Safety approach for the International Habitat for Gateway Cislunar man-tended station

TRISMAC 2024

ESA –ESRIN | Frascati (Rome), Italy

Authors: Miriam Burrone (TAS), Claudio Pesce (TAS), Maria Sarno (TAS)

24 - 26 June, 2024

Date: 26 June 2024
Ref:
Template: 83230347-DOC-TAS-EN-010

TABLE OF CONTENTS

ThalesAlenia Space

a Thales / Leonardo company

TAS expertise on manned spaceflight programs

- /// TAS has constituted a major actor in the International Space Station design and development, providing contribution to several infrastructures, module subsystems and scientific payloads. To these days, it continues to provide support to ensure ISS safe on-orbit operations (PASO functions for Columbus).

- /// TAS wide experience, gathered in design, development and utilization of ISS modules, is now a valuable foundation for the next challenging deep space exploration frontier: the Gateway Lunar Space Station.

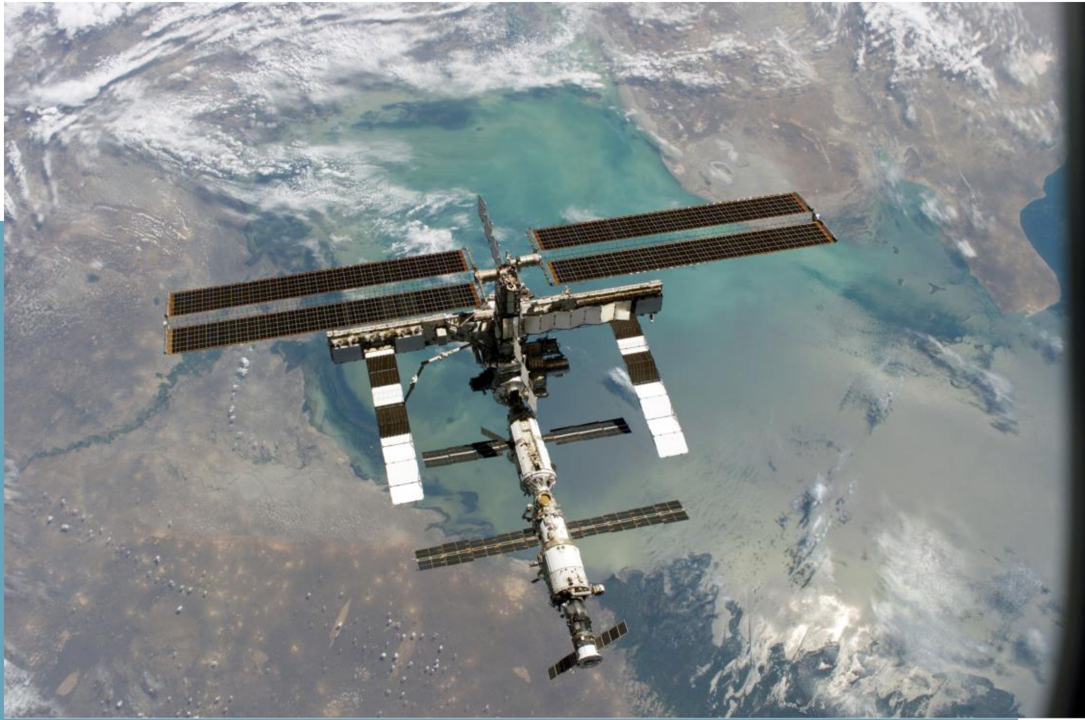
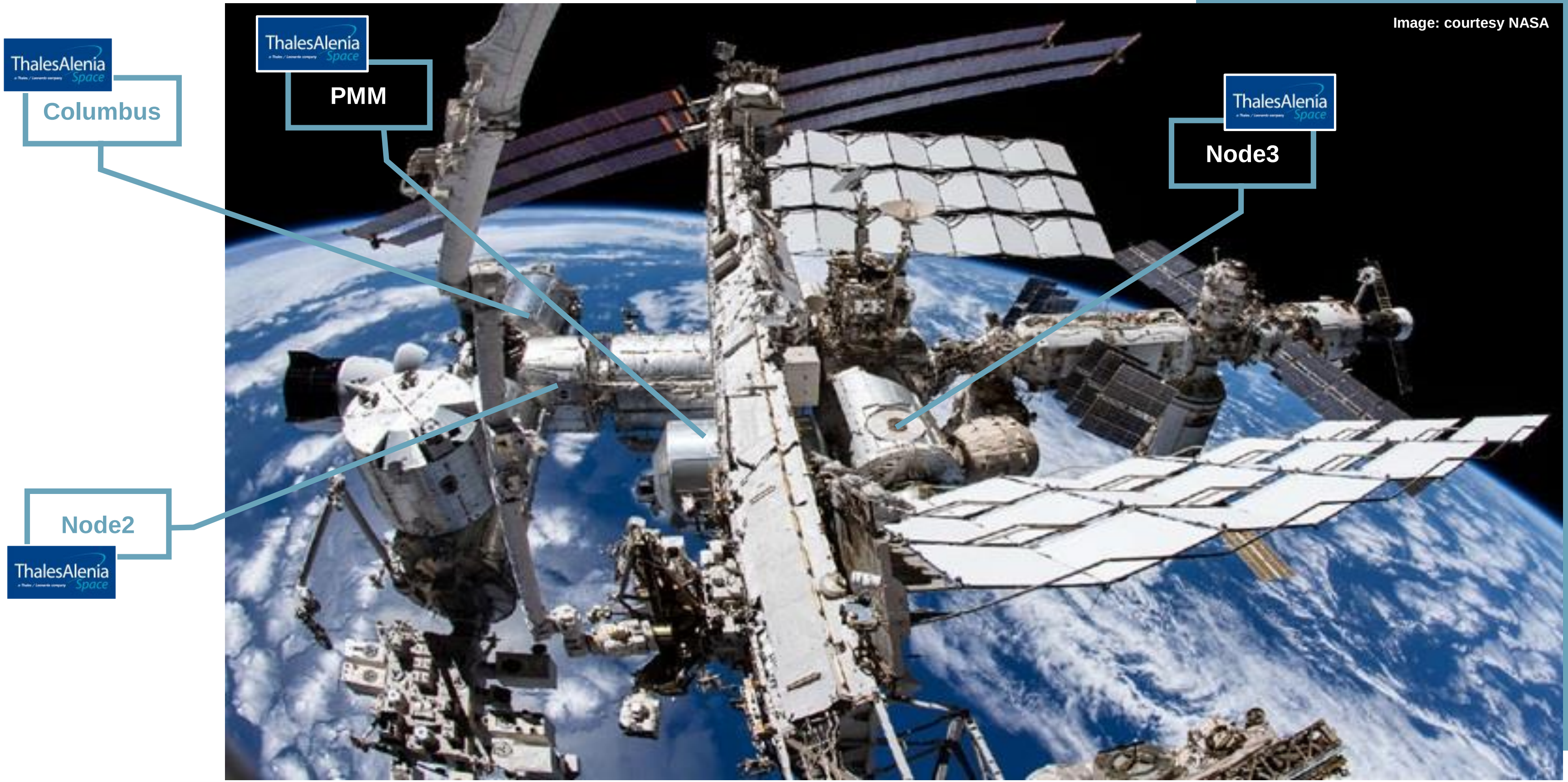


