TRILATERAL SAFETY AND MISSION ASSURANCE CONFERENCE 2024

ABSTRACT BOOK

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LUNAR EXPLORATION

Moon to Mars (M2M): Exploration Atmosphere

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As humans leave the bounds of Earth to explore the lunar surface and beyond, crew will don extravehicular activity (EVA) suits to learn more about these extraterrestrial environments, establish sustained presence, and perform needed upgrades and maintenance to their space vehicle and habitation systems. Spacefaring vehicle and habitation design will need to support these EVA excursions while ensuring crew health and safety. A crucial technological design advancement towards this goal is the use of a lower pressure exploration atmosphere (EA) that enables high efficiency EVA, rather than the sea level atmosphere of 14.7 psia, 21% oxygen (O_2) found on the International Space Station, Shuttle, and most other Russian and Chinese space vehicles and stations. Early space vehicles (Mercury through Apollo Programs) used a 5 psia, 100% O_2 environment, which eliminated the need for pre-EVA denitrogenation protocols, simplified the life support system to a single gas, and saved structural mass. For longer duration missions (Skylab), a diluent gas was added, changing the atmosphere to 5 psia, 70-74% O_2 to prevent atelectasis while remaining normoxic. As in-flight science became a top priority, Shuttle and ISS atmospheres were chosen to operate at sea level allowing for simpler ground-based study control conditions. Consequently this led to long pre-EVA denitrogenation protocols involving up to 4 hours of O_2 prebreathe because the EVA suit still operated at a low pressure of 4.3 psid. To increase operational efficiency, the Shuttle was retroactively certified to operate using 10.2 psia, 26.5% O_2, reducing O_2 prebreathe time to 40-75 min. Current plans for M2M habitats on the Lunar surface require EVA, thus EA recommendation became 8 psia and 32% O_2 but was revised to 8.2 psia and 34% O_2 to decrease hypoxia exposure. Unfortunately, the benefits of EA in support of safe and efficient EVAs comes with the challenge of fire management in a higher-than-normal O_2% environment. Although known for decades, the recommended forward work to address fire management has only recently begun. Current flammability tests include examining material propagation and ignition sources as well as fire mitigation processes to better understand these properties for proposed new EA environments. Fire safety, DCS risk, and mission design all contribute to the multifaceted parameters of EA. Thus while it is clear that EA is required to achieve the goals of future exploratory space missions, final specifications are still being evaluated for optimizing crew health and safety.

Lunar Surface Challenges

NASA EHP SRP Chairman Steven Fuqua[1]
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The last time Lunar regolith was stirred with human feet was by the Apollo 17 astronauts in 1972, over 50 years ago. Thanks to NASA's Artemis campaign and with the help of International Partners and commercial companies, the Lunar regolith will soon be stirred once again by a renewed human spaceflight commitment to explore the Lunar surface. A return to the Moon comes with an assortment of challenges. In addition to the necessary design and development of complex exploration spacesuit and mobility systems, the operational environment of the Lunar surface, especially for the intended South Pole destination, presents unique hazards and risks to be confronted. During this presentation, we will explore NASA's current efforts to develop a new, more mobile spacesuit system for the Lunar surface and initial concepts for both a Lunar Terrain Vehicle (LTV) and Pressurized Rover (PR) mobility system. We will also focus on key operational risks for lighting, communication/navigation, and Lunar dust – all of which will influence the success we intend to achieve through the Artemis campaign.

Model Based Safety and Reliability Development Method for Crewed Pressurized Rover

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In conventional aerospace development, hazard identification and comprehensive extraction of causes are achieved through commonly used techniques such as Fault Tree Analysis (FTA) and Failure Mode Effect Analysis (FMEA) in safety and reliability engineering. For example, in the case of the International Space Station (ISS), a combination of FTA and FMEA is employed to enhance comprehensiveness and ensure redundancy, thereby reducing risks. However, the comprehensive extraction of failure causes located in the complex spacecraft systems requires a significant amount of development time. Additionally, in lunar surface exploration systems exposed to unknown and harsh environments, there are concerns about potential oversight of risks and the need for design revisions.

On the other hand, automobile for the earth development at Toyota Motor Corporation adopts a comprehensive safety and reliability evaluation method from both the perspective of design based on failure modes (DRBFM: Design Review Based on Failure Mode) in FMEA and actual driving evaluations for the development of their automobiles. DRBFM is a development method that identifies changes and modifications in design, manufacturing, environment or customer usage, identifies anticipated failures and their causes associated with these changes, and explores design methods and verification techniques that serve as solutions with experts' discussions. The safety and reliability development methods that have been cultivated in automobile development, to meet the demands of various users worldwide on earth, can contribute to the development of higher reliability and lightweight systems by combining them with safety and reliability development methods for spacecraft systems especially mobility on planetary exploration.

The Crewed Pressurized Rover system requires high mobility on the rough road, comfortable livability on the lunar polar, high safety, reliability and durability for the long-term mission. In order to develop efficient, safe, and reliable systems within limited mass constraints, a development method that leaves no room for oversight is necessary. However, there are concerns about significant increases in development time and potential oversights of risks in document-based development. In this presentation, the new model-based safety and reliability development method is proposed, which estimates failure rates by considering the changes in the lunar environment based on the reliability records of automobiles on Earth. The proposed method is characterized by the adoption of a model that combines safety and reliability development methods from both conventional spacecraft systems and automobiles. This presentation will overview of the method and introduce several case studies.

Charting Safety in the New Space Era: Planetary Protection considerations

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Article IX of the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (the "Outer Space Treaty"), requires that State parties to the treaty conduct the exploration of outer space, including the Moon and other celestial bodies, "so as to avoid their harmful contamination and also adverse changes in the environment of the Earth resulting from the introduction of extra-terrestrial matter and, where necessary, [to] adopt appropriate measures for this purpose".

The ESA Agenda 2025 and Terrae Novae vision 2040+, articulate ambitious space exploration plans for the next years, aiming to increase European autonomy and leadership in space. These plans include the search for extraterrestrial life, returning samples from Mars, the unprecedented desire for a stable European presence on the Moon's surface and crewed missions to Mars. The complexity of such missions has enhanced the importance of safety aspects, as well as challenging current methods and approaches.
The debate over the governance, legal, scientific and commercial aspects of space exploration must evolve to consider the interests of new actors in space exploration. The negotiation of very often conflicting needs requires a multidisciplinary approach, and the development of credible tools to enable space explorations, while ensuring safety and sustainability in space.

This work describes the major planetary protection challenges faced in the frame of ESA missions; as well as the strategy and plans put forward to trigger modernisation of safety practices and standards. Planetary protection highly benefits from international consensus. Any effort in that direction shall take into account the interest of the extended planetary protection community, the presence and importance of new strategic partners (i.e. private and commercial sectors), with the aim to develop sensible standards and requirements.

The decisions we make now about planetary protection, the tools we develop and the procedures we put in place will determine the kind of missions that future scientists can carry out and the quality of data that they can collect. This is a huge responsibility: this adds up to the necessity of keeping target planets as pristine as possible (to allow future generations to pursue their scientific goals) and protect our biosphere by the unwanted release of potential detrimental pathogens.

