Thales Alenia Space
a Thales / Leonardo company

Lunar Exploration Programs. Dust Contamination Prevention and Testing Approach.

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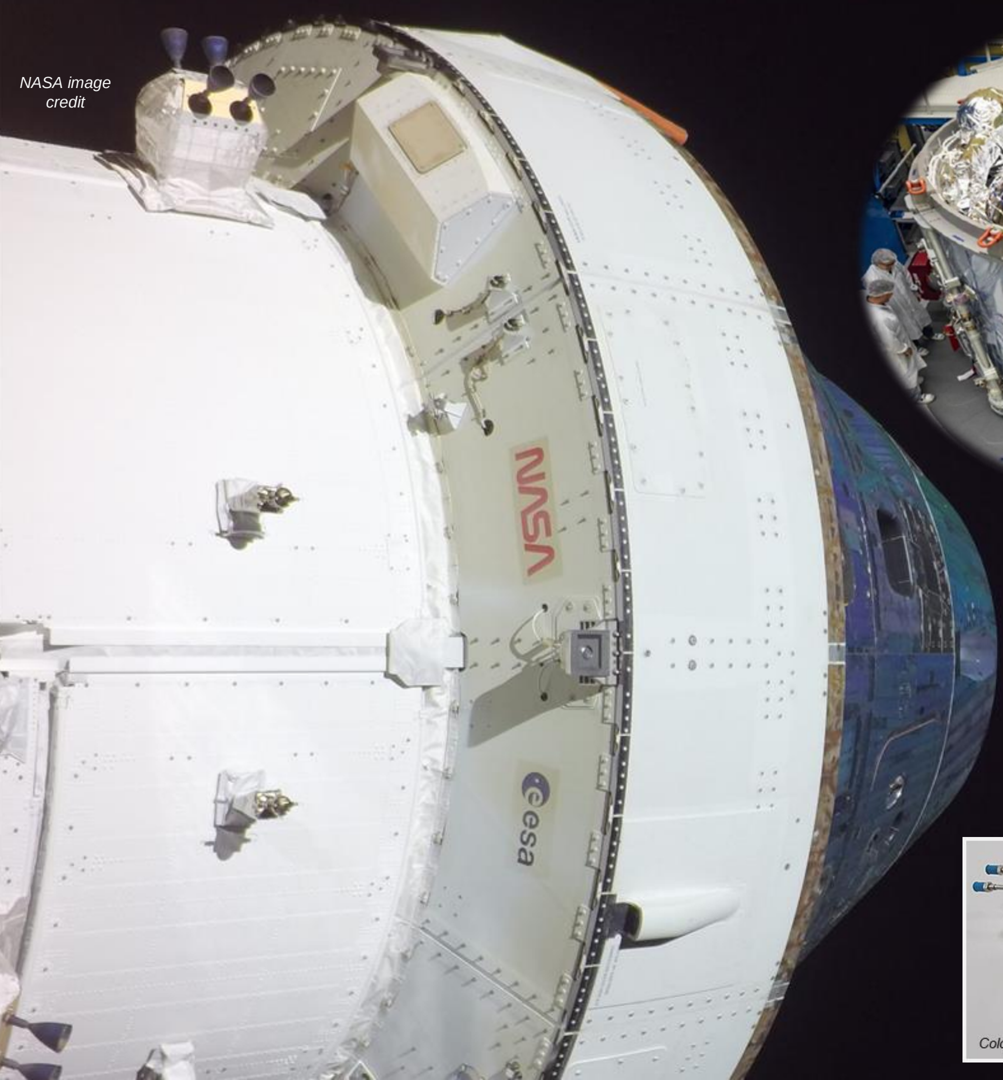
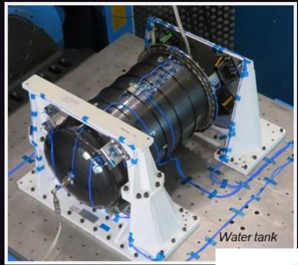
To the Moon with Orion

