VI SMALL SATELLITES & SERVICES INTERNATIONAL FORUM

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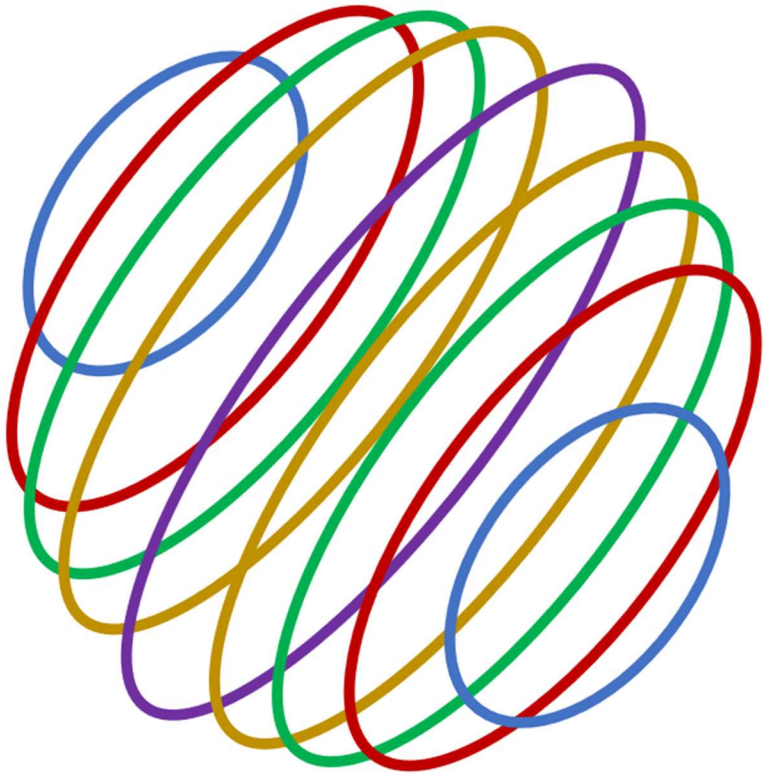
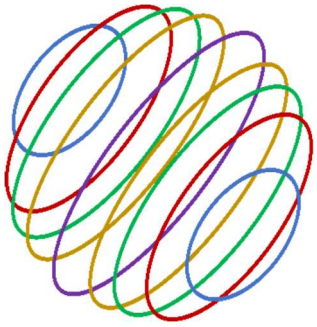
BOOK OF ABSTRACTS





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ABSTRACTS

P01

THE ORBIT-SPECTRUM RESOURCE: A HURDLE OR AN OPPORTUNITY

Julian Seseña

HOLISTIC INNOVATION (SPAIN)

ABSTRACT

This paper will review the status of notifications submitted to the ITU Radiocommunications bureau in the past years, benchmarking the actions taken by countries around the world, with particular emphasis on the non-geostationary satellites and short duration missions, and their specific applicable regulation. The key procedures applicable to access to orbit-spectrum resources will be reviewed.

Keywords: Satellite, Regulation, Orbit, Spectrum, Coordination, ITU

P02

IMPORTANCE OF DUAL CIVILIAN AND MILITARY USE IN THE SPACE DOMAIN

Efrén Díaz

BUFETE MAS Y CALVET (SPAIN)

ABSTRACT

This paper explores the dual-use nature of space technologies, focusing on the legislative frameworks in Spain and Europe, compared to the United States. Since the launch of Sputnik in 1957, outer space has become a strategic domain for both civilian and military applications. The rapid development of space technology has led to dual-use systems, posing significant regulatory, ethical, and security challenges, particularly in Europe and Spain, where legislative frameworks are continually evolving.

The concept of dual-use refers to technologies that can be used for both civilian and military purposes. In space, this includes satellites for telecommunications, Earth observation, and navigation, which can serve commercial, scientific, and military operations. The paper highlights the complexities of regulating such technologies, given their potential to be repurposed for military use.

The militarization of outer space is a pressing issue, with major powers capable of deploying satellites and other instruments that can disrupt or destroy rival nations' space assets. This militarization raises the risk of preemptive strikes and escalates the potential for conflict. The paper examines the legal frameworks governing space activities, including the 1967 Outer Space Treaty, which prohibits the placement of weapons of mass destruction in space but does not explicitly ban conventional weapons.

Spain's legislative approach includes the Law on Official Secrets and the Law on the Control of Foreign Trade in Defense and Dual-Use Material, which regulate the export of dual-use technologies. The creation of the Spanish Space Agency in 2023 aims to integrate civilian and military space activities, ensuring compliance with international arms control and non-proliferation obligations.

The paper concludes that while significant progress has been made in creating legislative frameworks for dual-use space technologies, challenges remain in a highly militarized environment. Future policies must balance technological innovation, security, and international cooperation to ensure space remains a safe and sustainable domain for all humanity.

Keywords: Dual-use, Outer Space, Militarisation, Legislation, Space technologies

P03

USING A 16U CUBESAT TO BENCHMARK RADIAN, A CLOUD-BASED THERMAL ANALYSIS SOFTWARE

David Criado, Laura González

RADIAN (SPAIN)

ABSTRACT

Radian is a thermal analysis software conceived to provide agility to engineers, both at modelling and computing processes. Our software is accessible through a regular web browser and counts on a scalable network of computing resources in the cloud. Thermal analyses are supported by the Databank, a catalogue of satellite components and other reusable entities. Thermal models are based on a wide range of geometrical primitives, which are selected within the tool of imported and simplified from a CAD file. The underlying simulation engine reproduces the orbital environment and the thermal solution.

Over the course of 2024, as part of the ESA BIC Madrid incubation program, our team has compared the results computed by our simulation engine with other tools of varying purpose. Initially, we have assessed the Radian routines that compute direct radiative heatfluxes in orbits around the Earth against ARTIFIS and TOPIC, two well-tested legacy tools provided by the European Space Agency. In the second stage, we assessed the outcome of complete thermal analyses provided by Orora Technologies and performed in ESATAN-TMS, a robust and widely adopted commercial solution. These activities have counted with the support and guidance from the Thermal Analysis and Verification Section of the European Space Agency.

Furthermore, several new features have been included both in the user interface and the simulation engine (e.g. additional parameters and setting proxies for scenarios, wider configurability of geometries and cutouts).

Keywords: Thermal analysis, Software, Cloud, Satellite

P04

HAPS AS A COMPLEMENTARY LAYER IN EARTH OBSERVATION AND SATELLITE COMMUNICATION SYSTEMS: A LAYERED HYBRID APPROACH

Julio Verdasco

B2-SPACE (SPAIN)

ABSTRACT

The integration of high-altitude platform systems (HAPS) into Earth observation and communication systems establishes a "layered hybrid approach" that strengthens the response capacity and coverage of current satellite constellations. Operating between 18 and 25 kilometres in altitude, HAPS provide a strategic intermediate layer that complements both low Earth orbit (LEO) and geostationary orbit (GEO) satellites, addressing gaps in coverage, revisit frequency, and real-time data accuracy.

This layered approach enables HAPS to deliver more detailed and frequent imagery and data, overcoming the limitations of satellites in critical situations such as natural disasters. In emergencies —such as wildfires, floods, earthquakes, ...— HAPS can be rapidly deployed over specific areas to capture high-resolution data, a task that would be more complex and costly with a new satellite mission. This additional layer allows continuous and targeted monitoring in remote and hard-to-reach areas, essential for damage assessment and coordinated relief efforts.

In communications, HAPS also play a vital role, acting as relays when ground-based infrastructure is damaged or out of service. During a disaster, they ensure the transmission of data and communication between rescue centres and field operations, providing robust and rapid connectivity. Furthermore, the flexibility of HAPS allows them to be repositioned according to emerging needs, dynamically supplementing satellite coverage.

This layered hybrid approach —integrating the strengths of both satellites and HAPS— offers a comprehensive solution for observation and communication, maximizing the potential of both technologies and enhancing the ability to deliver fast and accurate responses in critical moments.

Keywords: HAPS, Communication, Satellite, Earth, Observation, Emergencies

P05

STELLARFENCE: MULTI-DOMAIN APPLICATIONS USING CONSTELLATIONS IN LEC

Daniela Jovic, Jakub Kapus, Natalia Gogolova

SPACEMANIC (CZECH REPUBLIC)

ABSTRACT

The Stellarfence concept explores the potential of deploying low Earth orbit (LEO) constellations of nanosatellites and small satellites to address emerging challenges in surveillance, secure communications, and real-time data acquisition. Designed around modular 6-12U CubeSats, and optionally microsats, the concept integrates technologies such as AI-driven data processing, satellite-to-satellite communication, and advanced payload adaptability to enable continuous global monitoring and data analysis.

Key elements of the Stellarfence concept include leveraging SWARM technology for decentralized network communication, enabling greater resilience and flexibility, and the use of optical communication for secure, high-speed data transfer. Payload designs envision high-resolution optical and hyperspectral cameras, SIGINT sensors, and secure communication modules tailored for applications like monitoring environmental changes, border security, disaster response, and signal intelligence.

By integrating AI both on satellites and in autonomous ground stations, the concept enhances data processing efficiency and improves resource allocation for real-time, actionable insights. Potential configurations focus on balancing mission objectives with economic scalability, ensuring feasibility for a range of users.

The presentation will delve into the technical innovations underpinning the Stellarfence concept, including advancements in satellite platform design, onboard AI processing, and SWARM-based communications. Emphasis will also be placed on the challenges of designing and optimizing a nanosatellite constellation, such as coverage analysis, orbital dynamics, and compliance with emerging space debris mitigation policies.

Stellarfence offers a framework for exploring how such constellations could meet the growing demand for accessible, scalable, and dual-use space-based services. This concept contributes to the broader dialogue on the role of small satellites in advancing sustainable and secure operations in LEO

Keywords: Nanosatellite, Constellation, Defense, Sigint

P06

DEEP SPACE 6U CUBESAT COTS PCDU IMPLEMENTATION

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SPACE POWER AND ELECTRONICS SYSTEMS GROUP, UNIVERSITY MIGUEL HERNÁNDEZ OF ELCHE (SPAIN)

ABSTRACT

This work presents the implementation of the 6U CubeSat Power Conditioning and Distribution Unit (PCDU), which is intended for deep space missions. This PCDU is composed by four Solar Array Sections (SAS), four Solar Array Regulators (SAR), an Energy Storage System (ESS) and a Power Distribution Unit (PDU). All these subsystems use only Commercial of the Shelf (COTS) components.

Concerning the ESS, it should be noted that an extended evaluation across low temperatures of nine different commercial 18650 Li-ion cells has been performed before its implementation. The findings of this study show the relevance of good cell selection during battery design. In addition, an aluminium battery holder has been designed and implemented in order to stabilize the temperature of all the cells of the battery.

The behaviour of the system has been also studied. On the one hand, a sun simulator has been used to validate the performance under a specific irradiation condition. On the other hand, the Total Ionising Dose (TID) effects have been analysed, and a fault-free operation has been obtained since 70 krads. These tests have been performed in with the Co-60 irradiator of the 'Centro Nacional de Aceleradores' (CNA) in Seville, Spain.

This work was supported by the European Union NextGenerationEU and Generalitat Valenciana under Grant ASFAE/2022/21. Authors thank the Seville 'Centro Nacional de Aceleradores' (CNA) for allowing us to use their installations for the TID tests.