Evolving, Enabling and Ensuring Safety of Terrestrial, Orbital and Planetary Environments: Planetary Protection's Lunar Policy Evolution and Implications for Future Policy Needs

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Planetary protection (PP) as a discipline focuses on the safety of terrestrial, orbital and planetary environments as well as the safety of the public due to potential harm from a sample returned from other solar system bodies. The COSPAR Planetary Protection policy is leveraged by agencies as the international consensus standard. This international standard is developed and managed by a panel of space agency representatives and selected members of the science community. Technical objectives and guidance within this standard are updated by achieving scientific consensus through a series of agency level assessments, peer reviewed publications, workshops, open and closed panel meeting discussions, and consensus by the panel.

The evolution of lunar planetary protection policy from the 1960s to present day demonstrates the responsiveness of policy to scientific consensus. In 1960 the risk posture was conservative with the absence of scientific data, resulting in what would be considered a decontaminated and sterilized bioburden-controlled spacecraft today (i.e., PP Category IV for landers) for forward planetary protection. Backward planetary protection required the need to contain and quarantine astronauts and lunar samples (i.e., PP Category V(r), restricted Earth return). As more science data came in from Apollo in terms of orbital science, quarantine, and sample safety assessments, PP requirements changed to PP Category I and Category V(u) (unrestricted Earth return) missions starting with Apollo 15. In the early 2000s, more orbital and impacting assets provided data to substantiate that permanently shadowed regions and poles of Earth's Moon were recognized as needing protection for future science; thus, changing to a Category II in 2008. Finally in 2002-2021, further scientific consensus was achieved by the National Academies of Science, Engineering, and Medicine (NASEM) Committee of Planetary Protection and COSPAR. The resulting change of lunar categories expanded to Category II, IIa, and IIb to reflect the level of risk/documentation required for missions orbiting and landing on the lunar surface.

Here we will further showcase the latest policy changes, mission implications for recent NASA missions, and continued conversations with the science and engineering community to ensure current and future science is enabled by PP policy. Lessons from the Lunar policy process can help provide a critical perspective as we continue to work in a collaborative environment to continue to evolve, enable, and ensure safety of terrestrial, orbital and planetary environments.

Lunar dust contamination on our habitat for Artemis missions: impacts and mitigation approach for MPH

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Apollo astronauts learned first-hand how problems with dust have an impact on lunar surface missions. It was found that the effects could be sorted into nine categories: vision obscuration, false instrument readings, dust coating and contamination, loss of traction, clogging of mechanisms, abrasion, thermal control problems, seal failures, and inhalation and irritation. Although simple dust mitigation measures were sufficient to mitigate some of the problems (i.e. loss of traction) it was found that these measures were ineffective to mitigate many of the more serious problems (i.e. clogging, abrasion, diminished heat rejection). The severity of the dust problems were consistently underestimated by ground tests, indicating a need to develop better simulation facilities and procedures.

Key strategies for lunar dust contamination control includes both passive and active measures. Passive preventive actions deals implementing dust-resistant materials and defining operational constraints can minimize dust entry into modules. Additionally, employing robust filtration systems and establishing strict decontamination protocols for spacesuits and equipment can mitigate internal dust accumulation. Actively, developing efficient preventive and cleaning technologies for external items, such as electrodynamic dust removal systems, proves to be essential for maintaining habitable conditions within modules.

However, several challenges persist in the effective management of lunar dust contamination over prolonged periods. MPH (Multi-Purpose Habitation) is designed to properly work for 10 years of operations. The presentation will focus on possible mitigations and verification methods. Design advance development and dust testing were proposed for most critical items and materials characterization. TAS facilities are herein presented, as well as test definition approach.

Evolution of Safety approach for the International Habitation Module of Cis-lunar Space Station: challenges and way forward.

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25-years long experience in human spaceflight programs, with sustained human presence in space environment, has represented a great source of valuable technical data to implement a new approach to the safety human rating requirements for the challenging objective of a human outpost around the moon and beyond: the Gateway Cis-lunar Space Station and its International Habitat module.
This new approach, derived from lessons learned in human spaceflights thanks to International Space Station (ISS) program, will be applied to a different mission and operating scenario. Wider distance from Earth, limited presence of crew on board, severe radiation environment and lunar dust presence constitute the peculiar challenges to be faced by I-HAB and Gateway Program.
Relevant outcomes from ISS experience led to human rating requirements evolution, improving the definition of the safety-related technical requirements and background rationale, other than detailing of requirement verification methods.
As an evident difference in the safety and program approach for Gateway, failure tolerance requirement has been changed from prescribing tolerance to combination of two failures against catastrophic hazards in ISS, to at least single failure tolerance in IHAB and Gateway. Furthermore, requirement for critical hazards control has evolved from levying single failure tolerant design to require control of this hazard category.
This approach must be seen in conjunction with the need to optimize the design in terms of mass constraints, considering the more challenging target of the NRHO compared to the Low Earth Orbit, maintaining a safe design as primary objective.
In this framework, an evolution of ISS Safety approach based on return of experience led to the implementation of the concept of “Failure Tolerance Exemptions”, which requires particularly accurate and structured supporting documentation for deviation acceptability.
Significant difference between ISS and Gateway operability lies in the fact that, while on ISS crew is permanently present, thus ensuring the capability to perform preventive/corrective maintenance, on Gateway intermittent crew presence makes mandatory an extensive autonomous recovery capability of on board anomalies.
The process for I-HAB safety analyses and Program overall residual risk acceptance consists in a Phased Safety Review with an extensive participation of safety experts from multiple Space Agencies, with respect to previous NASA owned processes.
In conclusion, I-HAB witnesses an evolved safety human rating requirements development and represents a main actor in this approach implementation, giving fundamental contribution to ensure the safe design and operations of present and future deep space missions.

NASA Space Nuclear System Safety and Authorization Activities for Lunar Missions

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This presentation will introduce the audience to NASA's nuclear safety and mission assurance activities related to ongoing system development and future lunar missions. It will introduce the potential uses of space nuclear systems, including radioisotope power systems and fission reactors, within the NASA lunar architecture in both NASA-managed and commercial services contexts. It will then discuss the safety and mission assurance activities that are seeking to create greater harmony between U.S. agencies and with the international community for space nuclear systems toward creating greater "regulatory certainty" for these missions. These activities include terrestrial possession and use, terrestrial transport, launch safety and launch authorization, and in-space safety topics. Activities to be highlighted include NASA's own guidance activities, U.S. interagency forums including the Interagency Nuclear Safety Review Board, and a voluntary consensus standard development activity within ASTM International. The presentation will also describe NASA's bilateral and multi-lateral exchanges with the international community in this same topical area. The presentation will conclude by pointing out opportunities for cooperation between NASA, ESA, and JAXA Safety and Mission Assurance organizations in light of the greater international cooperation that is occurring between these entities for development and deployment of space nuclear systems.

Launch Safety Authorization Proces for ESA space missions with Nuclear Power Systems

<u>Mr David Le Falc'her</u>[1]
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Capacity to act is physically constrained by power availability. In space, when solar or chemical power is not efficient enough for specific missions, the only widely used and proven solution is the nuclear power that is able to provide heat and electricity. Despite some emblematic missions carried out in collaboration with non-European states, Europe does not have autonomy today for launching missions involving nuclear power sources. ESA has been driving for a few years the activities necessary to make it possible with a strong emphasis on the building of a system level nuclear safety demonstration. Ensuring Nuclear Safety requires for Europe to demonstrate technical safety performances of all the components of a mission: the nuclear power source, the launcher, the spacecraft and the launch base. It requires also to build a solid methodology for obtaining authorization by the French authorities, namely CNES (Centre national d’études spatiales) and ASN (Autorité de sûreté Nucléaire, French nuclear safety authority) for missions to be launched from Guiana space center or Centre Spatial Guyanais (CSG, in French). Nuclear safety demonstration still needs important effort to make it possible to launch European nuclear power sources from CSG, significant progresses have been achieved these last years. The ESA safety policy on the use of nuclear power sources has been issued in 2018 as ESA/ADMIN/IPOL-INSR (2018)1. The ESA Space Transportation safety framework for NPS space applications has been drafted, in line with the ESA/ADMIN/IPOL-INSR and based on the guidance provided in the Safety Framework for Nuclear Power Source Applications in Outer Space and using best practices reflected in the national safety frameworks of states with experience in using space NPS.