esa

ESM





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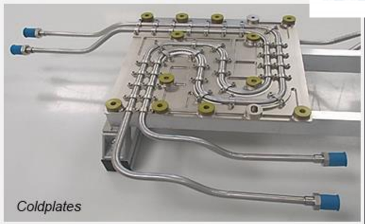
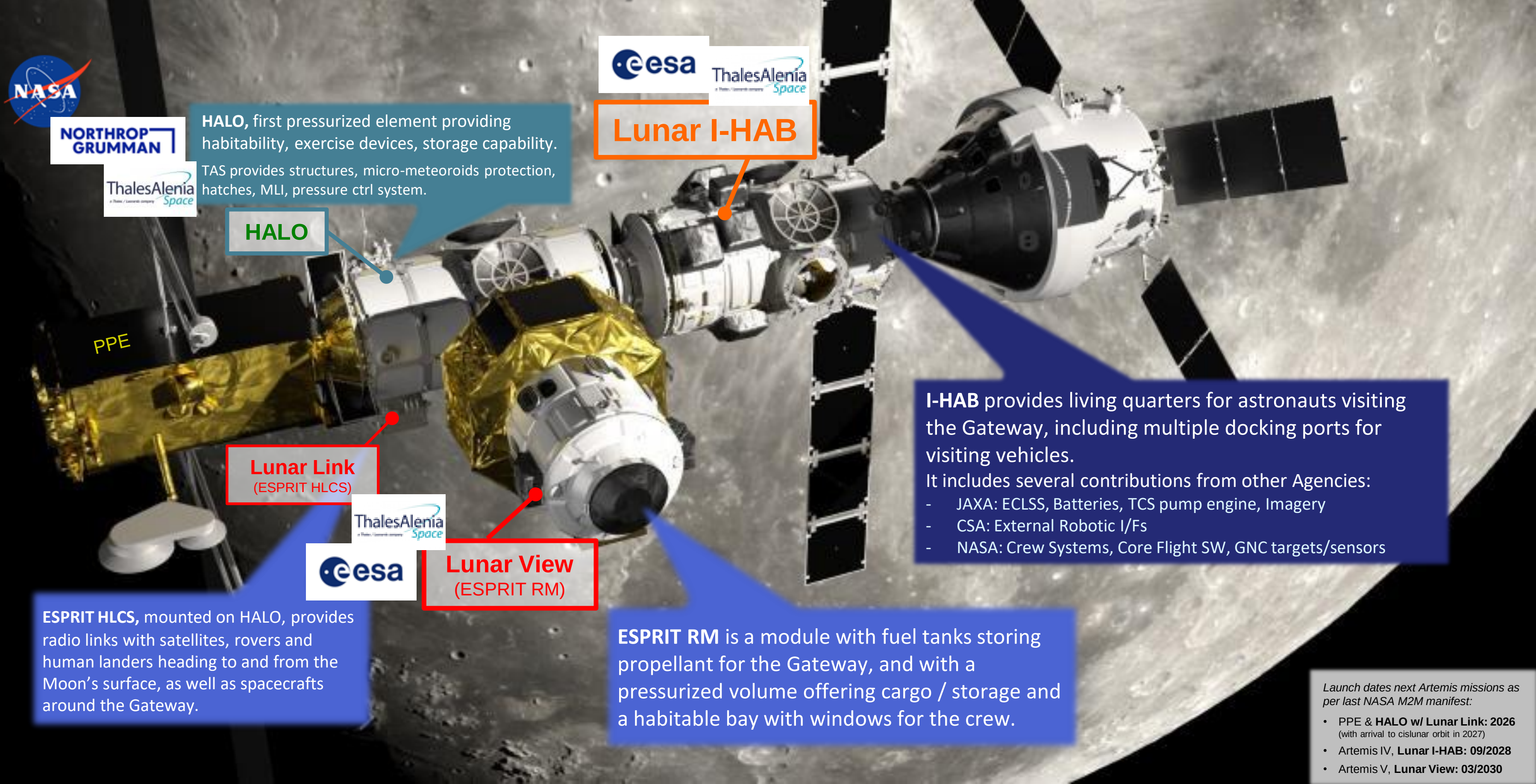


In Orbit around the Moon:
TAS contribution to the Gateway



HALO, first pressurized element providing habitability, exercise devices, storage capability.

TAS provides structures, micro-meteoroids protection, hatches, MLI, pressure ctrl system.

I-HAB provides living quarters for astronauts visiting the Gateway, including multiple docking ports for visiting vehicles.