Keywords: Cubesat, Power, Batteries, Deep Space, Low temperature

P07

CONVERGING SATELLITE AND NETWORK OPERATIONS FOR 6G NON-TERRESTRIAL NETWORKS

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ABSTRACT

The rise of satellite-based Non-Terrestrial Networks (NTNs) introduces unique challenges to operations, as satellite and network operations have historically been managed independently, each with distinct objectives and methodologies. Satellite operations focus on platform stability and resource optimization, while network operations prioritize service quality and user experience. However, the interdependencies between satellite and network operations demand a unified approach to ensure their mutual effects are considered. This convergence is essential to achieving seamless integration of NTNs with terrestrial networks envisioned in 6G, where satellite resources and service quality must be aligned to common goals. This paper proposes a novel task scheduling framework that bridges the operational gap between satellite and network operations. Designed for robust integration into heritage satellite operations, the framework incorporates network operations requirements, including 3GPP procedures and quality of service metrics. It enables automated operations in NTNs, a critical capability for managing the heterogeneous and scalable nature of such systems. The framework leverages feedback and telemetry-aware scheduling to address scenario uncertainties, optimizing both satellite resource usage and network performance. The framework's architecture, algorithms, and models are detailed, along with the validation roadmap culminating in a CubeSat mission. This mission demonstrates the dynamic scheduling capabilities and integration of the framework with satellite network operators and ground control systems. Key interfaces required for this integration are described, enabling real-world implementation. Initial validation results from simulation tests, comparing the proposed framework against a baseline CubeSat operations approach, are presented. These results highlight significant improvements in relevant performance metrics, demonstrating the framework's potential to enhance overall NTN operations. This work sets a foundation for advancing the convergence of satellite and network operations, paving the way for future 6G NTN deployment.

Keywords: Non-Terrestrial Networks, Operations Convergence, Tasks Scheduling, CubeSat Mission, 6G

P08

DRIVING SUSTAINABILITY AND AUTONOMY IN LOW EARTH ORBIT OPERATIONS: INNOVATIONS FROM SATELIOT'S 5G NB-IoT CONSTELLATION

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ABSTRACT

The Sateliot 5G NB-IoT Constellation project, initiated with the launch of the first four CubeSat platforms aboard the Transporter-11 mission to a 590 km altitude low Earth orbit (LEO), addresses the challenges of achieving self-sustainable and efficient operations in an increasingly congested orbital environment. The mission relies on GMV solutions for all flight dynamics related operations, which are provided as a service and supported by the Sateliot Flight Dynamics Team expertise. This paper presents the technical innovations developed to enhance operational safety, including the generation of high-precision two-line elements (TLEs) with controlled temporal degradation, early GNSS-based orbit determination using minimal data, and advancements in orbital data correlation to identify Sateliot satellites within Space-Track data for all the objects in the launch. GMV tools enable continuous and automated management of conjunction risks through persistent screening of operational orbits against an extended LEO object catalog and automated ephemeris sharing with Space-Track. Furthermore, the project includes comprehensive thrust characterization of the onboard propulsion system for collision avoidance and maneuver strategy implementation, supported by Delta-V and mass consumption estimations derived from orbit determination processes. These capabilities are critical for optimizing satellite behavior post-maneuver and maintaining constellation integrity and Sateliot mission requirements. The results underscore the effectiveness of the implemented measures and emphasize the importance of automated systems with constant monitoring and operational capacity for mitigating risks in low Earth orbit. The lessons learned provide a foundation for future strategies aimed at fostering safer and more sustainable space operations

Keywords: Self-sustainable Low Earth Orbit Operations, Autonomous Flight Dynamics, In-Orbit Risk Management, Satellite Propulsion Optimization, Space Sustainability

P09

AVS LUR-100 PLATFORM BASED EUROPEAN SPACE AGENCY ASTRONOMY MISSION

Cristina Ortega, Rainer Díaz de Cerio, Mónica Martínez

AVS (SPAIN)

ABSTRACT

AVS is currently undertaking the development of a satellite platform to be provided to the European Space Agency for an advanced astronomical mission targeting the study of dark matter. This mission, now in Phase A/B, leverages the AVS LUR-100 platform, a modular and scalable solution optimized for demanding scientific payloads. The spacecraft, with a wet mass of approximately 500 kg, will host a sophisticated payload with passive observation capability in the VIS and NIR range, capable of providing inputs to the Fine Guidance System implemented in the on-board AOCS.

The LUR-100 platform, with its robust architecture and high-performance subsystems, used in its most redundant and dependable configuration, is tailored to meet the stringent requirements of this mission. Its capabilities include precise arcsecond-level pointing through advanced ADCS, efficient power management via a kilowatt-class EPS, and dedicated redundant processing units for real-time payload data handling. These features ensure reliable operation and continuous scientific observation without interruptions.

This paper outlines the mission's objectives, the preliminary platform design concept, and the current spacecraft and mission configuration

Keywords: Microsatellite, Minisatellite, Standard Platform, Astronomy, Science

P10

AVS LUR-1 MISSION UPDATE: SUCESSFUL LAUNCH, LEOP, AND COMMISSIONING

Rainer Diaz de Cerio, Cristina Ortega, Mónica Martínez

AVS (SPAIN)

ABSTRACT

LUR-1 represents a complete space mission developed by AVS, encompassing the Space Segment (SSEG), Ground Segment (GSEG), and User Segment (USEG). Initially presented as a design and development endeavor, LUR-1 has now successfully transitioned to an operational mission. The satellite was launched aboard SpaceX's Transporter-11 in August 2024 from Vandemberg Spaceforce Base in California, marking a significant milestone for AVS.

As an ESPA-class microsatellite with a wet mass of 58 kg, LUR-1 carries a primary Earth Observation (EO) VNIR camera alongside a suite of innovative payloads, including a QKD communication physical layer IOD payload and passive servicing interfaces. These payloads, along with AVS's advanced microsatellite platform, have undergone thorough testing during the Launch and Early Orbit Phase (LEOP) and subsequent commissioning, without experiencing any faults or anomalies.

LUR-1 has validated AVS's LUR platform as a cost-effective, modular, and scalable solution for microsatellite missions. With its advanced arcsecond-level ADCS, kilowatt-capable EPS, and dedicated high-performance payload processing unit, the platform has reached TRL 9. This achievement positions the LUR platform, in its two available versions, LUR-50 and LUR-100, as a completely validated and operational solution for current and future applications. These range from simple and cost-effective configurations for LEO constellations to advanced configurations that maximize redundancy and availability for more critical applications and harsh environments such as GEO and Deep Space.

This paper presents the in-orbit results of the LUR-1 platform and payloads

Keywords: Microsatellite, Minisatellite, Standard Platform, Satellite, Mission

P11

PROBABILISTIC RECONSTRUCTION OF THE EVOLUTION OF SPACECRAFT MODES IN MINIMUM TELEMETRY SCENARIOS

Víctor Ribera, Sergio Cuevas del Valle

FOSSA SYSTEMS (SPAIN)

ABSTRACT

Recent efforts within the community have proposed a shift of paradigm from the classical mode-based software design approach to an object-oriented methodology; with advantages towards onboard autonomy, high-level operations and increased design flexibility. Under this approach, the autonomous evolution of the ADCS subsystem of a platform, for example, follows a finite state machine (FSM) defined by standardized and modular activities (after abstract objectives, such as detumbling) and FDIR transitions between them.

In telemetry low-throughput scenarios, such as a typical NewSpace mission, where ground resources are scarce, autonomy is not always aligned with ease of operations: due to lagged communications with the bus, FDIR conditions and autonomous activities performed by the probe may remain unrealized by the Operations team. Increased online autonomy requires of more intelligent ground capabilities.

This work presents a graph-theory-based approach for the reconstruction of the logical states evolution of a FSM, in sparse telemetry-available data scenarios. The design allows to probabilistically explore all FDIR recovery procedures and activities implemented by the spacecraft, as well as the most immediate next transition, without the use of any housekeeping telemetry; but only using the extremes of such transition path, and the time difference between the two. We exploit exploring tree-structure graphs to optimally fit in the temporal sense all possible FSM paths between the known extreme states, thus predicting plausibly triggered FDIR safe modes without telemetry requirements, as well as presenting future outcomes of the spacecraft in a predictive sense.

Several real-hardware scenarios are introduced to demonstrate the benefits of the presented approach against traditional, telemetry-based operative procedures, in terms of time, cost and engineering efforts.

Keywords: ADCS, Graph Theory, FDIR, Autonomous Operations.

P12

AI-DRIVEN AND MODULAR ARCHITECTURE AND SOLUTION FOR DENSE LEO SATELLITE CONSTELLATIONS INCLUDING A NETWORK DIGITAL TWIN

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INTEGRASYS (SPAIN)

ABSTRACT

In the context of implementing, deploying, and monitoring satellite constellations in Low Earth Orbit (LEO), the need arises for advanced tools to optimize their design, simulation, and operation. This work presents an innovative solution that integrates digital twins and advanced artificial intelligence (AI) techniques, developed to keep building upon solving the challenges addressed in existing research and literature. The conduction of accurate simulations of LEO constellations, calculating link budgets for dense satellite constellations, including small satellites and their relative services, makes it possible to enrich the information processed by reinforced and deep learning engines. Therefore, the digital twin is able to provide dynamic representations of satellites and their operations, simulating positions, and calculating key metrics. This is made possible by a modular architecture that integrates a 3D visualization module of the constellations, a simulation, processing and computation module, and an AI services module. Together, these enable efficient management of the hybrid optical-RF links. Beyond the link management, the AI incorporated into this system is employed to calculate advanced metrics, perform accurate predictions and process real-time data. This allows the system to select the optimal constellation configurations and operational parameters based on expected targets, user requirements, and weather conditions. In this way, the system can recommend the ideal parameter configuration depending on the satellite constellation and the coordinates of the designated terminals, with the goal of achieving optimal results. By improving the accuracy of results and tailoring them to the needs of the satellite network operator, facilitating data-driven decision making, and optimizing resources, this work positions itself as a versatile solution to address the technical and operational challenges of modern satellite systems.

Keywords: LEO, Digital Twin, Artificial Intelligence, Link Budget

P13

IACSAT-1, DETECTING EXOPLANETS IN THE VIS-NIR-SWIR FROM A SMALL SATELLITE

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ABSTRACT

Astronomical activities from ground-based observatories on Earth are limited by the filtering and distortion of electromagnetic radiation due to the Earth's atmosphere. By avoiding the Earth's atmosphere, space-based observatories open up the possibility of achieving much higher precision in photometry and/or observing in wavelength regions blocked by it. IACSAT-1 will be a space-based observatory, the first of the Instituto de Astrofísica de Canarias (IAC), which will complement the IAC's ground-based observatories, ranked among the best in the world. IACSAT-1 will be able to perform high-precision photometry in the VIS-NIR-SWIR bands for a variety of scientific cases led by the confirmation of Earth-like candidate exoplanets in the habitable zone orbiting medium-M-sized dwarf stars in the solar neighborhood, taking advantage of the expected collecting power, twice that of TESS. Therefore, IACSAT-1 will be key to drawing a more complete picture of habitable planets in the solar environment and to provide targets for spectroscopic characterization using the James Webb telescope and future giant telescopes such as the ELT and TMT.