DIGITAL ENGINEERING AND ASSURANCE

Developing Safety and Mission Assurance Cases with AdvoCATE

Dr Ewen Denney[1]
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Assurance cases represent the state of the art in assurance technologies, and are often required for applications in many safety-critical domains (e.g., nuclear, automotive, railroad, defense, medical devices, etc.). They are also applicable in domains where regulations have not yet kept up with technology, such as autonomous vehicles.

An assurance case demonstrates that the risks associated with a specific system concern (such as safety, security, etc.) have been identified, are well-understood, have been appropriately controlled, and that there are processes in place to monitor the performance and effectiveness of the risk management measures. Thus, assurance cases are risk management artifacts whose purpose is to convince the various stakeholders of a system, that the system has been designed to be safe, is operated safely, and that it meets the required assurance properties.

In this talk, we describe the integrated assurance model that underpins AdvoCATE, which combines hazard analysis, requirements, structured arguments, barrier models (bow tie diagrams), and verification artifacts.

Instantiating Safety and Mission Assurance as part of NASA's evolving Digital Engineering Eco-System

Mr. Anthony Diventi[1]
[1]Nasa, Washington, United States

Provides an overview of activities NASA's Office of Safety and Mission Assurance (OSMA) is taking in partnership with NASA's Office of Chief Engineer (OCE) and the Agency's Digital Transformation initiative to evolve from a largely "document-centric", to more of a "data-centric", organization that leverages structured data and model-based approaches to help transform the robustness, efficiency, delivery, and decision velocity associated with engineering and SMA related information and activities in support of NASA's missions.

Highlighted initiatives include: (1) Mapping of OSMA's Strategic Roadmap and supporting Digital SMA implementation planning with OCE's Digital Engineering (DE) Needs, Goals, Objectives implementation planning to help align activities around a "shared" set of capabilities needed for DT; (2) Development of a Cross-Organization Policy model/meta-model as a foundational piece (i.e., common core of terms, definitions, roles, responsibilities, and artifacts) to integrate Objectives - Driven - Planning, Requirements, Processes, Standards, Mission Development, and Mission Execution, including enablement for future AI/ML assisted capabilities; and (3) Extending scope of NASA-HDBK-1004 NASA Engineering Acquisition Framework Handbook, initially released in April 2020, to address contractual language for Statements of Work and Data Requirements Descriptions (DRDs) needed to instantiate SMA Related artifacts/data as part of the expanding digital engineering environment and eco-system. Elements such data structure definition, Domain-Specific Views/Reports; Triple-Stores,
ontologies, interoperability standards, and general guidance to adapt the methods needed to implement digital engineering environments are all candidates for inclusion into the extended
handbook framework.

Finally, will discuss NASA's MBMA Program desire to continue leveraging Trilateral collaborations to help build corresponding application examples and guidance needed to support SMA practitioner involvement in the emerging Digital engineering and SMA environment(s).

References

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2. Hill, Terry R., NASA's Digital Transformation & Digital Engineering. 08/29/2023; https://ntrs.nasa.gov/api/citations/20230012166/downloads/DTDE%20at%20Siemens%20Aug%202023-Final.pdf

The Design Digitalization Strategy Progress of NEC Space Technologies

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We are going to present the design digitalization strategy progress including the model-based system engineering (MBSE) and model-based design (MBD) of NEC Space Technologies (NECSpace), the manufacturer of satellite components. In TRISMAC 2021, our previous presenter mainly reported on the MBD promotion activities based on the OJT-style education using computer aided engineering (CAE). There, the CAE specialist in the quality assurance department leads the engineers in the design department for the higher and broader use of CAEs. As a result, we increased the skills and number of the CAE users, and recognized that the CAEs are powerful for the designs for equipment which demand complicated specification. Currently, we are expanding our scope to further and broader regions. One of them is the set-up activity of the MBSE collaborating with NEC, our parent company responsible for manufacturing the satellite systems. The other one is the further MBD promotion using MATLAB/Simulink.

In the MBSE initiative, NEC and NECSpace are collaborating to create SysML models that will adjust the interface specification between the satellite system and its components. The model information is also shared so that the impact of a specification changes can be checked visually as well as digitally. Through this data management, the design quality is expected to be improved since the specifications are more clarified and the engineers can always handle the more accurate information. The quality assurance department of NECSpace is not only setting up the models used for the collaborations but also leading the SysML education for the engineers inside the company.

In the MBD expansion initiative, the quality assurance department is promoting the transformation from conventional document-based design to MBD using MATLAB/Simulink, which is a de facto model-based simulator for one–dimensional (1-D) CAE designs. When we judge the Simulink model should be newly applied to some component designs, we support the engineers by providing these environments, such as transforming algorithms from text-based design resource like Excel and C/C++ to the model-based approach using MATLAB/Simulink. In addition, we support the effective use of the add-in option of Simulink, which automatically generates RTL cords.

In this way, NECSpace is proactively utilizing the MBSE and MBD for the design digitalization. Some of these are still in the demonstration stage, but we are going to expand them to actual projects and also standardize them to enhance QCD.

SUSTAINABILITY

Thales Alenia Space activities and solutions to guarantee a sustainable and safe space

Ms Bianca Beatrice Ratti[1], Mr Lorenzo Bitetti[2], Mr Roberto Destefanis[1]
[1]Thales Alenia Space, , Italy, [2]Thales Alenia Space, , France
The evolution of space traffic, with the emergence of the constellations, has prompted the development of more stringent sustainability standards and regulations (e.g. update of ISO 24113 and of ECSS-U-AS-10C Rev2, ESA Space Debris Mitigation Policy and Requirements, ESA Zero Debris Charter initiative, etc..).
These new requirements impact a wide range of design and operations aspects to lead to safer spaceflights:
• proper preparation, assessment and execution of the End of Life disposal,
• faster development and implementation of remediation activities (e.g. active debris removal and in-orbit service),
• improvement of practices for collision avoidance and space traffic coordination
• management and reduction of the expected number of casualties during the re-entry of Spacecrafts to the Earth surface.

Activities performed by Thales Alenia Space in these fields, both in the R&D domain and on specific missions, are briefly detailed in this presentation. In particular:
1. Space Debris Mitigation and Space Traffic Management
• Involvement in the review of ISO 24113, ECSS-U-AS-10C, ESA ESSB-ST-U-007 and French Space Operational Act
• Review of the standard proposal on Space Traffic Coordination
• Contribution to EC Space Label and Space Law
• Support to the ECSS Mirror Working Groups on Space Traffic Management and Space Debris Mitigation
• Real-time reliability monitoring of ESA and ASI Earth Observation constellations and application of life extension risk assessment techniques.