Image: courtesy NASA

TAS expertise on manned spaceflight programs



Date: 26 June 2024
Ref:
Template: 83230347-DOC-TAS-EN-010

TAS expertise on manned spaceflight programs

Cupola

MPLM

Cygnus

TAS in Gateway Lunar Space Station

- TAS is strongly committed in the design and development of several infrastructures for the next deep space human outpost, the Gateway Lunar Space Station, in the frame of the NASA's Artemis Program.

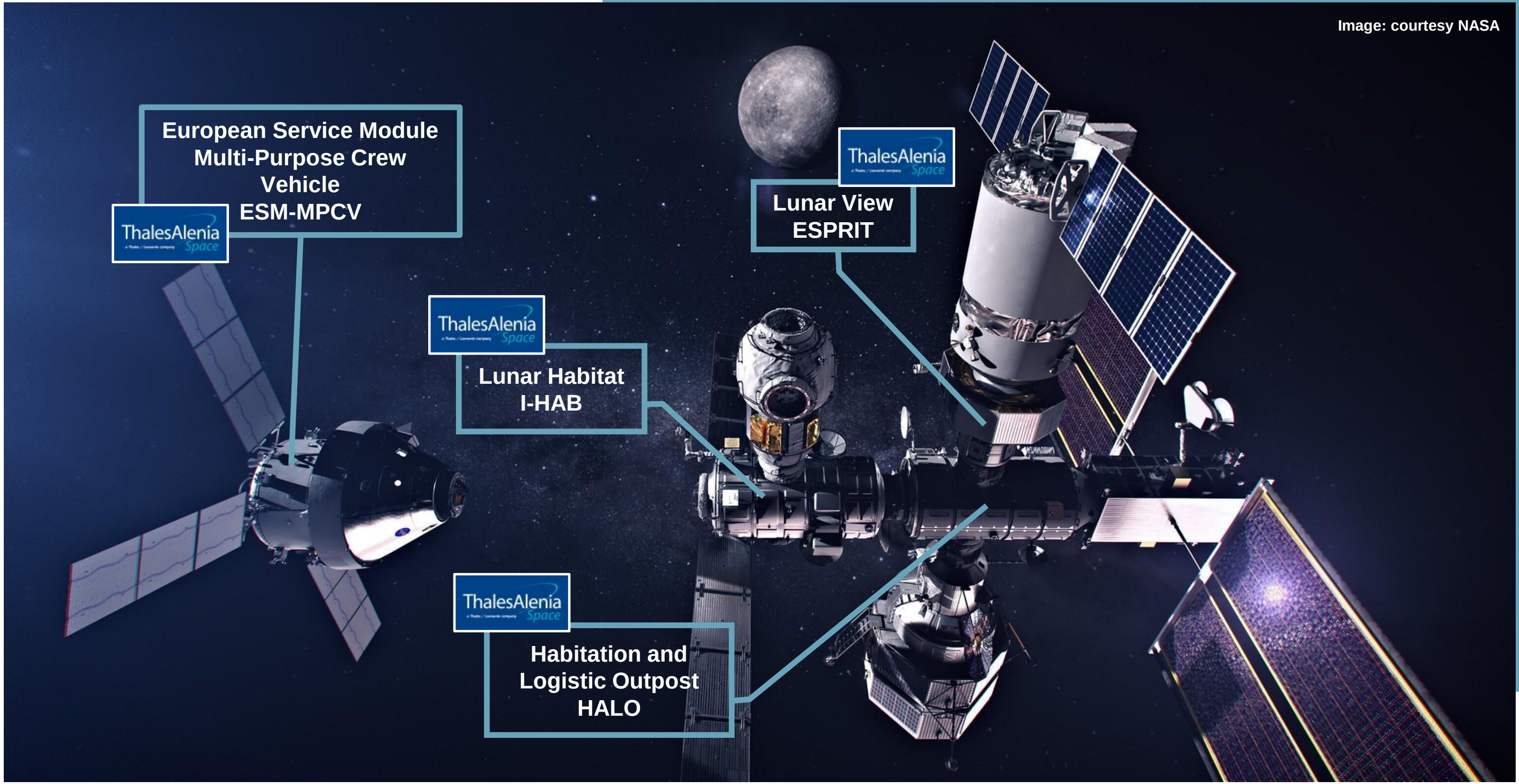
- TAS contribution includes the design of I-Hab and ESPRIT as ESA Prime Contractor, and part of the realization of MPCV and HALO modules.

- Gateway Program related activities allow TAS to broaden its expertise, in a different environment with respect to the ISS one.

