CP) problem in quantum chromodynamics (QCD). The science prospects of such an instrument on a future SmallSat platform will be discussed in this talk as well as the proposed mission timeline.

A cubesat experiment to detect cosmic explosions in hard X rays

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With the recent explosive expansion of the cubesat-based satellites, new low-cost, rapid-development opportunities to launch scientific experiments in low-Earth orbit have materialized. Here we report the development of the LECX astrophysical experiment that will be the payload of a 2U cubesat satellite (nanoMIRAX) to be launched in the near future. The mission will detect, take spectra and localize in the sky cosmic explosions on the 30-200 keV energy range. In the current gravitational wave era, it is of paramount importance to patrol the sky for electromagnetic counterparts of gravitational wave events. The instrument employs 4 CdZnTe X-ray detectors in a 2x2 configuration. Each detector is a 10mm x 10mm square with a thickness of 2mm. The detector plane is surrounded on the lateral and back sides by a passive graded shield. The field-of-view is 53º x 53º FWHM and 90º x 90º FWZI. A new method for the determination of the incidence direction of a point source can achieve a position accuracy of a few degrees for a typical GRB. The achievable sensitivities in 10-keV energy bins permit highly significant detections of Gamma-ray bursts and other cosmic explosions at a possible rate of 2 each month. In addition, the nanosat will be a test bed for technology being developed in the framework of the MIRAX project, a hard X-ray imaging and monitoring satellite mission. In this talk we will present the nanoMIRAX satellite project and demonstrate its capabilities for the detection of cosmic explosions in the hard X-ray range.

Towards a Network of GRB Detecting Nanosatellites

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At some point in the future, we are looking forward to having multiple GRB detecting smallsats in orbit, all looking for transients and all streaming their data to the ground to somewhere in some format and from there out to the scientific community. We organized an international workshop in September of 2018 for the people working on these projects to get together and discuss how we might work together to maximize the science output of our instruments. We will report on the results from the workshop and progress made since then.

Ultra wide-field UV transient exploration satellite Hibari

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Hibari is a 6U CubeSat mission which explores transients in NUV (230–280nm). Our primary science goal is to detect the NUV counter part of gravitational wave sources. To cover the large error region of LIGO/Virgo, Hibari has an ultra wide Field ~100 deg² telescope coupled with a delta-doped BI CMOS sensitized to UV band. The limiting magnitude is 20 mag(AB) for 30 min exposure. When no major Gravitational Wave event is happening, Hibari conducts a NUV transient survey. It aims to discover a few supernovae events within 100 Mpc per year. The potential targets are the early rise in NUV of shock break out, tidal disruption event (TDE), SuperLuminous Super- Nova (SLSN), and Type Ia supernovae. The basic survey strategy is to sweep 400 deg² (4 pointings) sky per orbit. Each pointing has 5 min exposure which leads to 19th magnitude (AB) depth (5σ) in NUV. One field (400 deg2) is monitored for 3 weeks and move on to the next field. We expect to monitor 17 fields per year which corresponds to 6800 deg². In this presentation the mission concept and the development status are reported.

Glowbug: A gamma-ray telescope for bursts and other transients

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We present the design and development status of Glowbug, a 30 keV to 2 MeV gamma-ray telescope for bursts and other transients. It is funded by the NASA Astrophysics Research and Analysis program, with an expected launch in the early 2020s. Similar in concept and sensitivity to the Fermi Gamma-ray Burst Monitor (GBM), Glowbug will join and enhance future networks of burst telescopes to increase sky coverage to Short Gamma-Ray Bursts from neutron star binary mergers, including possible bursts from neutron star-black hole mergers. Given both the discovery of the burst coincident with the gravitational wave transient GW170817, and the high observed merger rate from LIGO O3, we know such joint events occur with reasonable frequency. Expanded sky coverage in gamma rays is essential, as ground-based interferometers will deliver increasingly more detections of gravitational waves from such mergers, and finding an electromagnetic counterpart is a powerful probe of the merger dynamics.

ULTRASAT's view of the transient universe: From neutron star mergers to planet habitability

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ULTRASAT is a UV space telescope with an unprecedentedly large field of view (250 sq. deg.), planned to be launched in 2022. It will revolutionize our understanding of the hot transient universe by opening a new wave band (UV) and cadence access (minutes to months), and by providing a transient detection capability similar to that of LSST (the largest ground-based optical transient survey, planned to begin operation in 2022). ULTRASAT will have a broad science impact across the fields of gravitational wave sources, supernovae, variable and flare stars, active galactic nuclei, tidal disruption events, compact objects, and galaxies. A review will be given of ULTRASAT's capabilities and science goals, with a focus on the detection of electro-magnetic (EM) emission from mergers of binary neutrons stars, that are detectable by gravitational wave detectors.