2. Close Proximity Operations and In-Orbit Servicing
• EU EROSS (European Robotic Orbital Support Services) study:
o to demonstrate approach and capture/docking capabilities with vision-based algorithms, ORU (Orbital Replacement Unit) transfer and refuelling.
• ESA Safe Rendezvous and Close Proximity Operations study:
o to define V&V methodology, verify and validate safety guidelines/requirements for CPO (Close Proximity Operations) and apply these methodologies on a use case.
• ASI IOS (In-Orbit Servicing) LEO demonstrator:
o to perform target relocation and disposal, including providing refueling and ORU replacement, and to validate the technologies and operations necessary to assist and refurbish other satellites.

Codification of Technical Considerations and Mission Assurance to Enable Viable Servicing/Active Debris Removal/Assisted Debris Disposal (ADR/ADD)

Mrs. Nancy Lindsey[1], Mr. Fabrice Cosson[3], Mr. Toru Yoshihara[2]
[1]NASA-GSFC, Eldersburg, United States, [2]JAXA, [3]ESA,

The intent of Servicing or Active Debris Removal (ADR or Assisted Disposal (ADD)) is to sustain the space environment for useful assets or spacekeeping. This means enhancing current asset utility through repair and service. It also means eliminating debris and un-useable assets without creating additional hazards/debris. Therefore, Servicing or ADR missions have the overall goal of "Do no harm to space environment assets involved and other assets" over their lifecycle.

However, as with any space mission servicing and ADR are complex and potentially risky undertakings. There are risks to the client, to the servicer, and the orbital environment but the rewards can be great. The risks include attitude control impacts (imparting loads/spin), functionality losses, collisions, debris generation, and modified reentry operations. Whereas, the rewards include additional use or replenishment of a costly system, increased availability of orbital space, reduced potential for conjunctions, reduced debris, and reduced risk of cascading conjunctions (domino effect), or Earthly large debris impacts.

Therefore, this presentation provides a summary of the framework prepared by the PMD Trilateral task force for assisting spacefaring entities in assuring that their designs and operational plans for Servicing/ADR mission are as safe or risk reduced as possible from ESA-TECQQD-TN-2023-000647/CAA-2022037/NASA/SP-20230002885 (see these for further details).

ESA Policy on Space Debris Mitigation

Ms Paloma villar[1]
[1]ESA, Noordwijk, Netherlands

ESA new Policy on Space Debris Mitigation was released in November 2023. It has been made applicable to all missions in which ESA is contributing. The Policy calls upon the new ESA Standard on Space Debris Mitigation. A new ESA Space Debris Mitigation Standard ESSB-U-ST-007 to replace the currently applicable ECSS-U-AS-10C.
New state-of-the-art technical requirements, applicable to ESA missions, in a step-by-step approach to implement a Zero Debris by 2030.

ESA goes from applying SDM International Standards to adopting advanced requirements generated by ESA.
These requirements hopefully will be adopted in the future by other regulators and international standards.

Introduction to Trilateral S&MA Task Force "Space Sustainability"

<u>Dr. Kumi Nitta</u>[1], Mr. Shinichiro Taura[1], Dr. Yukihito Kitazawa[1], Mr. Hiroyuki Hirabayashi[1], Dr. Matthew Forsbacka[2], Dr. Frank Groen[2], Dr. Paloma Villar Ruibal[3]
[1]Japan Aerospace Exploration Agency, Tsukuba-shi, Japan, [2]National Aeronautics and Space Administration, Washington DC, United States, [3]European Space Agency, Noordwijk, Netherlands

A participant raised an opinion upon continuous Space Debris increase; "Isn't there anything Trilateral S&MA (Safety and Mission Assurance) could do against the worsening orbit situation?" at TRISMAC 2021; in May 2021. Then JAXA, NASA, and ESA agreed to form a Task Force dedicated to "Space Sustainability" at the meeting between three agencies; in June 2021.
Many regulations, guidelines, and recommendations related to space sustainability (including space debris mitigation) have been issued, and "What to Do" for Space Actors is becoming more apparent.
However, consistent compliance with the regulatory framework above continues to be problematic. It is in the common interest of all Space Actors to establish and share possible approaches to meet the full intent of policy related to space sustainability.
S&MA will provide "How to Do" support to the operators (projects and businesses) inside and outside each agency by utilizing its accumulated technology, knowledge, and various networks.
The goal is to provide helpful information and technical support to assist operators in "implementing" the requirements and recommendations (Shall, Should, Recommend) specified in various guidelines, ISO, and standard documents of each agency into their products, design, manufacturing, and operation technologies.
Phase 1 Achievement started from LTS B.8 high-level requirements, extracted technical keywords (Discussion Items; DI) for which "How to Dos" should be developed and shared.
The "Information Package of Small Debris" provided comprehensive information from three agencies.

Orbital Debris and the NASA Orbital Debris Program Office

Dr. J.-C. LIOU[1]
[1]NASA, Houston, United States

As the global community continues space exploration and expands activities in near-Earth space for social, scientific, and economic benefits, the threat from orbital debris to space missions also increases. Orbital debris is any human-made object in orbit about the Earth that no longer serves any
useful function. Approximately 28,000 large objects are being tracked by the U.S. Space Force (USSF) and have their orbits maintained in the U.S. Satellite Catalog. However, the large/tracked objects only represent the tip of the iceberg of the orbital debris population. There are many more orbital debris too small to be tracked by the USSF but large enough to threaten human spaceflight and robotic missions. This presentation will cover two broad topics. The first is an overview of the orbital debris environment, including sources, historical population increase, protecting the International Space Station and robotic missions from orbital debris, and environment management via mitigation and remediation. The second is an introduction to the end-to-end orbital debris research and mission support activities at the NASA Orbital Debris Program Office (ODPO), including measurements using radars, telescopes, in-situ, and laboratory experiments, modeling of the current and future environment, reentry human casualty risk, and ODPO's efforts to define the environment and mitigate risk from orbital debris for the safe operations of the current and future space missions.

Product Assurance for Space Reusable vehicle

Mrs Elisabetta Traino[1]
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In the frame of ESA Programme "Space Rider", a Space reusable vehicle mission, the presentation will focus on the lack of Quality Standards for Reusability, on the need to issue such Standards going towards an era of Space reusable vehicle and launchers, and how this gap is being currently approached in the “Space Rider” Programme.
Reusability is key for the progress of Space missions in terms of: sustainability, cost and time reduction, and, then, commercial opportunities. The Quality/ Product Assurance Standards for Reusability shall focus on PA aspects such as Materials and Processes, Reliability, Maintainability, Inspectability, Qualification and readiness for re-flight.
The current ECSSs Standards cover Space missions whose decommissioning happens in Space.
Compared to a classic Space mission, a Space mission of a reusable vehicle would include the re-entry environment and the post-flight activities on Ground as part of the mission. These two environments could pose additional risks to the Spacecraft and the personnel, hence they shall be assessed and managed properly.
In the frame of Space Rider Programme, a Working Group has been organised in order to fill the gap present in the current ECSSs Standards baseline, and as a result a set of guidelines have been set for the Development phase.
With the Space market evolving, there is the need to create a set of Standards (or guidelines) to cover reusability aspects at European Space Agency level. This would allow a quicker, clear and well defined, definition of the Mission Requirements for future Programmes.