Image: courtesy NASA

Date: 26 June 2024
Ref:
Template: 83230347-DOC-TAS-EN-010

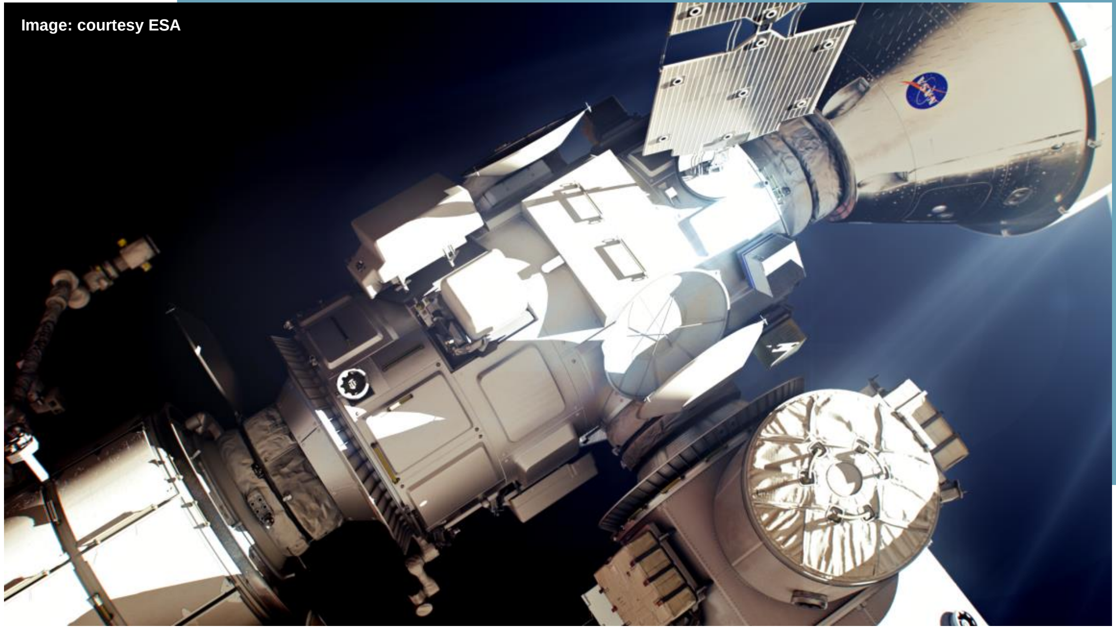
TAS in Gateway Lunar Space Station



Date: 26 June 2024
Ref:
Template: 83230347-DOC-TAS-EN-010

The Lunar I-Hab: the International Habitat

- The Lunar I-Hab will be the key habitable module of the Lunar Space Station, providing the cabin environment conditions that will enable crew operations and utilization for human day by day life in deep space.
- The Lunar I-Hab will be pivotal in sustaining human life, constituting also a basis and a fall-back for the subsequent lunar surface and deep space exploration missions.
- Due to its peculiar functions and use, I-Hab is indeed on the safety critical path of the entire Lunar Space Station, where Safety critical path refers to the sequence of activities or components that are necessary for the operation and well-being of crew members on the Lunar Gateway.