It includes several contributions from other Agencies:

- JAXA: ECLSS, Batteries, TCS pump engine, Imagery
- CSA: External Robotic I/Fs
- NASA: Crew Systems, Core Flight SW, GNC targets/sensors

ESPRIT HLCS, mounted on HALO, provides radio links with satellites, rovers and human landers heading to and from the Moon's surface, as well as spacecrafts around the Gateway.

ESPRIT RM is a module with fuel tanks storing propellant for the Gateway, and with a pressurized volume offering cargo / storage and a habitable bay with windows for the crew.

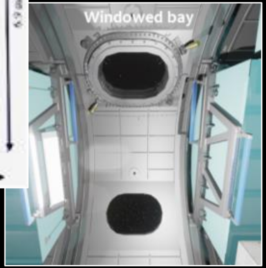
Launch dates next Artemis missions as per last NASA M2M manifest:

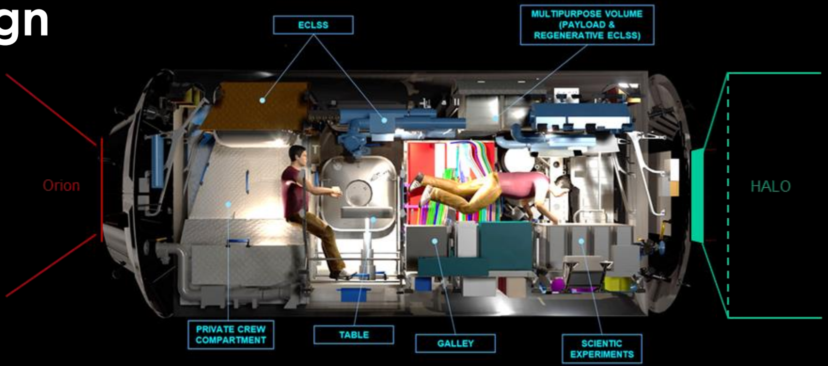
- PPE & **HALO w/ Lunar Link: 2026** (with arrival to cislunar orbit in 2027)
- Artemis IV, **Lunar I-HAB: 09/2028**
- Artemis V, **Lunar View: 03/2030**

Gateway elements on going design and production

Lunar Link (HLCS), Baybox PFM and HGA Assy

Lunar View, ERM XL configuration and design

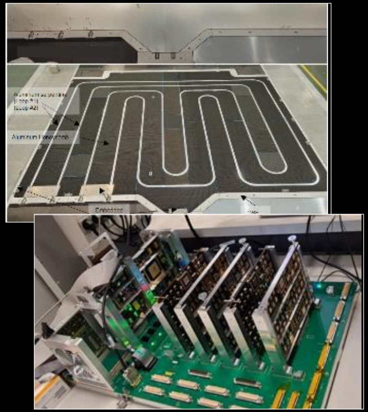


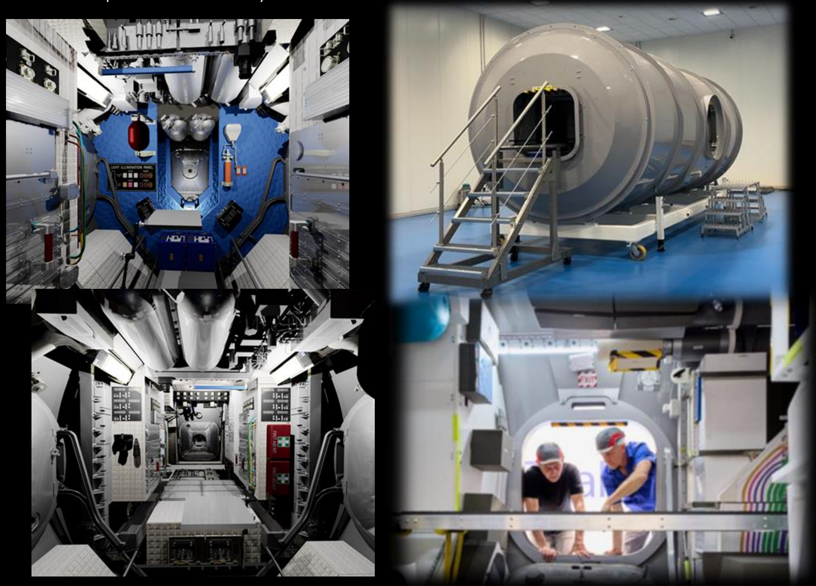


I-HAB Mock-up (low-fidelity) for **Human-In-The-Loop** tests, performed in May 2024 with ESA & NASA teams incl. astronauts