LL AND REX

JUICE RIME Antenna in-flight anomaly

Johannes Gumpinger[1], Ronan Le Letty[1], David Monteiro[1], Alessandro Atzei[1], Daniel Escolar[1]
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The Jupiter Icy Moons Explorer (JUICE) is ESA's first large-class science mission in the cosmic vision 2015-2025 program to explore the habitability of the Jovian moons Ganymede, Europa, and Callisto. JUICE will characterise the icy moons as planetary objects, and study the Jupiter system as an archetype for gas giants. The spacecraft has 10 powerful science instruments, that required a high number of deployments: the Magnetometer-boom, the Langmuir probes, the Radio Wave Instrument (RWI) dipole antennas, and the Radar for Icy Moons Explorer (RIME) antenna.
Previous ESA and non-ESA missions have shown that deployable appendages need to be carefully designed and tested so that these can function correctly. Nevertheless, deployments are still challenging today, and JUICE's RIME antenna proved to be no exception.
The presentation shows the nominal steps that were executed to deploy the antenna, until the anomaly was observed. Key design features of the hold down and release mechanism will be highlighted to introduce the failure investigation, followed by the systematic analysis of the anomaly and the ensuing recovery measures that resulted in a successful recovery. Finally, the associated lessons learned will be presented.

THE ARTEMIS PROGRAM AND THE EUROPEAN SERVICE MODULE: THE ESA SMA APPROACH TO A CHALLENGING MISSION AND ITS OPPORTUNITIES

Mr Raffaele Campagnuolo
[1]ESA, Noordwijk, Netherlands

The European Service Module (ESM) is the powerhouse of the NASA's Orion spacecraft; it is procured by the European Space Agency (ESA) and built by the prime contractor Airbus in Germany. Its function is to provide the power, propulsion, thermal control, air, and water to the Orion spacecraft, which is the NASA space vehicle built for sending astronauts to the Moon on the Artemis Missions and eventually to Mars. The Artemis I Mission, launched in November 2022, has been a great success for the first ESM; five additional modules are currently under production, integration and testing phases, incorporating the required design changes necessary to support the different future Artemis Missions. The purpose of this paper is to illustrate the ESA perspective on the roles of the Safety and Mission Assurance (SMA) within the ESM Project. It includes insights in the methods, tools, standards, best practice, challenges, and lessons learned related to this multifaced role, gathered from the early design phases up to the successful Artemis I Mission and beyond. The contribution of PAS (Product Assurance and Safety) and CM (Configuration Management) is analysed at different levels, including design reviews, validation and qualification programs, production control, testing supervision, suppliers' surveillance, and mission support. Special consideration is given to the European PAS and CM contributions to the human-rated requirements including the crew safety aspects, the processes and materials selection methods, the collaboration with NASA and industries counterparts, and the challenge of a sustainable production of several ESMs in parallel. The PAS and CM roles are recognized as fundamental contributors to the success of a space mission; the paper demonstrates how these functions need to harmonize standards and rigorous discipline with flexible and open-minded methods and approaches to accommodate cost and schedule pressure, while also guaranteeing the highest level of quality and risk mitigation. These are key requirements for a human-rated spacecraft able to support humanity largest effort to create a sustainable presence on the Moon and beyond.

Backward Planetary Protection Public Safety and Mission Assurance Considerations

Elaine Seasly[1], Nick Benardini[1]
[1]NASA Headquarters, Washington , United States

Apollo 14 was the last restricted Earth return mission that implemented backward planetary protection requirements where preventing harmful contamination of the Earth's biosphere is the highest priority. Over the past 50 years, engineering and science technology advancements have been made to manage, sterilize, contain and assure safety of particles and biological contamination that provide a robust trade space for enabling and implementing a sample return mission. As missions start to plan sample return from restricted Earth return targets (e.g., Mars, Europa or Enceladus) considerations should also be made to understand the complexities of campaign architectures with multi-mission elements, regulatory and external governmental decision makers, and multiple international partners.

Ensuring public safety and mission assurance for a restricted Earth return mission will require an objective driven, risk-informed and case assured approach to address backward planetary protection compliance. The safety and mission assurance stakeholders play a key role in this process by consulting and coordinating processes to assure the safety and containment of Earth-return samples and the public. Throughout the life cycle of the mission planning consulting and coordination should consider the following: A. how modern advancements play a role in trade space where heritage design and prescriptive approaches can overshadow early formulation, B. establishment of technical roles and responsibilities and interface controls between agencies and partners within established legal frameworks, C. coordination of the end to end assurance case between multi-mission elements and partners, and D. development of objective-base, performance requirements for managing backward planetary protection. Fostering continued awareness and openness of these considerations will continue the dialogue, a critical step on the path, to enable sample return from restricted Earth return targets from a backward planetary protection perspective.

Return of Experience (REX) on ESA Missions from a Dependability perspective”

Mr Guillaume Schang[1], Mr Fabrice Cosson
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Satellite Reliability and Availability predictions are performed in order to assess the technical risk of not achieving the mission objectives in case of failures. Accurate predictions are needed to optimize the design in particular in terms of redundancy need. Predictions are essentially based on existing databases and theoretical data and are not backed-up by test data due to development inherent schedule and cost budget constraints. Therefore, there are benefits of performing in-orbit Return of experience (IO-REX) analysis, using operated missions data to improve the predictions.
The main outcomes foreseen for the in-orbit REX are:

- The satellite in-orbit vs. prediction reliability comparison (for reliability and availability).
- The distribution of failures per satellite sub-system.
- The equipment measured failure rates when sufficient data can be collected.
- Identification of failure modes that were not detected during the design phase.
- Satellite outage distribution between subsystems or between planned/unplanned outages.
- The satellite availability evolution over the mission lifetime.

The presentation will give an overview about the approach followed at ESA and the REX Digital Dashboard tool developed to support the exploitation of the results. This dashboard allows to import and display the data analysed in an efficient and structured manner. It provides metrics and details of interest in a user-friendly environment in order to encourage sharing and distribution of the REX within the organisation. The main outcomes from the ESA in-orbit satellites already analysed and the inherent challenges encountered during this activity will be exposed.

ACES - the challenges of building a time machine; past, present and future

Mr Jason Williamson[1]
[1]Esa, Didcot, United Kingdom

ACES (Atomic Clock Ensemble in Space) is an external payload for the International Space Station (ISS) due for launch early in 2025 on SpX-32. It is an experiment to compare atomic clocks in a zero-g environment against a network of ground-based clocks to study and evaluate Einstein's general theory of relativity. The experiment also targets the ultimate stability and accuracy of the clocks at the level of 1E-16. The programme has encountered a number of difficulties over its development period and this paper will present the past, current and future challenges from a PA perspective along with the mechanisms adopted to resolve them.

The asteroid sample return mission Hayabusa2 and its activity of SMA

Dr. Satoru Nakazawa[1]
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The first asteroid sample return mission Hayabusa came back to Earth in 2010 overcoming numerous on-board equipment and operational troubles. The following Hayabusa2 was developed with improving upon the lessons learned and was smoothly succeeded to return to Earth in 2020 with the sample of asteroid Ryugu.
Hayabusa2 was launched from Tanegashima Space Center in December, 2014 and arrived at C-type asteroid Ryugu in June, 2018 after long cruising with using Ion engine and Earth swing by. With countermeasure for the unexpected surface topography, it was succeeded in the first touchdown and collected the asteroid sample on the surface. Then, small carried impactor created an artificial impact crater on another area with edjecting the inner material around it. The Hayabusa2 was succeeded in the second touchdown just beside the crater and collected the sample including inner material.
The spacecraft came back to Earth in December, 2020. In the reentry phase, the sample return capsule was released to the exact reentry trajectory at a distance of 220,000 km from Earth. After the release, the spacecraft escaped from the trajectory and passed by Earth and the capsule was successfully landed as planned in Woomera Prohibited Area in Australia on Dec. 5, 2020. The returned sample is being investigating and was reported that it is similar to primordial carbonaceous meteorites (Ivuna-type).
After passing by Earth, the Hayabusa2 spacecraft move into the extended mission to two new asteroids by taking advantage of the remaining fuel and the healthy state. This mission aims at visiting two asteroids, 2001 CC21 to flyby in 2026, and 1998 KY26 to rendezvous in 2031, both of which provide us valuable opportunities to contribute to the planetary defense and small body science.
The success of Hayabusa2 owes a lot to the previous experience of Hayabusa. In this presentation, the activities of SMA in Hayabusa2 development and operation will be introduced.