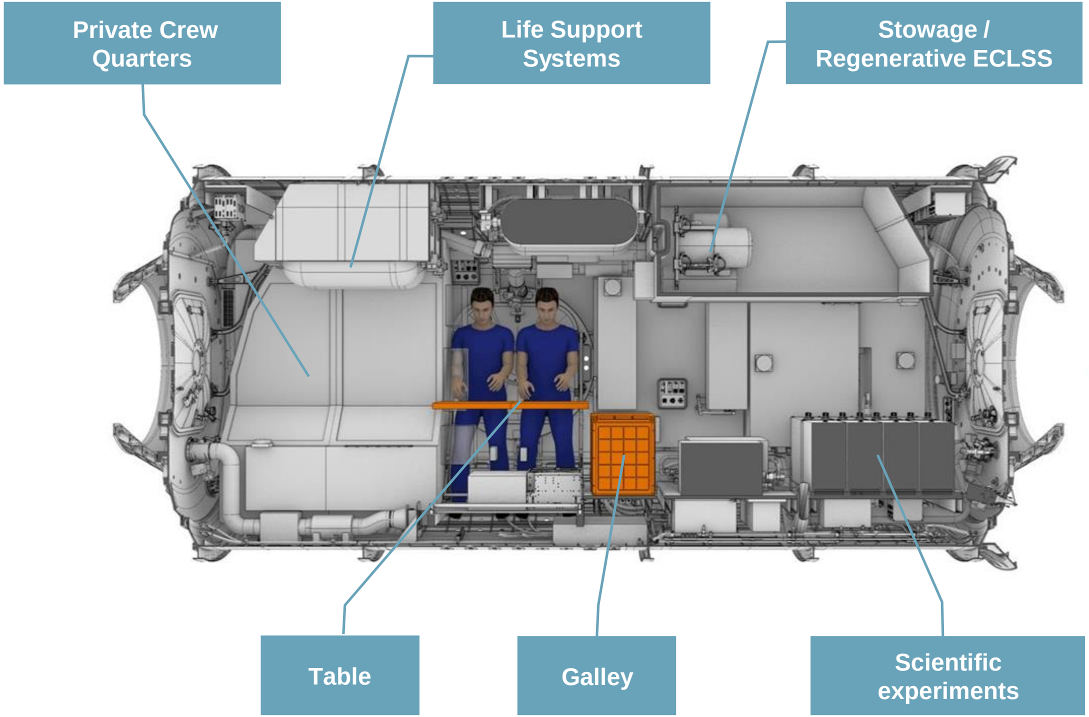


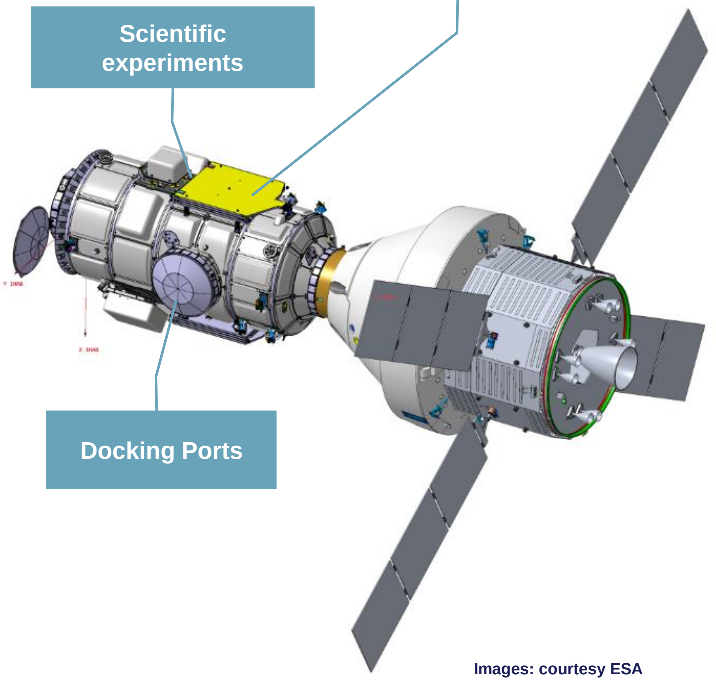
Date: 26 June 2024

Ref:

Template: 83230347-DOC-TAS-EN-010

The Lunar I-Hab: the International Habitat





Images: courtesy ESA

Date: 26 June 2024

Ref:

Template: 83230347-DOC-TAS-EN-010

Gateway vs ISS Concept Of Operations

GATEWAY

Near Rectilinear Halo Orbit: 400K Km distance

Mostly **uncrewed**

Deep Space Radiation environment

Lunar Dust Presence

Pressurized volume: <**125 m³**

ISS20

Low-Earth Orbit: 400 Km distance

Continually crewed

Earth's **magnetosphere shielding**

No Lunar Dust presence

Pressurized volume: <**920 m³**

Date: 26 June 2024
Ref:
Template: 83230347-DOC-TAS-EN-010

Gateway vs ISS Concept Of Operations

/// Significant difference between ISS and Gateway operability lies in the crew presence on board:

- on ISS, the crew is permanently present, ensuring preventive/corrective maintenance;
- on Gateway, the crew presence is limited in time, requiring an extensive autonomous recovery capability of on board anomalies;

and in:

- Gateway distance from Earth imposing increasing criticalities in rescue support;

/// For Gateway Space Station, limitation on mass at launch forced a design optimization with the adoption of reduced diameter pressurized infrastructures, imposing a very compact internal layout, based on extensive configuration and human factor aspects investigations.