IACSAT-1 proposes the use of a 24 cm primary mirror telescope capable of achieving a photometric precision better than 350 ppm for 1 hour of observing time when observing stars of magnitude 13.5. This precision allows, for example, the detection of an Earth-sized planet transiting a low-mass M dwarf with a precision > 5 sigma (transit depth > 2000 ppm).

IACSAT-1 contemplates two innovative technological developments, on which this talk will be focused. On the one hand, the use of an eInGaAs detector that will open the possibility of observing cooler stars compared to CHEOPS by extending the observation range to regions of the spectrum more useful for exoplanets. On the other hand, a pointing and focusing correction system that will reduce the platform's pointing requirements, significantly improving the photometry of the observations.

Keywords: Small Satellite, Astrophysics, Exoplanets, Science, eInGaAs

P14

ANALYSIS OF DIRECT AND HAPs OPTICAL LINKS AND THE IMPACT OF ATMOSPHERIC CONDITIONS AND MODULATION ON ADVANCED FSO GROUND-TO-SATELLITE COMMUNICATIONS

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INTEGRASYS (SPAIN)

ABSTRACT

The increasing expansion of satellite constellations and advances in space technologies have led to a growing demand for high-speed data transmission. This increase has highlighted the limitations of traditional radio frequency (RF) communication methods, such as spectrum congestion and limited bandwidth capacity. In the face of these challenges, Free Space Optical (FSO) communications have emerged as a promising alternative, thanks to their ability to operate at higher frequencies, offering higher transmission rates, lower latency, and more compact and lightweight equipment, which favours integration into satellite platforms. However, FSOs also face significant challenges, such as the required accuracy in transmitter-receiver alignment and their sensitivity to adverse weather conditions, which can significantly affect link quality. In simulation-based approach, evaluating two key metrics: the symbol error probability (SEP) and the probability of failure (i.e., outage probability). Both analyses are carried out considering different scenarios, with variations in the tilt angle between the satellite and the ground station, as well as different orbital heights. The impact of the use of High-Altitude Platforms (HAPs) as intermediaries in optical links is also explored, comparing their performance with direct links. The results of this study provide detailed insights into how geometric and atmospheric factors affect the quality of optical links, providing a basis for optimising parameters such as satellite altitude, modulation and pointing configurations to improve the efficiency and reliability of future optical and hybrid systems.

Keywords: HAP, Free Space Optic, Satellites-to-Earth Links, LEO

P15

uD3RN MICRO RELEASE NUT QUALIFICATION TEST CAMPAIGN

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DCUBED GMBH (GERMANY)

ABSTRACT

The Micro Release Nut is a compact, yet high performance SMA release actuator. In this paper, the qualification campaign is presented. In particular, the reliability of the actuator in a space environment and its rapid resetability is verified. It is shown how resilient the mechanism is against vibrations and harsh thermal-vacuum environments.

Keywords: HDRM, Release Nut, Actuator, SMA, Mechanism

P16

^{3}COLSTAR KIBO CUBE COLOMBIA SGCMG IOD

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ABSTRACT

In response to the eighth round invitation of the United Nations Organization in cooperation with Japan Space Agency "Kibo Cube" program, an interinstitutional team was formed to present the proposal entitled "^{3}ColStar Kibo Cube Colombia"

This 1U CubeSat is equipped with two main payloads, the first one, the MiniPIX TPX3 SPACE device; the second, an IoT device designed for data transmission to a mobile ground station. Additionally, the CubeSat incorporates an in-house developed Fine Sun Sensor and a proof-of-concept for research development of a SGCMG and magnetorquers.

The SGCMG IOD general objective is to validate the technology of CMG-type inertial orientation and pointing actuators developed from low-cost commercial components (COTS) by University of Barcelona.

The stabilization and orientation of small CubeSat-type satellites has traditionally been based on the use of reaction wheels (RW), due to the simplicity of the design and low manoeuvring speeds (less or equal to 1°/s).

The trend in the development of CubeSat for earth observation satellites applications with greater capacities also requires greater manoeuvring agility (1 to 10°/s), which is why the agile earth observation satellites (AEOS) classification is greater frequency in current developments and involves the use of new technologies, this agile orientation capacity could be achieved at the CubeSat level using gyroscopic moment control actuators or CMGs, thereby achieving greater benefit from the CubeSat for each effective pass over the area of interest, being able to cover different targets.

The prototype for de SGCMG IOD, was designed and built from COTS components; for the flywheel a MAXON BLDC motor is employed and for the gimbal a NANOTECH stepper motor is used, with 95 g. mass and 53 cm^{3} (2.5x3.1x6.8) volume, the SGCMG can theoretically slew manoeuvre the CubeSat up to 5°/s.

Keywords: ADCS, Actuator, CMG, COTS, CubeSat, IOD, Kibo Cube

P17

INT-UQKD: A GLOBAL SOLUTION FOR QUANTUM SAFE COMMUNICATIONS

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STARION GROUP (LUXEMBOURG)

ABSTRACT

INT-UQKD is an ESA project funded under Public-Private Partnership with the objective of develop and demonstrate international use cases for Quantum Key Distribution (QKD) in operational IT environments. In view of demonstrating in-the-field global capabilities, the development activities leverage space and fibre-based QKD sub-systems, in combination with Post-Quantum Cryptographic (PQC) elements to ensure optimal reach and resilience. Initially, the scope of the project is to connect QKD trusted nodes in Luxembourg, Belgium and Singapore. In follow-up phases, the network is expanded geographically to other European and non-European countries. The INT-UQKD hybrid network architecture includes seamlessly both optical fibre links and satellites in low-earth orbit. For the satellite based QKD links, two Optical Ground Station (OGS) are built in Luxembourg and Singapore. The first demonstrations via satellite are carried out via the Speqtre and Speqtral-1 satellites under construction by European partners.

Through its Space Systems for Safety and Security (4S) programme, as part of the wider Advanced Research in Telecommunications Systems (ARTES) programme, ESA has brought together a consortium of European and international partners, including Starion Luxembourg, POST Luxembourg, the University of Luxembourg's SnT, HITEC Luxembourg, evolutionQ (Canada), and SpeQtral (Singapore).

The 4S strategic programme line develops innovative secure satellite communication systems, integrating them with terrestrial networks where relevant. Through projects, such as INT-UQKD, the programme aims to enhance the safety, resilience, and security of our critical infrastructures and applications, including transportation across land, air, and sea.

Keywords: QKD, PQC, Quantum Safe Communications, Optical Communications, LEO Satellites

P18

GENERAL FRAMEWORK FOR THE OPTIMIZATION OF SATELLITE CONSTELLATIONS

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ABSTRACT

The rapid growth of satellite constellation projects has created a dynamic landscape in space technology, with most initiatives currently being at the stages of prototype development and first launches. For start-ups investing in these ambitious projects, the financial stakes are high, making the preliminary design stage crucial to establish optimum constellation architectures. The significant rate of project cancellations highlights the critical need for comprehensive evaluations that go beyond technical specifications to include financial feasibility.

To address the urgent need for rapid and comprehensive system assessment, we present a general framework to design and optimize satellite constellations. The methodology offers a holistic approach to constellation design, incorporating multiple critical components: terrestrial traffic distribution, communication channel modelling for satellite-to-ground and inter-satellite links, parametric satellite mass and cost estimation, and launch strategy assessments. A novel feature of the framework is the integration of a generic routing protocol, which enables an estimation of data packet transmission delays. By providing a comprehensive performance evaluation tool, the methodology allows researchers and engineers to holistically assess system's performance, identify potential architectural bottlenecks, and make informed design adjustments.

To demonstrate the framework's practical utility, the methodology is applied to a messaging service via SmallSats constellation using LoRa technology. As a modelling outcome, the preferable constellation architectures for a specific traffic demand have been identified, along with the impact of particular design parameters on overall system performance. This case study illustrates the approach's effectiveness in navigating the complex challenges of constellation design and offers valuable guidance for future satellite Internet projects, providing an analytical framework for optimizing satellite constellation architectures.

Keywords: Satellite Constellations, Communications, SmallSats

P19

ON GROUND TESTING OF THE ATTITUDE CONTROL SUBSYSTEM OF THE UPMSAT-3: ADAPTATION OF A 12U PLATFORM TO A SMALL AIR-BEARING TEST BENCH

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ABSTRACT

Satellite testing is a critical phase in the development process, to ensure that systems perform reliably in space. While all satellites undergo vibration and thermal testing to simulate launch and environmental conditions, the Attitude Determination and Control System (ADCS) is often not tested in a fully relevant operational environment. This gap in testing could lead to unforeseen performance issues during the mission. In recent years, specialized ADCS test benches have been developed to simulate realistic space conditions, providing greater reliability than traditional software-only analyses.

This work focuses on the ADCS testing campaign performed for the UPMSat-3 satellite. A key challenge addressed was the adaptation of a 12U-sized satellite to an air-bearing test bench originally designed for 3U satellites. The adaptation required the finding of solutions in terms of design, power management and communications. In addition, this adaptation shall ensure that to perform testing of flight components safely and within the size and weight limits imposed by the air bearing platform, while still being representative of the actual satellite.

The testing campaign allow to verify the correct functionality of the ADCS system by conducting the commissioning tests that will be carried out later in orbit. This included validating the individual performance of sensors, such as the magnetometer, sun sensor, and star tracker, and also the operation of the system as a whole.

Keywords: Satellite, ADCS, Hardware In The Loop, Testing

P20

MISSION ANALYSIS FOR ^{3}CAT-8, A REMOTE SENSING CUBESAT FOR IONOSPHERIC RESEARCH

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ABSTRACT

This work presents a comprehensive mission analysis of ^{3}Cat-8, a 6U CubeSat designed to advance ionospheric research through multiple scientific payloads and technology demonstrations. The spacecraft integrates GNSS radio occultation and reflectometry experiments, polarimetric aurora imaging, and novel technology demonstrators including a deployable Fresnel Zone Plate Antenna and a PocketQube integrated deployer. To validate the mission's technical feasibility, a comprehensive set of analyses and simulations was conducted.

Technical budget analyses were performed to assess mission feasibility. Communication link budget analyses demonstrated robust performance across four distinct communication channels (UHF, LoRa, X- and S-band), while data budget calculations confirmed sufficient downlink capacity for extensive payload operations. Power budget analyses validated the energy requirements across all operational modes.

Physical simulations using finite element modelling evaluated the satellite's structural and thermal behaviour. Thermal analysis confirmed adequate temperature control for all subsystems across expected environmental conditions, with particular attention to the deployable structures and sensitive equipment. Structural analyses, including modal, random vibration, and quasi-static loading simulations, verified the spacecraft's integrity under launch conditions.

The Attitude Determination and Control System simulations demonstrated successful detumbling and validated the magnetic and reaction wheel hybrid control, meeting the mission's pointing requirements. Additionally, space debris mitigation analysis confirmed compliance with current passive deorbiting requirements.

The results of this comprehensive mission analysis demonstrate that the ^{3}Cat-8 design meets all technical requirements for successful operation, validating the feasibility of integrating multiple advanced payloads and technological demonstrations within the constraints of a 6U CubeSat platform. This analysis provides confidence in the mission's ability to achieve its scientific and technological objectives while maintaining system reliability and performance.