HALO primary structure, currently under static test
(on foreground forged cylinders of I-HAB)

Lunar I-HAB components / equipment



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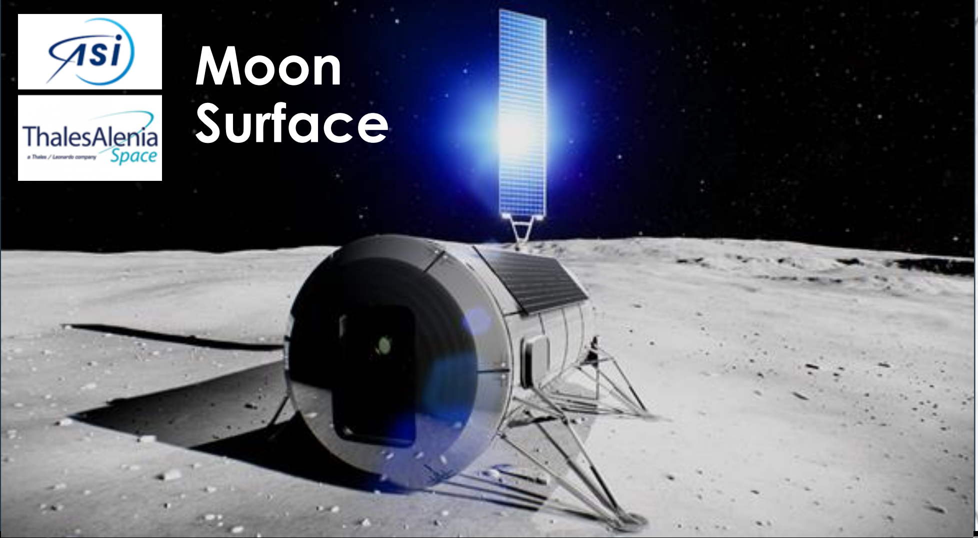
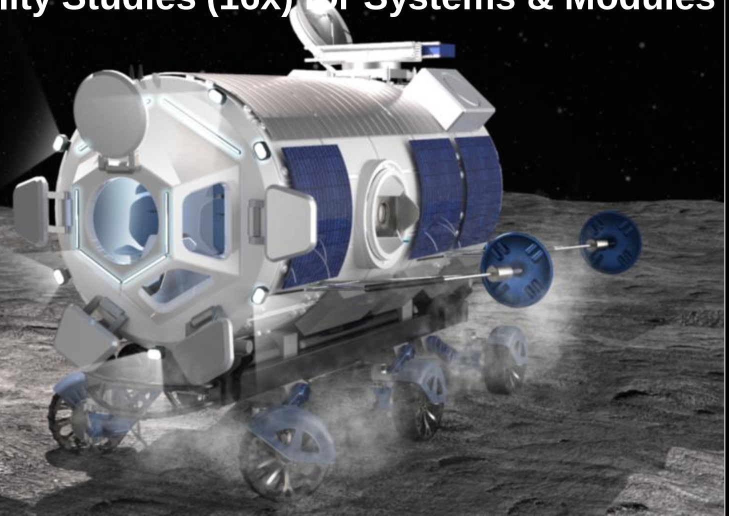
Moon Surface



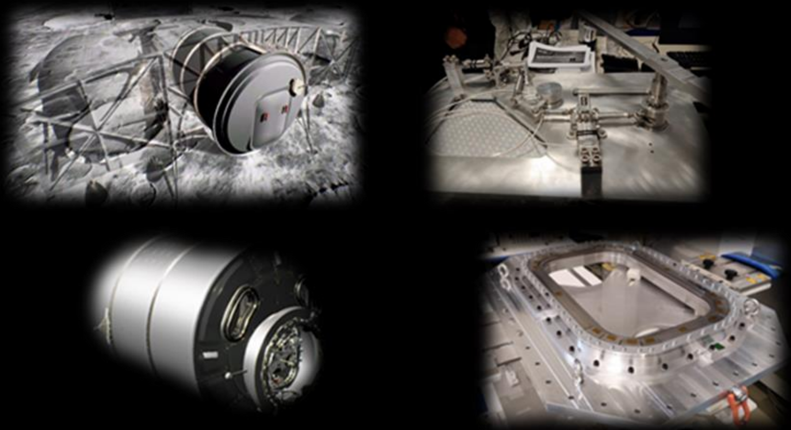
Lunar Feasibility Studies (16x) for Systems & Modules