Constellation of CanSats to explore Van Allen Belts

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Giant donut-shaped swaths of magnetically trapped, highly energetic charged particles surround the Earth. Ever since their discovery in 1958, Van Belts have became a bottleneck for Medium or High Earth Orbit satellites or deep space missions. Our current technology is ever more susceptible to these accelerated particles because even a single hit from a particle can upset our ever smaller instruments and electronics. As technology advances, it`s actually becoming even more pressing to understand and predict our space environment. This paper presents a sustainable approach to collect data from the Van Allen belts, using constellation of CanSats which would have high high end electronics to collect the radiative data from the belts and transmit it to the Earth. The system level architecture developed, allows redundancy in terms of functionality of the satellites, to ensure data acquisition even when one type of instrument would have failed. The mission architecture proposed through the paper has been designed to maximize the observable data from the belts. Tables will also be given to depict the amount of time that will pass at each mode of launch and more importantly, some idea on the cost in terms of energy, as well as money, will be discussed within today`s context. Even though the possibility of such a mission is probably non-existent for this decade, it is essential to do these exercises so that mankind`s understanding of the Van Allen Belts could be increased. In addition, this paper hopes to underline few ground work required in order to explore more of the Van Allen Belts.

Insights on Radiation Belt Precipitation and Losses using Low-Altitude Measurements in Conjunction with NASA's Radiation Belt Storm Probes

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The FIREBIRD-II CubeSats (FU3 and FU4) have been successfully operating in a high-inclination, low-earth-orbit since January 31st, 2015. FIREBIRD was primarily designed to observe relativistic electron microbursts, specifically improving the understanding of spatial dimensions, energy spectra at moderately relativistic energies and time evolution of the microburst precipitation region. Microbursts are sharp increases (often greater than an order of magnitude) in precipitating electron flux lasting ~100 ms. Microbursts have been simultaneously observed when the CubeSats were separated by as little as ~15 km. Protracted observations from the long-duration FIREBIRD-II mission utilize synergistic measurements from other CubeSats, stratospheric balloons, and magnetic conjunctions with NASA's Radiation Belt Storm Probes mission to reveal new insights on radiation belt electron losses. Each FIREBIRD-II CubeSat contains two solid-state detectors with complementary geometric factors measuring electrons from 200 keV to ~1 MeV. FIREBIRD observations are gathered in multi-week duration campaigns producing two data products, Context and HiRes. Context is an electron count rate from two energy channels at a 6 s cadence, and HiRes is at a cadence as fast as 12.5 ms. Context data is downlinked for the entirety of the campaign, but telemetry constraints allow only a selected subset of HiRes data to be downlinked. Microbursts, and precipitation in this energy range, can strongly affect the dynamic balance of radiation belt electron flux as well as influence atmospheric chemistry at a range of altitudes. This paper will present science highlights from the FIREBIRD CubeSats including spatial scale observations, energy spectra, and conjunctions with other missions.

ONERA nanosat project ONSAT-1 on radiation belt monitoring and effects

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In 2019, ONERA begins a project to launch its first nanosat in 4 years: ONSAT-1. Several missions were proposed for a phase A study, two of which concern the radiation belt and its effects: CREME and ESD-Cubesat. A mission will be selected in July 2019 for a launch in 2022.

To support this mission, ONERA develops also the SpaceLab, a tool for mission analysis and definition, and the OnsatLab, a laboratory to design, built and test the nanosat payload. The nanosat platform will be built by the partner of the mission.

The objective of CREME is to built a miniaturized radiation monitor on a 3U cubesat, based on long history of detector design (ICARE, ICARE-NG). In case of success, this instrument could be embedded on all satellites (smallsat as well as commercial ones) for providing new data for radiation belt in-house models and space weather products.

ESD-Cubesat carries a package of instrument to analyse the electrostatic discharge (ESD) phenomena which occurs in particular in LEO auroral zone. The instruments are fixed on the sides of a 3U cubesat and will measure the charge of the satellite, detect the ESD, discharge passively the satellite or create artificial charge (for period out of the LEO auroral zone).

The presentation will present the overall ONSAT-1 project, its status, with a focus on these both missions.

She-Space: A multi-disciplinary educational space project for high school girls

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Studies investigating the underrepresentation of women in STEM fields found several factors for the gender bias including; lack of female role models, insufficient exposure to STEM subjects, and gender stereotypes. The Earth and Planetary Image Facility (EPIF) in Ben-Gurion University of the Negev, academically accomplished an annual multi-disciplinary educational space project for high school girls, named "She Space". The project was supported and funded by the Israeli Space Agency in the Israeli Ministry of Science and Technology. The main purpose of this project was to ignite young girls interested in STEM studies by exposing them to female researchers using space sciences and remote sensing technologies (in particular the Venµs satellite), while enabling them to experience research via hands-on activities in the lab.