Keywords: CubeSats, Mission Analysis, Technology Demonstrators, Ionosphere

P21

NEXT-GENERATION SATELLITE BUS STRUCTURES WITH THERMOPLASTIC MATERIALS

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ABSTRACT

This study advances the circular economy of satellite buses by employing reusable thermoplastic materials in their structural design. It explores thermoplastics as an alternative to aluminium, leveraging their mechanical properties to withstand launch and orbital loads. This approach reduces reliance on metallic components and enhances cost-effectiveness. A feasibility and trade-off analysis at the satellite level evaluates the impact of thermoplastic structures on other satellite subsystems, with applications as external panels and primary structural components for small satellites. These features promote recyclability and enable low-cost manufacturing through thermoforming and over-molding techniques.

Thermoplastics are extensively used in aerospace due to their strength, temperature stability, and resistance to atomic oxygen. Their track record in space applications demonstrates their alignment with the stringent demands of the space environment. This investigation identifies suitable thermoplastics through a trade-off study evaluating key parameters such as outgassing, chemical resistance, manufacturability, and cost.

Three structural designs for small satellite bus structures were proposed and analysed using finite element models. Simulations assessed the response of these structures to various loading conditions, including static analysis (displacements and stresses), modal analysis, and random vibrations. Based on the results, the most promising design was selected.

For initial validation, a small-scale mock-up was 3D printed using PETG material, providing insights into the assembly and disassembly of satellite panels and components. The next phase involves manufacturing a full-scale demonstrator using the selected thermoplastic material and thermoforming techniques. This work highlights the potential of thermoplastics to revolutionize satellite design, making structures more sustainable and cost-effective while meeting aerospace performance standards.

Keywords: Satellite, Structure, Thermoplastic, Over-moulding, Thermoforming

P22

ORBITAL DEBRIS, SUSTAINABILITY, & THE FUTURE IMPACT ON SMALL SATS

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KALL MORRIS INC, KMI (UNITED STATES OF AMERICA)

ABSTRACT

The global satellite industry is continuing to expand, with an expected continued average growth rate (CAGR) of 8.1% from 2024 to 2034, according to Precedence Research. Orbital debris and the impacts it will have on space sustainability have the potential to slow or stop this growth in its tracks. As satellite operators and developers move forward in this growing market, it is vital that they consider the status quo and how that will need to change, particularly the importance we place on Space Situational Awareness (SSA) and Active Debris Removal (ADR) efforts. Considerations in these areas must include designing technology with end-of-life service and mitigation in mind should the satellite fail to respond to commands or be rendered inoperable due to an orbital debris strike. In such cases where design fails, as it often does, operational mitigations and plans for relocation or deorbit through contracted technology must become a viable component of the satellite ecosystem. While some companies are designing docking and servicing ports to preinstall on satellites before launch, this only addresses future vehicles, rather than legacy spacecraft or defunct satellites, or the potential for dock failure on these future crafts. Many debris objects that pose a risk in orbit are typically intact legacy objects or unidentifiable debris, which would not benefit from these methods. Kall Morris Inc (KMI) and the partners we collaborate with are striving to move the conversation of sustainable space closer to the reality of a circular economy in orbit. In this presentation, we will be covering upcoming ADR technologies available from a variety of companies, as well as changes to "status quo" operations that will be required for the continued, sustainable use of space for all.

Keywords: Active Debris Removal (ADR), Space Situational Awareness (SSA), Orbital Debris, Orbital Sustainability, Small Satellite Technology

P23

BLUEPRINTS FOR A SUSTAINABLE FUTURE: INTENTIONAL SATELLITE DESIGN AND OPERATION

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ABSTRACT

"Ad Astra per aspera"- "through hardships to the stars"- reminds us that progress often follows overcoming challenges. In the rapidly evolving small satellite market, one of the most pressing challenges is the proliferation of orbital debris. The increasing number of operational satellites in low Earth orbit (LEO) has amplified the risks posed by defunct objects and retired spacecraft, threatening the sustainability of orbital operations. Meeting this challenge requires a holistic approach that integrates sustainable design practices, regulatory frameworks, and advanced technologies:

1. Intentional Design for Sustainability: Small satellite platforms should prioritize modular and repairable designs, extending mission life and enabling nominal deorbit or repurposing at the end of operational use. Recent advancements in in-space manufacturing and recycling offer transformative potential, turning non-functional satellites into reusable components and minimizing waste.

2. Responsive Regulatory Frameworks: Regulatory bodies are already responding to the need for sustainability. Policies such as the Federal Communications Commission's (FCC) five-year deorbit rule and international initiatives like the Space Sustainability Rating (SSR) encourage responsible behavior and accountability. These frameworks, coupled with innovative cost-sharing models or competitive marketplaces for debris removal services, could significantly accelerate efforts to clear orbital pathways.

3. Emerging Technologies: Technological innovations in on-orbit servicing, refueling capabilities, and active debris removal systems are reducing risks and enhancing satellite longevity. Rideshare launches and compact designs are maximizing efficiency while minimizing redundancy, ensuring that resources are used effectively.

The future of small satellite platforms lies in balancing market growth with sustainable practices. By fostering collaboration across commercial, regulatory, and technological domains, the space community can secure long-term orbital access and preserve the space environment for generations to come. In this paper, Kall Morris Inc (KMI) will explore strategies for achieving this vision and highlight the importance of intentional design and cooperation in building a sustainable future for space operations.

Keywords: Sustainability, Space Debris, Satellite Design, Orbital Operations, Space Ecosystem

P24

SAFEPLACE: REVOLUTIONISING CRISIS AND DISASTER MANAGEMENT THROUGH SPACE, CONNECTIVITY AND AI

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STARION GROUP (SPAIN & BELGIUM)

ABSTRACT

The increasing frequency of natural disasters and humanitarian crises requires advanced technologies to support efficient, real-time emergency response. SAFEPLACE, a groundbreaking crisis response platform, addresses this need by leveraging space assets and secure connectivity solutions to revolutionize crisis management across Europe. Developed under a partnership led by Starion Group, with support from the European Space Agency's Civil Security from Space Programme (CSS), SAFEPLACE integrates satellite-based communication, IoT networks, and artificial intelligence to enhance situational awareness and coordination for first responders and decision-makers.

The platform provides robust, reliable, and secure communication in challenging environments where terrestrial infrastructure is compromised. It employs a combination of satellite constellations, portable IoT devices, and advanced data analytics to deliver precise geospatial information, real-time updates, and predictive insights. These capabilities enable rapid response, optimal resource allocation, and improved safety for both responders and affected populations.

Satellite data is central to SAFEPLACE's architecture, ensuring seamless connectivity and data exchange even in remote or disaster-stricken areas. Their cost-effectiveness, rapid deployment potential, and adaptability make them ideal for addressing the diverse demands of crisis scenarios. By coupling these capabilities with a user-centric interface, SAFEPLACE empowers a wide array of stakeholders, including emergency services, NGOs, and government agencies.

Specifically, for wildfire crisis management, SAFEPLACE will feature, under Starion Spain's responsibility, a marketplace for satellite imaging data sourced from public and private Earth Observation providers. This data will be managed using an AI-powered crisis assistant to deliver actionable insights, improve response efficiency, and support decision-making during wildfire emergencies.

This innovative integration of space assets, AI, and Earth Observation data services demonstrates the transformative potential of SAFEPLACE in addressing the unique challenges posed by natural disasters, offering a model for enhanced coordination and resilience in global crisis management.

Keywords: Satellite Data, Earth Observation, Artificial Intelligence, Civil Security, Connectivity

P25

AALTO SKYLINK-MODERN RADIO PROTOCOL FOR CUBESAT MISSIONS

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ABSTRACT

Despite the rapid development of CubeSat technology, many educational missions still struggle with outdated communication protocols. Secure and reliable protocols are often too complicated and simpler commonly used radio amateur protocols are outdated. Educational missions especially need relatively simple, but reliable and modern communication protocols tailored to UHF telemetry and telecommand links. This paper introduces an open-source robust narrowband link and transport layer protocol, called Aalto Skylink, designed specifically for single frequency small satellite missions.

Emphasizing efficient bandwidth utilization and frequency management, the protocol ensures reliable point-to-point data transfer, broadcasting, and supports up to four virtual channels, offering flexibility for diverse mission requirements. With minimal hardware and software dependencies, the protocol is accessible to satellite developers and radio amateurs, supports SatNogs network utilisation and allows customisation and innovation in low-resource environments.

Enhanced reliability is achieved through automatic retransmission mechanisms and advanced forward error correction techniques, including modern Golay-24 and Reed-Solomon framing (compatible with GomSpace Mode-5). A lightweight and adaptable framing structure simplifies decoding and allows mission-specific customizations while preserving backward compatibility. Security is reinforced using Blake3-based HMAC authentication, with optional encryption for confidential data exchange.

For half-duplex communication channels, the protocol employs a self-synchronizing windowed Time Division Duplex (TDD) mechanism, dynamically adjusting transmission windows to optimize channel usage under varying congestion levels. Selective-Repeat Automatic Retransmission Request (ARQ) logic ensures reliable data delivery, making the protocol suitable for tasks such as commanding, reconfiguration, and bulk data transfer.

The protocol includes an embedded-friendly, low-memory footprint open-source reference implementation with a simple seven-function API, enabling seamless integration on both satellite and ground station systems. It also features an open-source software-defined radio (SDR) modem for ground stations, leveraging the suo-modem library developed during the FORESAIL project. A user-friendly ZeroMQ (ZMQ) JSON protocol facilitates data transfer, metadata exchange, and control commands.

An open-source reference implementation is available on GitHub, and ongoing development aims to finalize the specification and publish peer-reviewed results, further supporting its adoption in educational and scientific satellite missions

Keywords: CubeSat, Communication, Radio Protocol

P26

IMPROVING SMALL SATELLITE CONSTELLATION DESIGN USING CONCURRENT DESIGN AND CDP4-COMET

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ABSTRACT

The dynamic evolution of the small satellite industry has created new challenges in the design and development of complex systems. The emergence of new technologies and the increase of commercial missions underline the need for efficient and integrated design approaches. While with traditional methodologies each engineering domain may tackle the initial design independently, alternative solutions exist to achieve higher performance results by implementing more efficient interactions between the domain experts, and ultimately reducing the overall project costs. The best example for this is the application of concurrent design at the early stages.

Concurrent design consists of a structured and multidisciplinary approach in which domain experts work together to arrive at an integrated and supported design solution. To facilitate interactions, teams require a dedicated facility with the proper infrastructure, like ESA's Concurrent Design Facility (CDF), or OHB's CEFO. The tools used also need to solve the challenges of synchronised data exchanges in collaborative engineering. Starion's CDP4-COMET, which is an implementation of the ECSS-E-TM-10-25 standard, offers such capabilities and allows engineers to work on an integrated design model concurrently during the design sessions. It is used in institutional, academic and commercial environments.

A model-based approach to systems engineering supports the definition of missions at system of systems level, where concurrent engineering can play an important role in the early design phases. Missions with multiple interdependencies, such as satellite constellations, can greatly benefit from this. Dedicated optimisation tools can be used to assess the combination of factors such as launcher selection, propulsion systems and deployment strategies for constellations. However, we still need means to facilitate multidisciplinary collaboration between engineering teams and tools to support data exchanges. This presentation summarises the benefits of concurrent design, using the example of its application in the design of new small satellite constellations.