- Lunar Shelter
- Foundation Habitat
- EVA Airlock
- Inflatable Pressurized Volume
- Lunar Lab
- Large Habitable Module in CFRP
- Large Cupola
- Transport Element & Logistics
- Mobile Habitat
- Robotic Rover & ISRU
- Automatic Exploration Vehicle
- Lunar Communication System
- Electrical Power Generation
- Lunar Data Center
- Integrated TLC/NAV Time Distribution
- Surface Radio Beacon for Landing



MPM (Multipurpose Press. Module)

An 'HLS-oriented' Crew Module structure design, with **technological pre-dev's** on windows, hatches, coatings, MLI (incl. dust contamination prevention..)

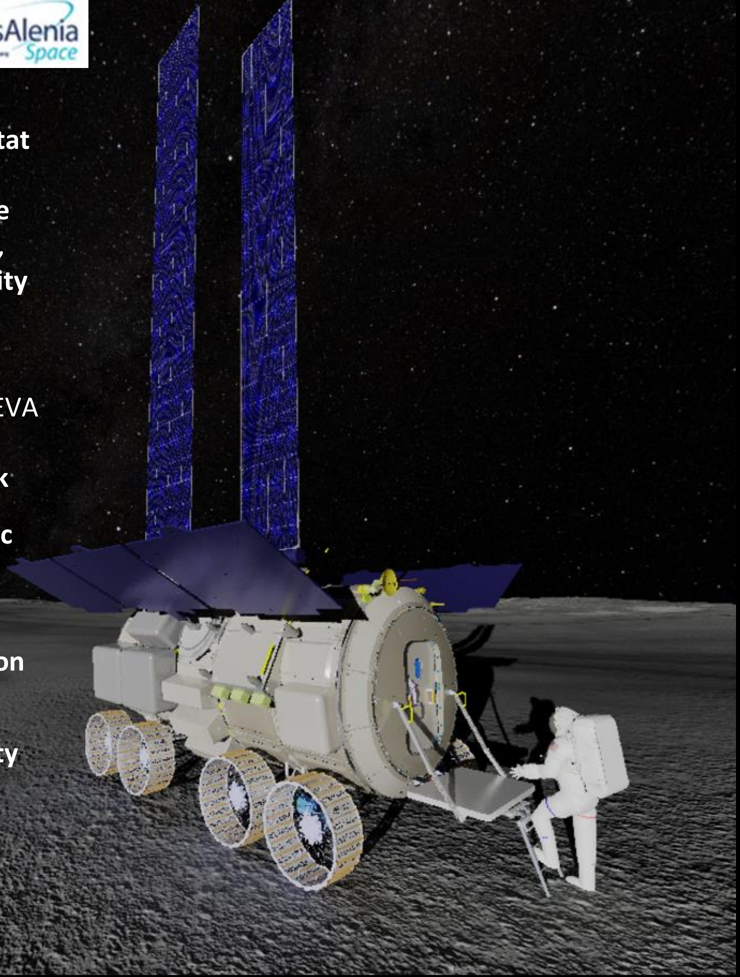


Lunar Surface Multi-Purpose Habitat (MPH)