During the project, the girls were introduced to remote sensing research and concepts. Satellite remote sensing is an attractive and interesting framework for high-school students as a learning topic and as a tool, and is not taught at high schools. The project implements three educational elements: 1) active learning, 2) A multidisciplinary approach, combining many aspects and terms such as physics, chemistry, biology, geography, and computer science. 3) Context- and project-based learning (PBL). At the end of the project, the girls reported an increase interest in physics and space oriented disciplines as well as increased confident in using computer software. Most of the girls claimed that the gender segregation of the project improved both the social atmosphere (80%), as well as the education atmosphere (60%) in the classes.

Land Surface Phenologies of Grasslands: Comparing VenµS Time Series from Naryn, Kyrgyzstan and the Eastern Sandhills of Nebraska, USA

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For two grazed grassland sites with contrasting terrain, soils, and vegetation composition, we modeled the land surface phenology (LSP) as a convex quadratic (CxQ) function of accumulated growing degree-days calculated from MODIS 1 km land surface temperature data. We fitted time series of three complementary VIs: Gitelson's chlorophyll index for erectophile canopies using the 742 nm red-edge band; the VENµS variant of the MERIS Terrestrial Chlorophyll Index; and the NDVI. Fitting was done separately for each pixel time series within the data frame, and it was done iteratively toward quality of fit targets. Four phenometrics from the CxQ models were used for comparisons: Peak Height (PH—the maximum model VI); Thermal Time to Peak (TTP—duration of the modeled green-up phase); Half-Time Value (HTV—VI at half TTP); and the early season AUC (Area Under the Curve above VI-specific bare soil threshold integrated from the first observation above the threshold to the peak height). Fits were primarily constrained by number of cloud-free observations but generally high. However, we detected a few anomalously high VI values associated with very low reflectance values, which occurred sporadically in space and time. Together the spectral bands, high spatial resolution, and quick tempo make VENµS a excellent sensor for characterization of land surface phenologies in grasslands.

VENµS PRODUCTION AND IMAGE QUALITY MONITORING OPERATIONS

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In CNES premises, VENµS scientific image ground segment is, on one hand; dedicated to process up to Level-2 products and, on the other hand, to expertise and monitor VENµS image quality.

In this context, the ground segment breakdown is first introduced to emphasize the image programming loop, and also to introduce the image quality monitoring process.

Afterwards, from telemetry downloading to upper-level products generation, the different processing involved are detailed and statistics are presented to give an updated status of the whole VENµS data archive. In this frame, the differences existing in the completeness of the time series delivered are explained (cloud coverage influence, internal evolution of correction parameters, status of reprocessing potentially ongoing…).

Concerning image quality monitoring, the main radiometric and geometric activities carried out are addressed, with a focus on reference data generation, which is highly dependent on the characteristics of the geographical area acquired. Additional operational activities are also considered to give, finally, a panel of the different procedures aimed at maintaining an optimal image quality for VENµS products.

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Oral

A. 4 Scientific results of the VENμS Earth observation mission

Remote Sensing Modeling of Ecosystem Productivity and Evapotranspiration: New Insights from VENμS

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VENμS provides surface reflectance images with high spatial resolution, rapid repeat cycle, two red-edge and one water vapor bands. Comparing VENμS spectral reflectance data from two sites in contrasting environments in southwestern Michigan (USA) and northeastern Inner Mongolia (PRC), we evaluate direct measurements of land surface properties (e.g., LAI, energy flux), ecosystem production, and evapotranspiration from intensive experiments and long-term monitoring stations, and explored their connections with VENμS spectral reflectance and derived vegetation indices to identify new insights into ecosystem functions from VENμS. At the VENμS site in Inner Mongolia (HGERS), five flux towers and a suite of manipulative experiments have been maintained by the CAAS team; whereas in Michigan (KALAM2-2), eight flux towers and large experimental plots of LTER and GLBRC at the Kellogg Biological Station provide rich ground data for validating model predictions. Land cover maps and the affiliated remote sensing metrics (e.g., NDVI, EVI) derived from VENμS (10 m), Landsat (30 m), Sentinel-2 (10 m) and MODIS imagery for 2019 enable downscaling of ecosystem functions to the corresponding resolution of the images. An expected advantage of VENμS is its capability in delineating smaller patches (e.g., 10 m), including many experimental plots. The corresponding predictions, including landscape patch mosaics, will likely enhance model predictions when scaling up to the landscape. Daily net ecosystem production and evapotranspiration derived from the eddy-covariance flux towers and sampling chambers will be used to seek new insights from VENμS data through comparisons with those from Landsat, Sentinel, and MODIS data.