Lessons Learned and Mission Assurance of Small Satellite Development in JAXA's "Innovative Satellite Technology Demonstration Program"

Mr. Yuya Kakehashi[1], Mr. Yasuyuki Takahashi[1], Mr. Kenta Nakagawa[1], Mr. Kengo Nakamura[1], Dr. Reina Hikida[1], Mr. Shinichi Suzuki[1]
[1]JAXA, Tsukuba, JAPAN

JAXA is conducting the "Innovative Satellite Technology Demonstration Program", which provides space demonstration opportunities for components, microsatellites, and CubeSats developed by universities, research institutes, private companies, and other organizations. (The demonstration mission is targeted at domestic organizations.) In this program, a component alone can be demonstrated by being mounted on a small satellite developed by JAXA. Three satellites have been developed before now, and the fourth satellite (RAISE-4: RApid Innovative payload demonstration SatellitE-4) is currently under development.
Characteristics of small satellite development in this program include the fact that multiple mission components are mounted on the small satellite and that the developers of the mission components are new to the space field and have limited experience in the space field. In addition, there are no standards for small satellites in Japan, and satellite manufacturers have little knowledge of small satellite development.
Therefore, to improve mission assurance, guidelines for mission component users are established based on Lessons Learned from past issues of this program. The guidelines allow them to understand the overall development flow and things to keep in mind during development and aim to improve the mission success rate. Additionally, to increase the reliability of satellite bus development, improvements to the development process based on Lessons Learned are being considered.
This presentation introduces previous Lessons Learned in the "Innovative Satellite Technology Demonstration Program" and discusses the approach to mission assurance based on Lessons Learned for small satellites developed by JAXA.

“Problème récurrent à étudier” – Product Assurance approach for problem resolution and Lessons Learned from the Galileo programme

Ms Patrizia Secchi[1], Mr Remo Cirone[1], Mr Andrea Guidi[1]
[1]ESA, Noordwijk, Netherlands

Galileo is Europe’s own global navigation satellite system, providing a highly accurate, guaranteed global positioning service under civilian control. Currently providing Initial Services, Galileo is interoperable with GPS and Glonass, the US and Russian global satellite navigation systems. By offering dual frequencies as standard, Galileo can deliver real-time positioning accuracy down to the metre range.
Galileo initial services became available on 15 December 2016. Then as the constellation is built-up beyond that, new services will be tested and made available. The current Galileo system consists of 28 satellites in all. All but two of these are positioned in three circular Medium Earth Orbit (MEO) planes at 23 222 km altitude above the Earth, and at an inclination of the orbital planes of 56 degrees to the equator.
In this presentation we will introduce some of the most significant failures and problems we had to face while building the Galileo system. The aim of the presentation is to focus on the approach used for problem solving and the lessons which were learnt and can help to avoid similar problems in the future.

LL and challenges from ORION ESM

Ms Begoña Gómez Arrocha[1]
[1] Airbus Defence and Space, Ho Space Systems Quality

In 2014, Airbus Defence and Space was awarded by ESA as prime contractor to develop and produce the ORION European Service Module (ESM) for the ORION spacecraft as part of the ARTEMIS program. This presentation gives an insight of the most important challenges and Lessons Learned experienced by Airbus in the last 10 years from a Product Assurance & Safety perspective. Those challenges came from the multi-purpose mission of the ORION Spacecraft, the industrial setup and the heritage of the involved products and standards. Lessons learnt are presented on hazard minimization, late design changes and a complex program structure, largely managed online.

Origins, Spectral Interpretation, Resource Identification, and Security–Regolith Explorer (OSIRIS-REx) Lessons Learned (and re-learned)

Mr. Ronald Perison[1]
[1]NASA, Greenbelt, United States

This presentation discusses some of the lessons learned from the recently successful Origins, Spectral Interpretation, Resource Identification, and Security–Regolith Explorer (OSIRIS-REx) mission that returned NASA's first samples from a Near-Earth Object (Asteroid Bennu) on 24 September 2023. OSIRIS-REx is a NASA Risk Class B mission under the New Frontiers Program Office managed by the Goddard Space Flight Center. It is a Principal Investigator lead mission under Dr. Dante Lauretta at the University of Arizona.
Key Mission details can be found on the following link:
https://www.nasa.gov/?search=OSIRIS-REx
Topics of focus are the preparations and execution for these two major critical events, the Touch-and-Go (TAG) that collected the asteroid samples and the Entry, Decent, and Landing (EDL) phase, including the challenges with each. This presentation will highlight SMA focused lessons learned and re-learned including use of "heritage" hardware, teamwork, testing philosophy, risk trades, configuration control, and role of mission rehearsals for major events.

ASSURANCE OF NEW TECHNOLOGIES

Toward a standardised approach for qualification of polymer additive manufacturing process.

Dr. Ugo Lafont[1]
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Development of additive manufacturing processes have enable new design freedom and capability and have led to a paradigm shift with respect to manufacturing concepts. Additive manufacturing of metallic species has been quickly adopted by designer and engineer for space application. In this respect, a lot of effort were devoted worldwide and at agencies level to develop standardise approach to enable space qualification (i.e ECSS-Q-ST-70-80C / NASA-STD-6030 standards). However, we are witnessing that, for space application, an increase of components made by additive manufacturing using high performance thermoplastics mainly using the Fused Filament Fabrication (FFF) process. At this stage there is no specific standard available on how such FFF process could be qualified for space application. In addition, FFF process often result in anisotropy as in the part performance as function of the printing orientation. In order to give designers and engineers the ability to get relevant data for designing parts to be produced by FFF, we have looked into several aspect to establish preliminary guidelines to have a more harmonised approach. Effect of the type, shape, and size of test samples (ASTM vs ISO), type of infill, printing strategy, type of material on the mechanical performance assessment reliability of the produced parts has been studied and will be presented. As conclusion, we will propose an initial guideline to enable process validation and qualification.

New COTS-Inclusive Parts Assurance in NASA

Dr. Jesse Leitner[1]
[1]NASA GSFC, Code 300, Greenbelt, US

This talk will provide insights into new options for parts assurance that are being introduced into NASA policy, which build on the results of the NASA Engineering and Safety Center (NESC) COTS Phase 2 study. It will provide some of the highlights and drivers for the use of COTS and brief recommendations for how to successfully select and use COTS parts. It will also briefly address common concerns about radiation and COTS.

Qualification Challenges for Additive Manufacturing Processes and Parts for Spaceflight

Mr. Andrew Glendening[1], Ms. Alison Park[2], Ms. Sarah Luna[3]
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Since the release of NASA-STD-6030 in 2021, NASA and its partners have struggled with the practical realities of qualifying AM processes and parts designed and fabricated within a complex supply chain. This talk will provide a brief overview of the basic principles of “The NASA Way for AM”, the specific challenges of process & part qualification for both manned and unmanned spaceflight systems, as well as near term solutions for wider adoption of AM technologies.