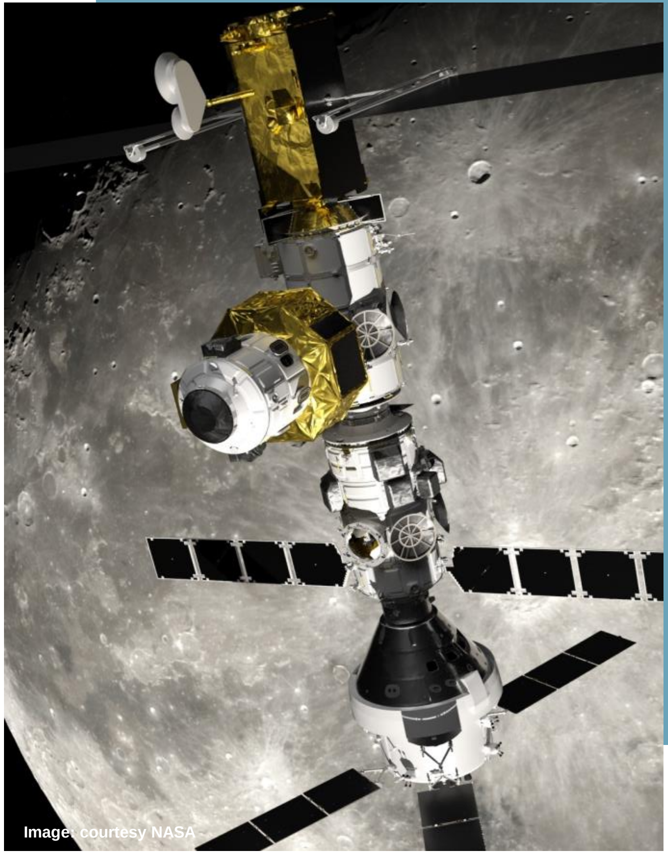


Image: courtesy NASA

Date: 26 June 2024

Ref:

Template: 83230347-DOC-TAS-EN-010

Safety Approach Evolution from ISS to Gateway

- ISS Safety Approach is generally based on double failure tolerance criteria, as primary hazard control strategy against potential loss of crew or loss of major infrastructures scenarios.

- A single failure tolerant design is then generally required for less critical hazards.

- This approach constitutes the basis for the safety and mission assurance evolution for the new operational scenario of Gateway lunar space station.

Date: 26 June 2024

Ref:

Template: 83230347-DOC-TAS-EN-010

Safety Approach Evolution from ISS to Gateway

/// Relevant outcomes from ISS experience led to human rating requirements evolution, improving the definition of the safety-related technical requirements and highlighting their rationale, as well as detailing the methods for requirement verifications.

/// As an evident difference in safety and mission assurance approach, failure tolerance requirement against **catastrophic hazard** has been changed:

- ISS Program: tolerance to the **“combination of two failures”**
- Gateway Program: tolerance to **“at least a single failure”**

Furthermore, requirement for **critical hazards** control has evolved from imposing failure tolerant design to levying general control of this hazard category.

/// This approach has been adopted based on the 25-years long valuable **return of experience from ISS**, in the frame of an overall accurate and in-depth evaluation of the mission **residual risk**, ensuring human safety requirements implementation while coping with relevant design constraints in terms of mass and volume allowable allocation.


Image: courtesy NASA

Date: 26 June 2024
Ref:
Template: 83230347-DOC-TAS-EN-010

Gateway Safety Approach Evolution: the “Exemption” Concept

- In this context of accurate residual risk characterization, the potential safety requirement deviations are managed through the implementation of the concept of “**Failure Tolerance Exemptions**”.

- The supporting documentation and specific data required to sustain such a deviation acceptability shall be submitted implementing a **structured and systematic analysis approach**, with regard to the specific hazard cause for which the deviation is raised.

- The information required as **technical merits for the acceptability** rationale shall address to more than 12 topics, as brief example:

  a) *Why is an exemption needed?*

  b) *What is the duration of exposure?*

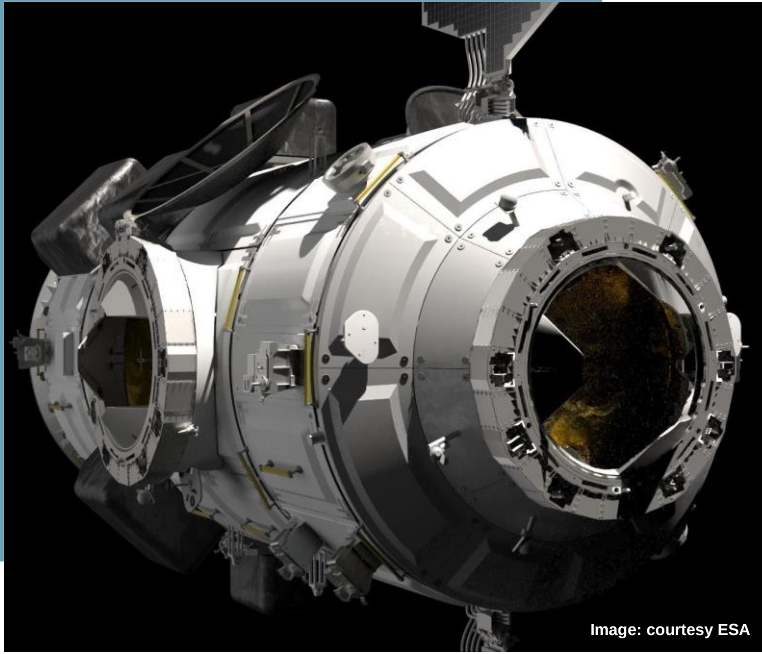
  c) *What is the time to effect?*

  d) *[…] i)*

  j) *What information supports producibility of the design within acceptable risk?*

  k) *Address any operational limitations or requirements for humans to control the hazard.*

  l) *Address ability to repair within time to effect, with margin.*



Gateway Safety Review Approach: the I-Hab case

/// The process for the characterization and the acceptance of I-Hab overall **residual risk** consists of a Phased Safety Review with an extensive participation of safety experts from multiple Space Agencies: ESA, NASA, JAXA and CSA.

- Flight Safety Technical Authority: **Gateway ESA Safety Review Panel GESRP**

  Co-Participation to the Safety Reviews of:

  - **NASA** Gateway Integrated Safety Review Panel **GISRP**;
  - Gateway **JAXA** Safety Review Panel **GJSRP**;
  - Gateway **CSA** Safety Review Panel **GCSRP**;

- Ground Safety Technical Authority: **NASA SLS/EGS combined Payload Safety Review Panel PSRP**

  Co-Participation to the Safety Reviews of:

  - NASA **MPCV** Safety and Engineering Review Panel **MSERP**


Image: courtesy ESA

The Lunar I-HAB: Safety Statistics

Phase 0/I Flight Safety Review

Performed in 2021:

- **67** Hazard Reports submitted
- **340** Hazard Causes Analyzed
- **1020** Hazard Controls identified

Delta Phase 0/I Flight Safety Review

Ongoing in 2023-2024:

- **43** Hazard Reports to be submitted
- **270** Hazard Causes Analyzed
- **810** Hazard Controls Identified

Numbers reduced thanks to Hazard Reports merging and optimization

Phase 0/I Ground Safety Review:

Performed in 2023:

- **28** Hazard Reports submitted
- **150** Hazard Causes Analyzed
- **375** Hazard Controls Identified

Up to 70-80 Safety Review Panel Members

Extensive participation of safety representatives and subject matter experts to each Safety Reviews, from different Space Agencies involved.

Date: 26 June 2024
Ref:
Template: 83230347-DOC-TAS-EN-010

The Lunar I-Hab: how to live on the moon orbit

- With support of ESA's and NASA's Astronauts, a preliminary Human-In-The-Loop test campaign verified accessibility of module subsystems by means of a low-fidelity mock-up of I-HAB.
- This allowed to collect valuable feedback on potential design changes and to improve in crew safety, efficiency, and well-being of the I-HAB module users to live on the cis-lunar orbit.
- Low-fidelity HITL tests will be followed by higher fidelity mock-ups development in line with the project evolution, to progressively verify human factor and safety operational requirements (e.g. emergency egress path obstruction).

Images: Thales Alenia Space

Date: 26 June 2024
Ref:
Template: 83230347-DOC-TAS-EN-010

Conclusions

/// **Increased distance from Earth** makes safety and mission assurance requirements implementation critical to ensure acceptable level of risk for crew safety, and external support for contingency scenarios more challenging.

/// **More demanding mass and volume constraints** require additional efforts for design and development optimization, though granting high safety standards for manned missions.

/// **Different operational scenarios** call for a more accurate and in-depth evaluation of missions residual risk, with an enlarged involvement and synergy of both quality and design engineering departments.

/// **Extended participation of safety representatives** and subject matter experts to the several Safety Forums and Program Safety Reviews attests the Space Agencies and Industries commitment to ensure implementation of the highest degree of safety and Mission Assurance level for the future deep space mission.

Date: 26 June 2024
Ref:
Template: 83230347-DOC-TAS-EN-010