Keywords: Concurrent Design, Collaboration, Model-based System Engineering, Constellations.

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HIGH RESOLUTION SATELLITE IMAGERY PLANNING, EXECUTING AND OPERATIONS: DEWASAT-2 MISSION

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ABSTRACT

DEWASAT-2, the second satellite in DEWA's constellation, was launched on April 15, 2023, with a mission focused on multispectral Earth observation and greenhouse gas (GHG) monitoring. Operated by DEWA using licensed S, X, and UHF frequencies and its proprietary ground station in Al Qudra, Dubai, the satellite is designed to enhance the operation and maintenance of DEWA's services. Its key applications include seawater temperature and salinity monitoring at desalination plants, construction monitoring of civil assets, solar PV plant oversight at the MBR Solar Park, oil spill detection off Dubai's coast, and emissions monitoring within the emirate. Data and images from DEWASAT-2 are distributed to DEWA business units, such as DP, via the SpaceD portal. The satellite's contributions are instrumental in tracking Dubai's progress toward COP28 environmental targets.

DEWASAT-2 has successfully acquired over 50 images to date, maintaining a steady acquisition rate of one image per day. Its imaging payload supports both line-scan and snapshot modes, offering a spatial resolution of 4.75 meters with fully adjustable parameters such as scan rate, exposure time, HS spectral band centre, At-aoeerture radiance (AAR), and time delay integration (TDI) for each spectral band. GHG emissions are monitored using an infrared spectrometer payload, which provides a spatial resolution of 2 km × 2 km at an orbital altitude of 500 km.

This paper presents the planning, operations, image and emission data acquisition, uplink and downlink management, and raw data processing of DEWASAT-2. Additionally, we explore innovative applications of satellite data for electricity and water utility management, highlighting the potential of space technology to drive sustainable practices in urban infrastructure

Keywords: Satellite Communication, Satellite Operation, Planning, Image Acquisition, Remote Sensing

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MARS GLOBAL MONITORING SCIENCE CONSORTIUM: SUPPORTING SPANISH CONTRIBUTIONS TO FUTURE MARS SMALL SATELLITE MISSIONS AND INSTRUMENTATION PROPOSALS

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ABSTRACT

We present a Mars science consortium of Spanish atmospheric and magnetospheric scientists, part of a larger international group, supporting the study and development of future mission concepts with small satellites and instrumentation that could be flown in orbit around Mars for meteorological and space weather monitoring, in line with the science and exploration priorities of ESA (SciSpaceE White Papers & TerraNovae2030+) and NASA (MEPAG Future Program).

Past and present Mars orbiters have focused mostly on targeted high-resolution measurements, lacking continuous global coverage. However, Mars atmospheric phenomena (clouds and dust storms in particular) and space weather (solar wind, aurorae, radiation, …) require global, continuous, and simultaneous observations to fully understand the dynamic variability of Mars climate and its environment.

We summarize here the various efforts of the scientific community to propose various possible mission concepts, defining scientific priorities and instrument requirements for orbiter missions studied in past years [Cardesin 2023&2024, Montabone 2022&2021, Parfitt 2021]. These include satellite networks in different high-altitude orbit configurations, with great advantages for meteorology, space weather monitoring, and extra communication and navigation capabilities that could pave the way for future human exploration, providing services to other orbiters and surface assets.

Keywords: Mars, Science, Small Satellites, Remote Sensing Instruments, Satellite Constellations, Meteorology, Space Weather

P29

6GSTARLAB: AN OPEN PLATFORM IN LEO FOR RESEARCH IN 5G & 6G

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ABSTRACT

The 6GStarLab mission introduces an open and flexible infrastructure aiming to become a pioneering platform for research and validation of 5G and 6G technologies in space. The mission is centered on a 6U CubeSat satellite scheduled for launch in Q2 2025. The satellite platform provides a versatile and flexible testbed where researchers will be able to upload and execute their experiments remotely, fostering innovation in the emerging non terrestrial networks (NTN) landscape. Designed with a modular payload architecture, 6GStarLab will support experimentation across multiple radio-frequency bands, including UHF, S, X, and Ka-bands, as well as an advanced optical communication terminal. This broad frequency capability ensures compatibility with a wide variety of communication protocols, allowing for the comprehensive testing of new technologies and experiments. Standardized by the 3GPP, the emerging NTN architectures promise to expand global connectivity, yet their full realization requires robust in-orbit experimentation platforms and the 6GStarLab mission is aligned closely with this ongoing standardization process. Ultimately, the mission aspires to bridge critical gaps in the NTN standardization roadmap, contributing significantly to the global deployment of 5G and 6G capabilities in space. By offering an open and flexible infrastructure, 6GStarLab not only facilitates technology demonstration but also promotes collaboration among academia, industry, and regulatory bodies. This work provides a comprehensive overview of the 6GStarLab mission, detailing the satellite platform, its advanced payloads, and the mechanisms enabling researchers to access and utilize this innovative in-orbit platform for experimentation.

Keywords: Satellite, LEO, 6G NTN, Open

P30

CARES: COLLISION AVOIDANCE AND RISK EVALUATION FOR SPACECRAFTS

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ABSTRACT

Small satellite constellations represent a transformative approach to Earth observation and communications, enabling dynamic coverage of specific planetary regions. However, these systems face critical challenges, such as collision avoidance with space debris. This paper presents a novel, autonomous collision avoidance framework for a constellation of four small satellites conducting scientific experiments requiring precise area coverage.

The proposed system utilizes differential drag control to modify the ballistic factor of individual satellites. By dynamically adjusting the drag coefficient, flight altitude can be altered with minimal reliance on traditional propulsion systems, leveraging the limited maneuvering capabilities of small satellites, such as reaction wheels.

The decision-making process for collision avoidance is powered by a decentralized, multi-agent deep reinforcement learning (DRL) model. Each satellite acts as an agent, employing an actor-critic algorithm to calculate optimal maneuvers. The reward function is tailored to balance debris avoidance with the requirement to maintain coverage over the designated area. The stochastic nature of debris encounters is addressed by training the model to respond dynamically to evolving scenarios.

To address computational limitations inherent to small satellites, the system incorporates a distributed computing architecture. Satellite nodes communicate via a dedicated RF link, pooling computational resources to execute the DRL model in real-time. This architecture ensures scalability and reliability while reducing the burden on individual satellites.

Additionally, the system integrates an open communication protocol to facilitate inter-satellite data exchange and enhance autonomy. This protocol could serve as the foundation for a standardized communication framework for future satellite constellations.

This work contributes to the field by integrating AI-driven decision-making, distributed computing, and differential drag control, offering a robust solution to collision avoidance while preserving mission objectives.

Keywords: Collision Avoidance, Small Satellite Constellations, Deep Reinforcement Learning, Distributed Computing, Differential Drag Control

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PAT-IA: DEVELOPMENT OF A STABLE AND HIGH ACCURACY ATTITUDE AND ORBITAL DETERMINATION AND CONTROL SUBSYSTEM (AODCS) BASED ON ARTIFICIAL INTELLIGENCE ALGORITHMS FOR SMALLSATS

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ABSTRACT

The increasing demand for high-data-rate optical communication in space missions has highlighted the limitations of traditional Attitude and Orbital Determination and Control Subsystems (AODCS) in small satellites (SmallSats). Current technologies, such as PID controllers and Kalman filters, struggle with the precision, adaptability, and energy efficiency required for modern missions, particularly in optical communication scenarios where fine pointing accuracy is critical. This paper introduces PAT-IA, a cutting-edge AODCS framework leveraging artificial intelligence (AI) algorithms, specifically deep reinforcement learning (DRL), to overcome these challenges.

The proposed system integrates a DRL-based controller into the AODCS, enabling real-time learning and adaptation to dynamic orbital and environmental conditions. By employing a reward-based closed-loop system, the controller optimizes SmallSat attitude adjustments, compensating for disturbances such as atmospheric turbulence and ensuring sub-arcsecond pointing accuracy. This innovation directly enhances communication reliability, minimizes signal losses, and improves energy efficiency, addressing key operational limitations in SmallSats.

The system's adaptability supports high-data-rate optical communication for both civil and defense applications, including Earth observation, disaster monitoring, and secure data transmission. Optical communication offers critical advantages over traditional RF links, such as interference immunity, reduced power consumption, and scalability through wavelength division multiplexing. By achieving precise alignment with terrestrial or space-based receivers, PAT-IA facilitates reliable and efficient optical links across varying orbital scenarios.

Developed by a multidisciplinary team with extensive experience in satellite missions, PAT-IA extends the legacy of projects like Xatcobeo and LUME-1. The results of this research contribute to advancing SmallSat technology, meeting societal and industrial needs, and enabling technology transfer to the private sector. This work underscores the potential of AI-driven solutions in revolutionizing the capabilities of SmallSats for future space missions.

Keywords: Attitude & Orbital Control, Optical Communication, Small Satellites (SmallSats), Deep Reinforcement Learning, Fine Pointing Systems

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TOPOLOGY OPTIMIZATION & COOLING STRUCTURES FOR ELECTRONIC EQUIPMENT IN SMALL SATELLITES

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ABSTRACT

Data processing capacity and power demands are rapidly increasing in telecom and scientific payloads. That, together with miniaturization of systems, leads often to performance limitation due to insufficient cooling, which therefore limits the revenue that can be obtained from the equipment. Optimized design of satellite structures and cooling systems combined is therefore key to enable the next generation of high through-put small satellites and to push the boundaries of the future space industry. This paper focuses on the application of topology optimization at the design of an electronics frame for a high-power satellite application. The main objective is to obtain a minimum mass design ensuring that it withstands the demanding mechanical and thermal loads. The design incorporates embedded heat pipes to improve thermal management and ensure efficient heat dissipation thanks to fluid phase change. Furthermore, this project aims to demonstrate the use of additive manufacturing as the optimal manufacturing method for optimized designs, allowing for agile and flexible processes which can be tailored to almost any use case.

The paper addresses the challenge of reducing the mass of satellite components while maintaining structural integrity and thermal performance. The Solid Isotropic Material with Penalization (SIMP) method was used for the topology optimization, using tools such as Hypermesh and Optistruct.

The outcome is an electronics frame with embedded heat pipes, designed to support a PCB within a satellite. The structure can withstand the mechanical loads experienced during launch and can dissipate the heat generated by the PCB and its electronic components. The optimization process allows to obtain a 15% lighter design in comparison with a traditional electronic frame. Furthermore, the maximum temperature is decreases by 15-30 degrees, which can be directly translated in an increased power throughput and therefore equipment value of 20-50%.

Keywords: Electronics, Cooling, Optimization, Structures, Performance

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DEVELOPMENT OF A LORA TRANSCEIVER ON SDR FOR THE IoT PERCEPTION CUBESAT MISSION

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ABSTRACT

The Internet of Things (IoT) has revolutionised sensor data collection, enabling innovative solutions for monitoring and managing remote environments. In the Amazon rainforest, a network of terrestrial towers collects climatic data to monitor the ecosystem's state. By employing a satellite in orbit, this information can be retrieved, creating backups and ensuring access to critical environmental data.

In this context, the University of Brasília and the University of Vigo have joined efforts to develop a LoRa transceiver that operates independently of proprietary chips, utilising software-defined radio (SDR) technology, and analysing the feasibility of such link. The system is built upon GNU Radio blocks to decode LoRa signals, offering an open and flexible solution that can be implemented on any SDR platform. The transceiver is designed to recover IoT data from multiple terrestrial LoRa nodes, enabling the efficient acquisition of information from remote and inaccessible areas, such as the Amazon rainforest.