Heat dissipation measures for Printed Circuit Boards (PCB) for space applications

General Manager YASUO TOYOKURA[1]
[1]OKI Circuit Technology Co., Ltd., Takarada, Tsuruoka, Japan

For future satellites that will handle large-capacity data processing and communications, it will be important to actively adopt the latest electronic components with consumer-grade, high-performance, and high processing capabilities. However, these consumer components are designed to be water-cooled or air-cooled, so if they are mounted on a spacecraft as is, they will not be able to exhaust heat enough and may cause failures due to thermal runaway. For that we are forced to handle with limited functionality in order to suppress the heat.
In the future, for operation within a predetermined temperature range in a vacuum of outer space, it is necessary to improve the thermal conductivity of a PCB on which the electronic components are mounted, promote the diffusion of heat into the substrate, and exhaust heat to a chassis of system through PCB. In March 2023, JAXA established a standard for a PCB with high heat dissipation materials and Copper Inlay technology as Appendix J of JAXA-QTS-2140 as a countermeasure. Here, we will report on the specifications and reliability evaluation status on the PCB of Appendix J for which we plan to obtain the certification.
The standard specifies Types 1 to 3 of printed wiring boards according to their structure. Type 1 is a conventional PCB with Copper Inlay added to it. Type 2 is a PCB with a thermal conductivity of 0.8W/m・K, about twice that of a conventional CCL, and Copper Inlay added to it. Type 3 is a PCB in HDI structure using a material with a thermal conductivity of 3 W/m・K, and also with Copper Inlay.
In particular, the Type 3 adopts HDI and Copper Inlay structure to diffuse heat in the horizontal direction of the board and exhaust heat to the back side.
We expect this structure to reduce temperature of BGAs by about 50 Degree Celsius, compared to more than 100 Degree Celsius in normal PCBs.
We continue to aim for the early practical application of these high-heat dissipation-PCBs in spacecraft and to further improve their heat dissipation characteristics.

Impact of adopting reduced pressure and Oxygen concentration on material flammability: limitations and safety implications

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The selection of materials, not only for the structural and functional aspects, but especially for the safety of H/W and people, has always been the basis of the design choices of each sector. Even more so for space missions with human presence, this last aspect becomes fundamental for the protection of the crew and equipment in which demanding environmental constraints are recalled.

In particular, spatial system assessments are based on the evaluation of the flammability of materials that strongly depends on the oxygen concentration in the environment to which the materials will be exposed (maximum current 30% for ISS/Shuttle) while the pressure effect is much smaller and can be ignored at cabin crew pressures < 1 Atm.
In addition, assessments of flammable materials behavior and acceptability criteria, to date, are based on ground testing facility and equipment capability at 1 g, used at different configurations and operative conditions.
Past and new investigations on how the 1g results, and the influence of O2 % vs pressure, could actually be applicable to flammability scenarios, are not fully consistent and deserve a step forward.

For this reason the Multi-Purpose Habitation Program (MPH) is in a challenging scenario in many respects, no less the environmental condition in terms of flammability risks. At the moment, design requirements for MPH moves to environments with higher concentrations of oxygen and this could be in conflict with the current understanding of fire behaviour in these atmospheres.

While awaiting progress and validation of tests in different g-conditions by agencies and the relevant update of applicable standard and methods, possible impacts and limitations, or, safety-wise, conservative assumptions to use will be analyzed in this presentation to emphasize the lack of documented assessments and flammability data.

Benefits of using functional safety in commercial space applications

Mr. Florian Lumpe[1], Mr. Michael Seidl[2]
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Functional safety is relevant whenever a product or system contains electrical, electronic or programmable electronic elements that perform safety-critical functions. It is used in many areas of technology, process industry (e.g. energy sector), automotive (transport sector), mechanical engineering and aviation. The presentation will compare the approaches and concepts of Functional Safety based on ISO 61508 with the RAMS approaches of the space industry, in particular the Flight Detection Isolation and Recovery (FDIR) approach.The presentation will provide an insight into the possibilities of minimizing risk at the component level, especially for complex integrated circuits. Traditionally, the space industry has focused on qualifying the components used for the extreme environmental parameters and the typically very long duration of use in space. However, as ICs have become more complex, there is now also an increasing risk of introducing systematic faults during the extensive chip, hardware and software development. The presentation will show how other market sectors work to eliminate systematic faults as far as possible and how so-called random faults can be detected as quickly as possible and their effects ideally eliminated or at least minimized with the help of the IC’s ‘functional safety features’ such as ECC, lock-step or BIST (Built-in Self Test).
The built-in self-diagnostic capabilities of functional safety components do further enable simplification of the ground support equipment and do also provide detailed monitoring capabilities for analysis during space flight and in Lessons Learned or Return of Experience efforts after the mission has completed. The successful mission of the Mars Rotorcraft Ingenuity from JPL (NASA) provides an insight into the practical application of functional safety in space applications.

The presentation is intended as a suggestion on how one could leverage features and IP blocks in semiconductor products and their associated tools developed for functional safety also for space applications.

Design, development and qualification activities for the ESA radioisotope power systems

Dr Alessandra Barco[1]
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Since 2009, the European Space Agency (ESA) has been conducting activities leading towards the future development of a European capability for the independent design, production and management of radioisotope power systems (RPS) for space applications. The program is focused on the use of americium-241 as an innovative alternative to the plutonium-238 fuel currently used by USA, Russia and China. The University of Leicester (UoL) is leading the development of a 10 W_el radioisotope thermoelectric generator (RTG) with a specific electric power of around 1 W_el/kg, and a 3 W_th radioisotope heater unit (RHU). The Am-based RHU is baselined for the lander in the Exomars Rosalind Franklin mission (EXM-RFM), with a launch expected in 2028. The Am-based RPS will also be part of the Argonaut program, formerly known as European Large Logistics Lander (EL3).

An important aspect of the ESA activities is safety. The design approach for the RPS is based on “confinement and containment”: a multi-layer containment approach is implemented, to encase the fuel within a system of physical barriers to limit its dispersal under (ideally) any foreseeable launch and re-entry accident conditions. It is therefore fundamental to verify and certify the RPS ability to survive different accident scenarios, by performing software simulations, and destructive and non-destructive testing, in order to establish a safety basis envelope. The current activities led by UoL address:
- Characterisation at elementary level, including sub-system tests;
- Modelling at system level;
- Testing at system level, in order to validate the final design.

From UoL’s perspective, the approach of working with stakeholders from both the US (for the EXM-RFM launch) and Europe (for future ESA missions) has included:
- Comprehensive analyses of historical technical work carried out both in US and Europe;
- Review of national policies governing the safety aspects related to the use of NPS;
- Enveloping, standardising and benchmarking.

This presentation will provide updates regarding the design, the development and the testing of RPS, and the safety activities involving the University of Leicester.

NEW PARTNERS AND ACQUISITION

Moon 2 Mars (M2M) Safety and Mission Assurance (SMA) Integration

Nathan Vassberg[1]
[1]Nasa

The Moon 2 Mars (M2M) Program is a new and diverse program of programs. It is comprised of 6 Programs with various contracting mechanism, includes multiple International Partners, and has 11 US Prime Contractors. It's missions are as varied as the Programs including a lunar orbiting Gateway, Lunar landing and surface EVA, and with eventual paths to Mars. It is unique in its complex integration. Safety and Mission Assurance (SMA) for M2M is equally complex, but has a singular focus to work with the programs to managing risk through SMA products and processes and working closely within each of the six programs and at the integrated M2M level. This presentation will explain and explore some of the unique aspects of executing the SMA functions on the M2M Program.