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A. 4 Scientific results of the VENμS Earth observation mission

DEM generation from native stereo VENμS acquisitions

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VENμS is an Earth observation mission which main purpose is to acquire images over 123 scientific sites spread around the world to monitor vegetation and land surface processes. In order to fulfil this goal, VENμS provides 5m resolution orthorectified images acquired every two days with constant viewing angle for multi-temporal analysis. Images contains 12 bands: 11 different spectral shortwave bands, and 1 redundant band (B06) which has the same spectral content as B05. Their B/H is 0.025, allowing us to compute a Digital Elevation Model from a single acquisition.

The DEM is computed from a single product in the sensor geometry of the two spectral bands B05 and B06. Radiometric corrections are applied (equalization, straylight correction). The geometric model is refined using ground control points computed between the current image and Venμs reference image. This allows to correct attitude restitution errors.

A subpixel correlation is computed between B05 and B06 bands to find homologous points. Images are not resampled in order to avoid adding noise from the resampling process. The shift due to the acquisition time difference between B05 and B06 is taken into account directly into the correlation process. Then, the intersection of viewing directions is assessed from each couple of homologous points found, providing altitudes.

Due to residual restitution attitude errors, we study the benefit of adding other bands correlation in the DEM creation process. The purpose is to robustify the calculation of viewing direction intersection and improve DEM quality. DEM quality is assessed compared to an external reference DTM.

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A. 4 Scientific results of the VENμS Earth observation mission

USING UAVs AND VENμS TO CHARACTERIZE THE PHENOLOGY OF MEDITERRANEAN WOODY SPECIES ACROSS SPATIAL SCALES

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Due to spectral similarity, discrimination between woody Mediterranean species via remote sensing is not straightforward. However, considering plants phenology potentially allows identification at the individual plant level. The VENμS satellite has a multispectral sensor, with high spatial (5.3m) and temporal resolutions (two days revisit time), increasing its potential for successful acquisitions of cloud-free data and enabling a more accurate detection of phenological events. This study aims to examine the compatibility between phenology patterns of woody Mediterranean species obtained from different platforms, over various spatial resolutions. We therefore explore the ability of weekly consumer-grade camera (VIS-NIR), monthly multispectral UAV (0.13m), and VENμS satellite images taken throughout 2018 from a research site located in the Judaean mountains (Mata), to monitor phenology. After illumination corrections, six vegetation indices (VI) values were calculated from the ground camera data (57 dates), followed by matching of a locally weighted scatterplot smoothing function (LOESS) and outlier removal, resulting in 691 individual plants of 12 common species. Due to low percentage of outliers the excess green (ExG) VI time series was selected to represent the phenology from ground observations. The ExG had the highest correlation compared to the other VIs computed, between ground-based measurements and UAV data (11 out of 12 species, R0.75; p-value0.01). The ability to detect phenology using sensors with coarser spatial resolution will be explored by resampling the UAV data (cell resizing to 0.3m and 1.25m) and computing VIs out of VENμS imagery, followed by evaluating the different scales correlation to the near-ground derived phenology.

Monitoring nitrogen application with VENμS

in the northern Negev, Israel

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In traditional farming irrigation and fertilization are applied uniformly in the field. Precision farming monitors the in-field spatial variability, thus enabling irrigation and / or fertilization according to the local (in-field) need. One way to assess the need for fertilizer application is by using reference strips. Base nitrogen (N) was applied in reference strips in commercial fields in the northern Negev, Israel

To monitor the spatial variability of agricultural crops we used vegetation indices (NDVI, REIP) from Sentinel-2 (10/20m, five days revisit time) and VENμS (5m, 2-day revisit time) satellites (Fig. 1). We used the Google Earth Engine platform to map the spatial variability of each field by calculating the mean VI, masking extreme values (three standard deviations, 3σ) of each field, and presenting the anomaly as deviation of ±σ and ±2σ.

The high temporal and spatial resolution of VENμS enables monitoring agricultural fields during the growth season better than the lower resolution sentinel-2 data. Moreover, Sentinel2 was unable to provide information due to cloud cover more often, and especially when top dress N application decision were taken. The high spatial resolution of VENμS Red-Edge band was very useful for detection of in-field anomalies. Hence, VENμS shows advantage versus Sentinel2 in representing the variation within fields and decision making

Fig. 1