An open and versatile system enhances the accessibility and scalability of IoT satellite missions, which are critical for the future of large-scale data collection on Earth. Agricultural, climatic, and industrial applications stand to benefit from this technology, particularly in remote regions where traditional systems are not feasible.

Keywords: Cubesat, Transceiver, IoT, LoRa, SDR

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MISSION ANALYSIS OF BIXO: AN ASTROBIOLOGICAL PROJECT IN LEO USING A 2U CUBESAT PLATFORM

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ABSTRACT

Defining the orbital characteristics during the post-launch phase is essential for the effective planning and execution of space missions. This step not only helps estimate the mission's total duration but also provides critical insights into the satellite's operational environment, including temperature variations, solar exposure, and ground segment contact durations. Such analyses enable the prediction of potential critical scenarios that could compromise the mission's success. In parallel, space debris mitigation analysis plays a significant role in ensuring compliance with the sustainability guidelines and requirements set by the European Space Agency (ESA). By addressing these requirements, the mission contributes to the long-term reduction of space traffic, encouraging a viable future for space exploration. This research focuses on summarizing the simulations and theoretical analyses conducted for the BIXO mission, a 2U CubeSat designed to carry a biological payload into orbit which primary objective is to investigate the Quorum Sensing bacterial intercommunication mechanism, advancing our understanding of microbial behavior in space.

Keywords: Budgets, CubeSat, Requirements, Space Debris Mitigation, Sun-Synchronous Orbit

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DESIGN AND IMPLEMENTATION OF DATA LINK AND PHYSICAL LAYERS FOR BIXO CUBESAT COMMUNICATIONS

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ABSTRACT

Effective communication between the ground segment and a CubeSat relies on a well-defined architecture. In this context, the Consultative Committee for Space Data Systems (CCSDS) proposes a satellite communication framework based on the OSI model, streamlined into five layers: application, transport, network, data link, and physical. This research focuses primarily on the data link and physical layers, providing an in-depth analysis of the complete architecture for both transmission and reception. The recommendations outlined in the CCSDS blue books are examined, followed by their implementation in GNU Radio. Several elements of the data communication scheme are analyzed: channel coding options, synchronization marker implementation, and modulation, as well as their impact on the occupied bandwidth and the bit error rate (BER). Since the BIXO mission will implement two channels, one in UHF and another in S-Band, both are studied with their corresponding modulations and estimated bit rates, considering the power constraints for the mission. Based on testing using Software Defined Radio (SDR), conclusions are drawn about the link performance, evaluating its efficiency and robustness under real conditions.

Keywords: CubeSat Communication, GNU Radio, Modulation, Channel Coding

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CORTIS MISSION: HARDWARE AND SOFTWARE ARCHITECTURE FOR IN-ORBIT VALIDATION OF RADIATION SENSORS & A COTS CAMERA

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ABSTRACT

The CORTIS (Camera Observation and Radiation Test In Space) mission is a payload integrated on UARX Space's OSSIE (Orbit Solutions to Simplify Injection and Exploration) orbital transfer vehicle. The mission was conceived to address the study of the principal components for a biological space mission called BIXO (Bacteriological Intercommunication Experiment in Orbit), which investigates the effects of radiation on bacteria over extended periods in orbit. Additionally, the BIXO mission includes a secondary payload consisting of a camera for capturing images in space. CORTIS integrates these components to perform in-orbit studies, serving as both a technology demonstrator for BIXO's secondary payload and a comparative evaluation of various radiation sensor options. The radiation sensors, developed by the team, offer alternatives to the commercial off-the-shelf (COTS) BG51 sensor from Teviso. Two custom-designed sensors were proposed, both with identical interfaces to the COTS sensor to enable seamless integration. One sensor replicates the PIN photodiode-based topology of the COTS option, while the other leverages advanced SPAD (Single-Photon Avalanche Diode) technology. The core architecture of CORTIS is built around a motherboard capable of hosting a pair of each sensor type, making a total of 6, allowing the study of radiation effects under different shielding thicknesses. The motherboard integrates multiple measurement systems connected to a primary microcontroller, which manages data acquisition and storage in high-capacity memory modules. Additionally, when image capture is required, the onboard camera performs the task, ensuring data is stored and subsequently transmitted during optimal telemetry windows. This work outlines the design and development of the CORTIS hardware and software architecture, showcasing its role in advancing sensor technology and contributing to the BIXO mission's broader objectives.

Keywords: Payload, Radiation, Camera, Technology Demonstration

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INNOVATIVE DEPLOYABLE ANTENNA TECHNOLOGIES FOR ENHANCED TELECOMMUNICATIONS IN SMALL SATELLITE PLATFORMS

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ABSTRACT

Deployable antenna technologies are transforming small satellite telecommunications by addressing size, weight, and performance constraints. Small satellites, including CubeSats and microsatellites, must incorporate high-gain antennas to meet increasing demands for data-intensive communications.

Advanced deployable reflector designs, such as bio-inspired folding mechanisms and modular Carbon Fiber Reinforced Polymer (CFRP) systems, provide lightweight, scalable solutions optimized for compact platforms. These reflectors stow efficiently during launch and deploy reliably in orbit, ensuring surface precision for high-frequency bands like Ka-band.

Bio-inspired folding reflectors emulate natural principles to achieve compact stowage while maintaining structural rigidity and precise communication capabilities after deployment. Modular CFRP reflectors offer scalable designs, balancing low mass with stability, enabling customization for mission-specific needs. These technologies allow small satellites to meet the demands of modern telecommunications while optimizing payload efficiency.

Applications span Earth observation, broadband connectivity, inter-satellite communications, and scientific exploration, where high-frequency communications are critical. These deployable antennas also support multi-satellite constellations, enhancing mission flexibility and reliability.

The integration of advanced materials, innovative mechanisms, and precise engineering ensures reliability during launch and in the harsh conditions of space. These technologies address current communication challenges while enabling scalable, cost-effective solutions for future missions.

As the space industry grows, deployable antenna systems will play a vital role in expanding global connectivity, enabling small satellites to compete with larger platforms and deliver diverse capabilities in telecommunications, Earth monitoring, and space research.

Keywords: Antenna, Flexible, Reflector, Telecommunications, Deployable

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CORTIS MISSION: DEVELOPMENT AND QUALIFICATION OF A SMALL PAYLOAD FOR RADIATION SENSING FROM A STRUCTURAL STANDPOINT

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ABSTRACT

The CORTIS (Camera Observation and Radiation Test In Space) payload is a compact mission designed to demonstrate two key technologies: the use of a Commercial Off-The-Shelf (COTS) camera for Earth observation in space and the validation of three different radiation sensors, two of which have been developed in-house. These objectives are set to be achieved in 2025, when OSSIE (Orbit Solutions to Simplify Injection and Exploration), the orbital transfer vehicle developed by UARX Space, will be launched, carrying CORTIS along with other payloads. This document outlines the process undertaken by the Structural and Thermal Department of UVigo SpaceLab to develop the shielding system that provides structural support for the payload, as well as the qualification and validation of CORTIS. The process spans from the initial concept design meeting to the final stages of payload delivery for integration into OSSIE, all accomplished within a timeframe of less than a year. The first section focuses on the development of the shielding, considering multiple constraints and objectives. Key factors include the strict size and mass limitations of the payload and the specific requirements for radiation measurement, for which two isolated zones were incorporated into the design, enabling the study through different aluminium thicknesses. The second section delves into the structural simulations conducted, along with the qualification and validation testing processes and their respective results. This section concludes by emphasizing the correlation achieved between the simulation data and experimental results, thereby demonstrating the reliability of the design and analysis approach.

Keywords: Manufacturing, Qualification, Simulation, Shielding, Radiation

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FORESAIL-1 PRIME- REDEVELOPMENT A CUBESAT MISSION FOR SPACE SCIENCE

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ABSTRACT

The CubeSat standard has made space access affordable, enabling many universities worldwide to launch their first satellites for educational purposes. A natural progression from these initial missions is to aim for impactful scientific objectives, leveraging existing platform technologies and payloads. However, not all missions succeed as planned, and setbacks can provide valuable opportunities for growth.

This presentation highlights the redevelopment of the Foresail-1 mission, initially launched in spring 2022 but unable to achieve its mission objectives. Following this failure, a comprehensive redevelopment process was initiated, leading to the creation of Foresail-1 Prime.

Foresail-1 Prime is a 3U CubeSat designed for Low Earth Orbit (LEO), with two primary goals: studying charged particle precipitation and testing an innovative deorbiting technology, the plasma brake (PB). Developed by the Finnish Meteorological Institute, the PB is a 60-meter-long electrostatic tether that interacts with charged particles in the plasma environment to reduce orbital speed and enable controlled reentry. Another key payload, the Particle Telescope (PATE), developed by the University of Turku, measures energetic electron precipitation and solar energetic neutral atoms. Together, these instruments offer valuable insights into space weather processes in Earth's magnetosphere.

The satellite's avionics and overall design were entirely developed by Aalto University, including modular systems for communication, attitude control, and payload management. During the redevelopment, the power system was completely redesigned, and a new, improved software configuration was developed alongside numerous other enhancements. To ensure the platform's reliability, the team adopted and simplified fault analysis techniques, including Failure Modes, Effects, and Criticality Analysis (FMECA) and Fault Tree Analysis (FTA).

This redevelopment process provided significant insights into CubeSat development within a university setting. The lessons learned are valuable for the wider space community. Currently, Foresail-1 Prime is in the integration and testing phase, with a launch planned for 2025.

Keywords: CubeSat, Mission, Science, Lessons Learned

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FIRST YEAR OF THE ANSER CLUSTER IN ORBIT: VALIDATION OF ENABLING TECHNOLOGY

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ABSTRACT

Traditionally large-satellite missions are being gradually replaced by clusters and constellations of small satellites, reducing the total cost of the mission and expanding its capabilities. However, this approach presents a number of challenges that must be addressed by validating the enabling technology in orbit. This becomes one the main goals of the Advanced Nanosatellites Systems for Earth observation Research (ANSER) cluster developed at INTA, which was launched in October 2023. During the first year in orbit, the three-CubeSat cluster (Leader, Follower 1 and Follower 2) has demonstrated the following key aspects and technologies: (i) robustness of CubeSat missions by reinstating the Leader satellite, which was lost during launch, by a spare Leader (Leader-S) in about 1 year; (ii) Formation Flying Control (FFC) by deploying large aerodynamic flaps and using passive aerodynamic forces in LEO, namely, differential drag. Responsive and high-accuracy control of the in-track relative positions between both Followers has been demonstrated by keeping the satellites between 100-200 km; (iii) commissioning and in-orbit calibration of the integral attitude determination and control solution that enables the operation of the payloads and a fine FFC; (iv) Inter-Satellite Link (ISL) to establish two-way communications between satellites, that is a key enabler for the autonomous FFC. The ISL has been active since the distance between the Followers decreased to less than 300 km. The future INTA missions within the ANSER programme (ANSER-AT and Q-ANSER) will also be outlined during the presentation.