Commercial Lunar Payload Services (CLPS) Initiative

Angela Melito[1]
[1]Nasa Headquarters, Washington , United States

NASA's Commercial Lunar Payload Services (CLPS) initiative allows rapid acquisition of lunar delivery services from American companies for payloads that advance capabilities for science, exploration or commercial development of the Moon. Investigations and demonstrations launched on commercial Moon flights will help the agency study Earth's nearest neighbor under the Artemis approach.

Initially welcoming nine U.S. companies to its CLPS project in November 2018, NASA added five more vendors to the project a year later, bringing to 14 the total number of eligible vendors. As science, technology demonstration and human exploration requirements for payloads develop, a request for surface task order bids will go to current CLPS contractors.

Individual task order awards cover end-to-end commercial payload delivery services, including payload integration, mission operations, launch from Earth and landing on the surface of the Moon. Companies are encouraged to fly commercial payloads in addition to the NASA payloads.

The CLPS contracts are indefinite delivery, indefinite quantity contracts with a combined maximum contract value of $2.6 billion through November 2028. When comparing the bids from all vendors, NASA looks at things such as technical feasibility, schedule, and price.

Early science investigations and technology experiments delivered to the lunar surface as part of Artemis will help lay the foundation for human exploration on the Moon. Through Artemis, NASA will land the first woman and the first person of color on the Moon, paving the way for a long-term, sustainable lunar presence and serving as a steppingstone for future astronaut missions to Mars. Artemis I successfully launched on November 16, 2022, and a subsequent test flight with crew is scheduled to occur in 2024 in advance of NASA sending humans to the surface of the Moon no earlier than 2025.

Emphasizing Space Parts Supply Chain and Space Parts Consortium in Japan

Mr. Norimitsu Kamimori[1]
[1]HIREC, Kawasaki, Japan

Japanese space community established Japan's Space Parts Consortium on Nov 2023. The main purpose of the consortium is to emphasize the space parts supply chain. To maintain the good supply chain for space parts for keep freedom to make spacecrafts from inconvenient to get necessary parts. One of the solutions may be newly development of important parts, ex National FPGA. The consortium is proposing various plans and directly requests budget to the government, ex Keepjng the beam time for evaluation of radiation hardness for parts to be used for space.

Mission Classification and Assurance for University-based Lean Satellite

Prof. Mengu Cho[1], Dr. Yoshihiro Tsuruda[2], Dr. Kikuko Miyata[3], Dr. Kazumi Masuda[4], Dr. Yukihito Kitazawa[5], Dr. Toshinori Kuwahara[6]
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A lean satellite is a satellite that utilizes non-traditional, risk-taking development and management approaches – with the aim to provide the value to the customer and/or stakeholders at low-cost and in short time to realize the satellite mission. It is another name to express the nature of pico/nano/micro/small satellites. It is well known that the mission success rate of university-based lean satellites is much lower than those of traditional satellites or non-university-based lean satellites. Since 2020, UNISEC (UNIversity Space Engineering Consortium) of Japan has worked together with JAXA to collect and analyse the lessons learned from university satellite projects. Based on the activity, the first version of Mission Assurance Handbook for the University-built Lean Satellite was published in February 2022. The handbook has been revised annually and the third version is now available. The handbook gives summary of points to be kept in mind by faculty members and students to improve the mission success rate. Although the handbook is targeted satellite projects at universities and polytechnic-colleges, some of the contents also apply to lean satellite projects at new space companies. It is organized in the order of project life-cycle, i.e. from the mission definition to the operation with three additional chapters on project management, post-operation and sustainability of university satellite program. Although the handbook is based on the lessons learned of Japanese universities, many of those apply to other countries as well. Therefore, English version has been published along with the Japanese version. While promoting the handbook, missions that can be done by lean satellites at present and in future have been discussed. The discussion led to mission classification based on the expected mission success rate by stakeholders. The missions are classified into seven levels from the national security to student education. There should be different sets of mission assurance activities depending on the mission classification level. In the presentation, the details of the classification and associated mission assurance activities will be discussed.

Charging and discharging of the harness

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As devices become smaller and higher-performance, they are becoming miniaturization of wiring through higher integration technologies. Along with these technological advances, Electrostatic Discharge (ESD) tolerance of devices is decreasing. Furthermore, while using conventional devices, ESD problems did not occur if ESD countermeasures were taken during manufacturing and assembly based on existing ESD models such as Human Body Model (HBM), Machine Model (MM), and Charged Device Model (CDM). However, as the ESD tolerance of devices has decreased, ESD during testing, i.e., device damage due to ESD that occurs when the harness is connected to the equipment, has become an issue for spacecraft. The reason for this is that ESD in harnesses faces more severe discharge conditions than existing ESD models because of the higher current value of the initial discharge current pulse.
In this report, we present the results of measurements on the following three points. And we present a simple ESD model to simulate the electrical discharge current when charged
harnesses are connected to equipment.
・Comparison of discharge currents of existing HBMs and MMs and ESD of the charged harnesses
・Harness charging characteristics depending on the harness length and type of the insulation of harness
・Discharge characteristics of harnesses depending on harness length and type of the insulation of harness coating

Future Space, New Tools and PA Services. ALTER View

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Is not new that the space sector is experiencing a fast evolution, requiring to implement new approaches to cope the challenges demanded by the new commercial and institutional missions. Factors like, EEE components policy, materials and processes requirements, radiation hardness assurance methodologies..., etc., are being revisited by agencies, but also by large companies and new space players.
The sector is becoming more diverse, and the necessities change rapidly, depending on a wide range of factors, not only the ones considered by the categories defined within the standard mission classifications by agencies, but also those introduced directly by companies, projects or market constrains, minimum budget, very high performance, new functionalities, time to market,..., etc.
ALTER, with the ambition to be ready to provide the support required by this fast-changing sector, has been involved in several projects and internal developments to dig in how wider the activities and provide new test - product assurance solutions to the sector.
Examples of these efforts are the following:

- Develop and stabilizing of Testing capabilities for small sat up to 500kg, getting compliance against ECSS-Q-ST-20-07 tailored by ESA-TECQQQ-TN-024614.
- Leading the ESA project 4000134569/21/NL/KMLHALT: “Highly Accelerated Life Test Pilot Supporting Agile Space Engineering”, assessing a methodology to validate commercial electronic boards for space.
- Participation in ATCOS project: “Alternative Test Methods for COTS”, with the main objective to gather information on the performance and reliability of commercial parts, including automotive components, investigating, and comparing the effectiveness and suitability of a typical board/unit test in comparison with the classic test at component level.
- Developing an internal process to offer space customers a methodology on how procures and safety use COTS component in different Space scenarios.
- Development of PRECEDER (Prediction of the Electrical Behaviour of Electronic Devices under Radiation, Spanish acronym) methodology, as a new concept to get confidence on device radiation hardness based on previous data.
- Design of a radiation test process at unit / system even satellite level, considering classic and mixed-field radiation environments.
- Adapted PA services, helping and supporting customers in adjusting requirements related to EEE components, materials, processes, and testing.
- Development of a low cost tool for analysis of the radiation environment for COTS (RADE-4SPACE).
- ..., etc.

A brief description of these developments and ALTER view will be introduced in the presentation.