Keywords: Attitude Control, CubeSats, Differential Drag, Formation Flying Control, Inter-satellite Link

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ONBOARD LoRaWAN GATEWAY DESIGN: FPGA AND LoRA RADIO IMPLEMENTATION FOR THE PERCEPTION SATELLITE SYSTEM

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ABSTRACT

The Perception mission aims to enable efficient and scalable Internet of Things (IoT) connectivity from space in the Amazon region, through a collaboration between the University of Vigo and the University of Brasilia. A key component of this mission is the implementation of a LoRaWAN server on an FPGA, integrated with a commercial LoRa radio, to establish a reliable and adaptable onboard gateway for IoT data acquisition.

The implementation of a LoRaWAN server tailored for space applications leverages the processing power and reconfigurability of FPGAs to manage the reception and transmission of LoRa signals from multiple terrestrial nodes. The integration of commercial LoRa radios provides a cost-effective and efficient solution while maintaining compatibility with existing terrestrial IoT infrastructure. This development focuses on optimising resource usage and maximising reliability, addressing the constraints inherent to the space environment, such as limited power, weight, and computational capacity.

The LoRaWAN server architecture is designed to support the aggregation and processing of data from terrestrial sensors. This approach facilitates real-time monitoring and data collection from remote and inaccessible areas, such as forests, oceans, and deserts, where traditional terrestrial infrastructure is impractical. The use of an FPGA ensures adaptability to future advancements, allowing for the integration of evolving IoT standards and the flexibility to meet new mission requirements.

Implementing this server on an FPGA enables its integration into small satellite systems, using commercial radios based on the Semtech chip. This approach allows for the creation of gateways with extended coverage from low Earth orbits (LEO), connected to the ground segment via other links. This design optimises IoT data collection from Earth, enhancing both efficiency and reach in remote scenarios.

Keywords: CubeSat, FPGA, IoT, Lora, Gateway

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AN EXPERIMENTAL CUBESAT PLATFORM FOR FLEXIBLE SPACE COMMUNICATIONS

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ABSTRACT

The next generation of communication technologies is driving a significant transformation in satellite-based communication systems, pushing them beyond rigid hardware designs toward more flexible, software-defined solutions. Traditionally, space communication payloads have relied on high-performance hardware-based platforms, such as FPGAs, for computationally intensive signal processing. Today, advances in software-defined radio (SDR) frameworks and general-purpose processing (GPP) platforms enable payloads to be more adaptable, easily upgradable, and reconfigurable in orbit.

We present the architecture of a communications CubeSat developed within the KSAT: Space & Entrepreneurship project, a student-driven initiative advancing innovative platforms. Specifically, we describe a 1U CubeSat intended for Low Earth Orbit (LEO) operations that integrates SDR technology with virtualization techniques to flexibly manage communication applications. Unlike conventional designs, our prototype employs a general-purpose single-board computer that hosts containerized services through Docker, allowing rapid reconfiguration of waveforms, protocols, and processing algorithms without requiring hardware modifications.

A key advantage is the ability to dynamically adapt to changing mission requirements, spectral regulations, or user demands post-deployment. To demonstrate feasibility, we employ the LoRa protocol as a representative link layer, leveraging its open, non-licensed spectrum and robust, low-power communication capabilities. By integrating the entire payload within a 1U CubeSat, we show that off-the-shelf (COTS) hardware, combined with software-driven techniques, can meet the constraints and performance demands of a small satellite platform.

This work highlights the potential of GPP-based SDR solutions to lower system complexity, reduce development time, and enable more agile mission operations. Through this student-led effort, we anticipate a future where software-defined, reconfigurable communication payloads become standard, facilitating a new generation of flexible and versatile space-based communication services.

Keywords: Small Satellite, Communications, Regenerative Payload, LoRa, SDR

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MECHANICAL DESIGN OF A MODULAR CUBESAT STRUCTURE

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ABSTRACT

The development of satellite swarms has grown significantly in recent years due to the reduced cost of launching small satellites, particularly CubeSats, thanks to their compact sizes. This paper focuses on the design process used to create a satellite prototype capable of being manufactured through various methods while ensuring structural validation under operational conditions. The prototype aims to support internal electronic components, such as PCBs and controllers, as well as external components like solar panels.

To achieve this, multiple simulations were conducted, including modal analysis, structural static analysis, random vibration, and thermal transfer analysis. These analyses guided the optimization of different design iterations by adjusting the geometry to meet specific operational requirements. The outcome of this process was a low-fidelity prototype, constructed from polymers such as PLA and ABS, using additive manufacturing (FFF). This prototype serves as a preliminary model for a high-fidelity version and the check for possible interferences.

The high-fidelity prototype is designed with a metallic frame produced through selective laser melting (SLM) and includes external electronic components manufactured via CNC machining and laser cutting. This progression from low fidelity to a high-fidelity prototype provides a clear pathway for validating structural integrity and manufacturing feasibility, ensuring that the satellite can withstand the conditions it will face in space while meeting functional requirements.

Keywords: FEA, DFMA, Structure, Prototype, Cubesat

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THE EMERGING MALAGA TELECOMMUNICATIONS SPACE ECOSYSTEM: ONGOING INITIATIVES AND OUTLOOK

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ABSTRACT

The next generation of communication technologies is driving a significant transformation in satellite-based communication systems, pushing them beyond rigid hardware designs toward more flexible, software-defined solutions. Traditionally, space communication payloads have relied on high-performance hardware-based platforms, such as FPGAs, for computationally intensive signal processing. Today, advances in software-defined radio (SDR) frameworks and general-purpose processing (GPP) platforms enable payloads to be more adaptable, easily upgradable, and reconfigurable in orbit.

Málaga Academic and Private sectors, with its strong foundation in Information and Communications Technology (ICT), telecommunications, and a growing microelectronics component, is positioning itself to be able to play a relevant role in the evolving space ecosystem. Various initiatives across education, research, and industry are contributing to this emergence.

A key example is the K-SAT: Space & Entrepreneurship Lab of the University of Málaga, and educational program, which is providing students with hands-on experience in satellite development and operations. Within this framework, the ongoing ESPETO CubeSat (Experimental Satellite Platform for Enhanced Telecommunication Operations) proposes a 1U CubeSat designed for Low Earth Orbit (LEO) operations.

Complementing these efforts, Málaga has also seen the emergence of entrepreneurial initiatives, such as ALBOR Space, an early-stage spin-off project from the Univ. of Málaga exploring new approaches to satellite-based communication technologies. While still in its formative phase, ALBOR represents the growing ambition of local talent to transition innovative concepts from research into practical solutions.

These activities, together with Málaga's broader strengths in ICT, are contributing to an emerging local space ecosystem. By combining student-led projects like ESPETO, the technical training provided by K-SAT, and the promising entrepreneurial efforts exemplified by ALBOR, Málaga is beginning to build the capabilities needed to support flexible, software-driven satellite missions. This positions the region to contribute meaningfully to the future of small satellite communications and related technologies.

Keywords: Small Satellite, Communications, Educational, SDR

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EXTENDING IoT CONNECTIVITY WITH 5G NTN: INSIGHTS FROM SATELIOT'S FIRST COMMERCIAL MISSION

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ABSTRACT

The rapid growth of the Internet of Things (IoT) represents a significant business opportunity, driven by the demand to connect an ever-increasing number of devices globally. To address this need, Sateliot launched four CubeSat satellites in August 2024, equipped with the world's first payload capable of extending Narrowband IoT (NB-IoT) coverage under the 5G Non-Terrestrial Networks (NTN) standard. This breakthrough enables seamless 5G NB-IoT NTN services for commercial customers, marking a pivotal milestone in the satellite communication industry.

Market demand for this innovation is evident, with Sateliot securing over €250 million in binding contracts to serve Mobile Network Operators (MNOs) worldwide. This demonstrates the critical role of satellite connectivity in enabling ubiquitous IoT deployments.

This article presents the mission status since the August 2024 launch, highlighting key lessons learned, technical milestones achieved, and the integration progress with customers. Additionally, it discusses service deployment and operational status, offering valuable insights into the transformative potential of Sateliot's 5G NTN-enabled IoT solutions.

Keywords: 5G, NTN, NB IOT, Satellite Constellation

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ENHANCING DEEP SPACE MISSION OPERATIONS WITH CCSDS STANDARDS

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ABSTRACT

As smallsat become a common platform for low-cost science missions and as spacecraft venture beyond the low Earth environment into deep space such as cislunar and beyond, missions would need larger antennas on the ground to maintain sufficient high-capacity link. This is especially true in off-nominal situation where the link is negatively affected by unexpected conditions. Since at the current time in the early phase of smallsat era where there are not many large antennas commercially available, the providers of 30-m class of antennas are mostly national space agencies such as NASA, ESA, JAXA, etc. These ground stations support standard data interfaces defined by the Consultative Committee of Space Data Systems (CCSDS) for the interfaces between the ground stations and mission spacecraft as well as mission operation control centers. This talk advocates for the use of standard data interfaces to increase robustness in mission operations, especially under a last-minute emergency support as in the case of the Lunar Node 1 mission. Standard data interface protocols such as space link extension (SLE) and cross support transfer service (CSTS) between mission operation control center and the ground station would facilitate the delivery of commands, telemetry and tracking data. The use of standard RF frequency band allocation would ensure a full compatibility between spacecraft and the ground station. Extending mission operational capability further to a network environment, the use of bundle protocols for disruptive/delay tolerant network would enable many available space assets to participate in the data transfer, rather than just limit to a point-to-point connection.

Keywords: SmallSat, Communications, Deep Space, CCSDS Standards

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DEPLOYABLE ANTENNAS AND STRUCTURES: A DISRUPTIVE CONCEPT FOR NEW MISSIONS AND BUSINESS

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ABSTRACT

Space deployable antennas and structures are enabling new kind of missions and business in space, as small satellites capabilities are being improved and scaled-up to classic large-scale missions such as NASA's SWOT, ESA's SWARM and others. Many kinds of deployable antenna configurations are being reduced to be accommodated in small platforms. These deployable antennas can be even combined in swarm satellites, enabling new possibilities that had not been imagined up to now.

These kind of antennas and structures can reduce the cost of the missions to ten times less its cost, and enabling their use in constellations, instead of launching one high-cost satellite with long revisit times. Additionally, the reduction of the payload size in the platform allows using small satellites with different main payloads for different purposes, instead of old-style platforms with one single main payload or purpose.

During the presentation, different real examples of these kind of architectures will be shown with the advantages they have with respect to other past configurations in the world of small satellites. References to past and future planned missions will be provided, including current developments in Europe and Spain in particular.

Keywords: Antennas, Deployables, Earth Observation, Satcom

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SMART ANTENNA ARRAYS: ADVANCING DIGITAL BEAMFORMING, INTERFERENCE MANAGEMENT, AND RESOURCE OPTIMIZATION

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ABSTRACT

Smart antennas with array processing offer transformative advantages for modern communication systems, including digital beamforming, interference detection and geolocation, and traffic-based resource optimization. These technologies utilize advanced signal processing algorithms to dynamically shape radiation patterns, mitigating interference and enhancing spectrum efficiency. Additional benefits include increased communication reliability, improved directional accuracy, and adaptive resource allocation, making them invaluable for highly dynamic and complex communication environments. Moreover, these systems are particularly well-suited for deployment on small platforms and space rovers, where compact and efficient solutions are essential for enabling dynamic, high-performance communications in constrained environments.

Recent studies underscore the potential of smart antenna arrays for next-generation communication systems. Salas-Natera et al. have made significant contributions to this field, particularly in the calibration and optimization of active antenna arrays for satellite communications and their integration with reconfigurable intelligent surfaces as well as novel beamforming algorithms (Salas-Natera et al., IEEE Access, 2024; Salas-Natera et al., IEEE Transactions on Antennas and Propagation, 2023). These works highlight methods for achieving high polarization purity, dynamic resource allocation, and low-complexity interference management. Similarly, advancements in adaptive array processing for geolocation and interference suppression are reviewed in articles such as those by Rahmat-Samii et al. (IEEE Transactions on Antennas and Propagation, 2023) and Chatzinotas et al. (IEEE Communications Surveys & Tutorials, 2022), which explore the integration of machine learning techniques into array systems.

This work synthesizes insights from recent efforts, providing a comprehensive review of the advantages and challenges of smart antenna arrays focused on smallsat platforms applications. Their scalability, flexibility, and robustness position them as key technologies for future applications, including small satellite platforms and space exploration vehicles requiring dynamic and complex communication capabilities. In this sense, recent developments and roadmap for IOD of UPM technology onboard UPMsat 4 will be presented.

Keywords: Flexible-payload, Array-Processing, Smart-Antennas, Digital-Beamforming, DoA

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PRELIMINARY RESULTS FROM AN AFTU PROTOTYPE BASED IN SMART AVIONICS

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ABSTRACT

Operating a launcher involves significant risks, even for reliable and tested systems, as they operate in extremely harsh environments. Any issue during the ascent phase can result in loss of control over a massive vehicle filled with flammable fuel, posing serious risks to human lives. To mitigate these risks, launchers are closely monitored and tracked during the ascent phase. It is required to ensure compliance with safety regulations which govern mission aborts when the nominal flight envelope is potentially violated, leading to unacceptable human risk levels. Traditional flight termination architectures rely on independent radar and telecommunication networks with human intervention, which entails: (i) significant budget allocation for infrastructure and operations, (ii) limited flexibility due to radar network requirements, (iii) vehicle monitoring constrained to line-of-sight (LOS) conditions, and (iv) delays inherent to communication and human decision-making processes.

Thanks to the maturation of several technologies, it is possible to overcome those limitations by targeting autonomous concepts to move the termination decision on-board: 1. Improvement in GNSS technology and hybridization techniques. 2. Increase of computational capabilities to implement complex algorithms on-board. 3. Utilization of an efficient avionics SW execution platform based on emerging standards (e.g., NASA CFS) to isolate SW safety critical applications.

Within Europe, there is no clear standard on the design nor operation of an AFTS. The critical part of this type of standards is related to the management idiosyncrasy of the flight regulation in each country. The definition of non-flight areas and corridor is a task performed by range safety officer which should guarantee that a faulty launch could not endanger human lives. These tasks are obviously closely related own country regulations, making it difficult to have a common standard in Europe. It is proposed a highly configurable unit, in which the range safety officer could even include proprietary software for the termination logic.

The proposed solution within the SAFEST project framework is an Autonomous Flight Termination Unit (AFTU) demonstrator. An AFTU processes different tracking input coming from the navigation solution or external sensors, to select the best solution and update the state vector. Furthermore, the flight rules, also known as mission rules, are defined by the user during the missionization phase. So, comparing the current estimated state to flight rules the safety of the flight is determined. The implemented algorithms are highly configurable, being suitable for a broad range of launchers and countries.

The paper is specifically focused on presenting the results obtained from the test campaign of the initial prototype. It also provides a detailed description of the prototype, the test equipment, the test campaign, and the roadmap for the technology development up to its flight qualification.

Keywords: Launcher, Software, Avionics, Autonomous Flight Termination System, Safety

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EODD-LYNX ACTIVE ANTENNA FOR EO DATA DOWNLINK

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ABSTRACT

In this article, we present the design, manufacturing, and testing of EODDL-LYNX, which is a fully electronically steerable antenna system operating in X-band with high-purity circular polarization. The system comprises two main components: an antenna tile and a signal conditioning board. The antenna tile features an array of sixteen double-stacked patches, each with its independent beamformer, while the signal conditioning board upconverts the signal from intermediate frequency (IF) to radio frequency (RF).

Although only one tile is manufactured for the time being, the final EODDL-LYNX product will feature a frustrum of five facets, each with independent pointing capabilities within a hemispherical cone. Each of the facets of the frustrum will cover a FoV of ±30º, centered in their locally defined boresight directions. The system includes an RFSoC responsible for data modulation from SpaceFiber, selecting the active tile, calculating amplitude and phase coefficients for beam steering, and controlling the beamformers of each antenna patch. It also oversees the DAC, upconverter and amplification stages. An RF switch selects the most suitable tile for signal transmission based on mission needs.

The control software and calibration algorithms have been successfully tested, enabling the antenna to steer and calibrate the beam up to 45º field-of-view from the broadside direction in any azimuthal plane. The axial ratio in the broadside direction remains below 2 dB across the entire band, with calibration algorithms capable of improving this value within milliseconds when the beam is tilted.

Control is managed by a Xilinx RFSoC system, which handles the required MODCOD as specified in CCSDS 131.2-B-2.

This system is designed for future Earth observation satellites and constellations, offering a more advanced, compact, and flexible solution compared to traditional technologies. In a future iteration, we plan to integrate the complete antenna with the transmitter into a single system, providing additional benefits in terms of flexibility, integrability, and cost. This comprehensive system demonstrates significant advancements, with potential applications in small Earth observation satellites.

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ADVANCED THERMAL MODELLING OF A SMALL ROVER POWERED BY SOLAR PANELS AND A RADIOISOTOPE THERMOELECTRIC GENERATOR (RTG) USING ESATAN AND ECOSIMPRO

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ABSTRACT

In this research a comprehensive thermal analysis and optimisation of a small size rover designed for operations at the lunar South Pole is presented as part of the ESA-funded AMPERS project. The rover is powered by solar panels and a Radioisotope Thermoelectric Generator (RTG) and operates in an environment characterised by extremely low temperatures and rapid thermal fluctuations. Robust thermal management is essential to ensure its functionality, and to this end, ESATAN and EcosimPro have been employed to model the vehicle's thermal behavior.

A geometrical mathematical model of the rover is developed in ESATAN and parameters, like radiative conductances (GRs) are incorporated into a simplified thermal model developed using EcosimPro. This model is very useful to accurately assess the heat dissipation and thermal behaviour of each component. The proper sizing and location of the RTG is optimized, based on the energy and thermal requirements across the rover's subsystems and evaluating several thermal control strategies to maintain components within their optimal operational ranges.

Our approach was further validated by comparing the findings with the operational experiences of NASA's Curiosity rover and the Intrepid mission. These comparisons provided practical insights, enabling us to refine our thermal strategies based on proven data from established missions. The results of this study offer valuable guidance for optimising heat management in future lunar rover designs, ultimately enhancing their operational feasibility in challenging extraterrestrial environments.

Keywords: Lunar, Rover, Thermal, EcosimPro, ESATAN

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REIMAGINING STANDARDIZATION: OPTIMIZING SMALL SATELLITE DEPLOYMENT IN THE SPACE INDUSTRY

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ABSTRACT

Standardization is a fundamental strategy for reducing costs and enhancing efficiency in the space industry. However, the application of existing standards can sometimes lead to unintended consequences, including increased overhead costs. This phenomenon is particularly evident in the case of small satellites in the 30 to 50-kilogram range, which often adhere to the CubeSat standard. This adherence necessitates the use of deployers that impose a significant weight burden compared to alternative separation systems.

In this paper, we explore the broader implications of standardization in the space industry, examining both its benefits and potential drawbacks. We then address the need for generalized standardization across various technologies, presenting a standardized small satellite structure designed to fit within 8-inch and 15-inch separation rings as a case study. This example illustrates how reevaluating and reimagining standards can lead to more efficient and cost-effective solutions.

Our analysis reveals several advantages over the current state-of-the-art CubeSat standard, particularly when compared to the 12U CubeSat deployers. These advantages include reduced weight constraints, lower deployment costs, and increased mission feasibility for small satellites. By analyzing the complexities and challenges associated with standardization, our research aims to contribute to the ongoing evolution of pragmatic and economical approaches in the rapidly advancing field of space exploration.

Keywords: Standardization, Deployment, Constellations, Small Satellite, Cost-reduction

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DEVELOPMENT OF A SYNCHRONIZED DEPLOYMENT SOLAR ARRAY WING FOR SMALLSATS

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ABSTRACT

SmallSats multi-panel solar array wings run the risk of colliding with protruding instruments from satellites during deployments. A project to develop a LEO solar array deployable wing with a deployment synchronization mechanism will help to deploy the wing in a controlled way also contributing to the stability of the satellite.

To develop this wing new additional technologies have been developed and tested: carbon fiber substrates improved for flexibility during manufacturing; flat cable interconnections ensure the resistant torque of the electrical harness is low and predictable while being able to withstand the ATOX environment; clock-springs driven hinges allow for adjustability during integration; and deployment sensors verify the wing has deployed in-orbit.

All these technologies have been combined in an engineering model that shall be tested in both thermal vacuum cycling and vibrations to guarantee its operation in the space environment. This project is being carried out in collaboration with the European Space Agency.

Keywords: SmallSats, LEO, Solar Array, Synchronization, ATOX

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GREEN MOON PROJECT

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ABSTRACT

As humanity prepares for long-term space habitation, sustainable food production is essential. The Green Moon Project (hereafter GMP) aims to address this challenge by creating a modular, autonomous greenhouse designed for space ecosystems, including orbital stations and lunar bases. GMP integrates engineering, biology, and geology to study seed germination and plant growth under reduced gravity and radiation, optimizing In-Situ Resource Utilization (ISRU). This innovative project will enable sustainable food and oxygen supply, advancing space agriculture and ensuring the economic and social sustainability of future human missions beyond Earth.

The innovative GMP instrument incorporates small cultivation cells containing a mixture of terrestrial fertile soil and the Lunar LZS-1 regolith simulant, mimicking the Fra-Mauro region explored during Apollo 14, produced from Lanzarote soil. Sensors will monitor critical parameters such as O_2, CO_2, temperature, radiation, luminosity, and humidity. The system also features LED illumination, VGA and multispectral cameras for plant growth analysis, and a water pump. This compact 3U instrument will maintain Earth-like pressure and atmosphere to support experiments.

In a significant milestone, GMP has partnered with the Spanish startup Orbital Paradigm to conduct its first Earth-orbit mission in 2026. Using a pressurized capsule developed by Orbital Paradigm, GMP will investigate plant growth under microgravity using LZS-1 regolith simulant. This mission integrates plant biology and planetary geology expertise within a real space environment and provides high-value scientific data to inform future space agricultural experiments. The advanced modular design of the capsule allows for real-time monitoring, maximizing the scientific output.

As an intermediate step before deploying GMP on the Moon, this Earth-orbit mission highlights the innovative capacity of Spanish space science and engineering. It underscores the role of New Space initiatives in democratizing space access, advancing breakthroughs in ISRU, and bringing humanity closer to achieving a sustainable lunar presence.

Keywords: Space Agriculture, Controlled Ecosystems, Planetary Geology, Plant Biology, Space Farming

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