Agenzia Spaziale Italiana

ThalesAlenia Space

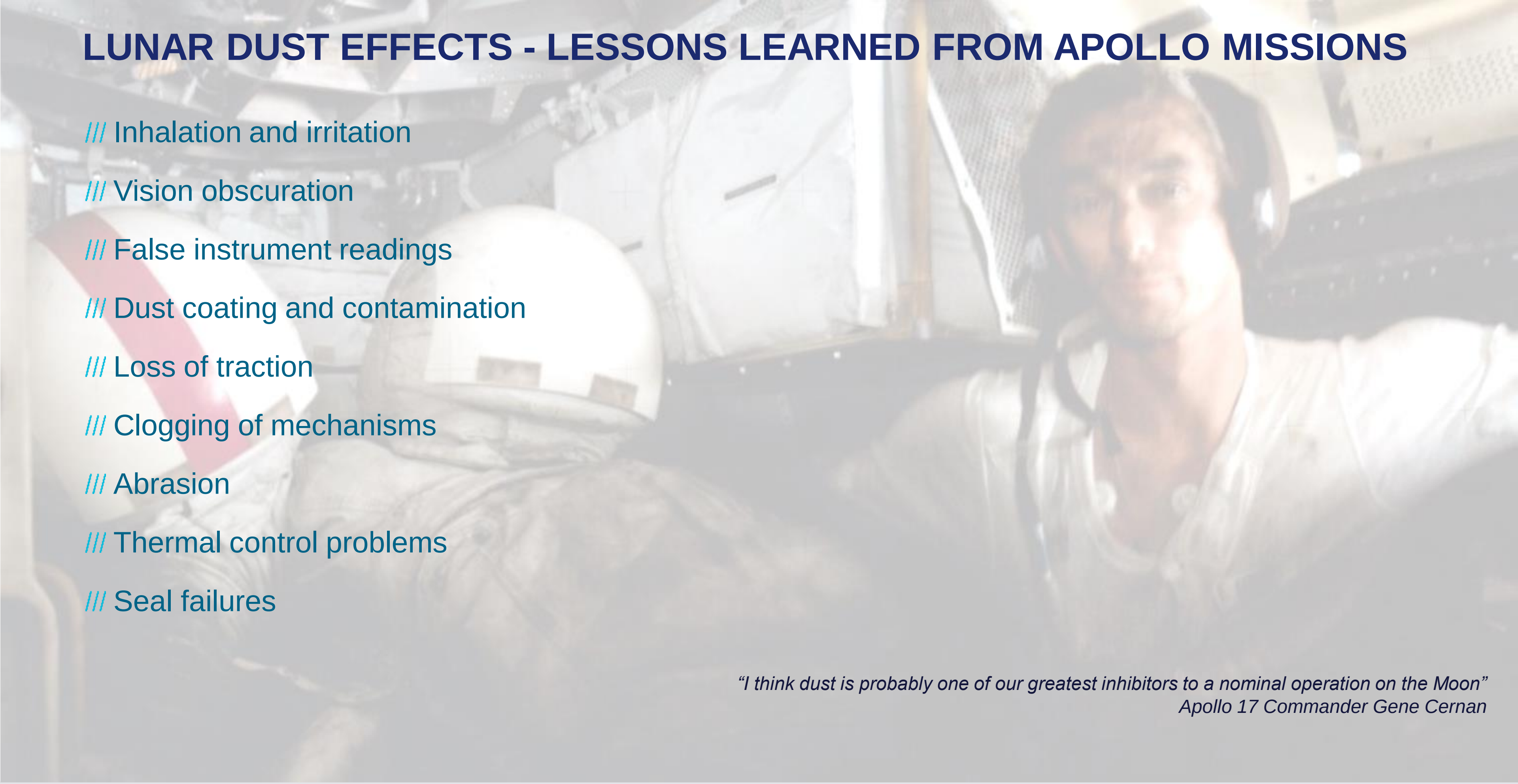
- **Pressurized habitat** (early 2030 timeframe) **at the lunar South Pole**, capable of **mobility**
- Safely **hosting astronauts** and facilitating their EVA through an integrated **airlock**
- Enabling **scientific research and experimentation**
- **10 years operation** in full autonomy
- **Synergy capability** with the other Artemis architecture's elements



Main design & technological challenges:

- **Mass and volumes** constraints
- **Habitability** in low-g
- **Offloading and mobility** on irregular soil
- **PNT and HMS, Energy** at high efficiency
- **Countermeasures against hostile env.:** large thermal excursions, lunar night, cosmic radiation, micro-meteoroids ..

.. lunar dust



LUNAR DUST EFFECTS - LESSONS LEARNED FROM APOLLO MISSIONS

- /// Inhalation and irritation
- /// Vision obscuration
- /// False instrument readings
- /// Dust coating and contamination
- /// Loss of traction
- /// Clogging of mechanisms
- /// Abrasion
- /// Thermal control problems
- /// Seal failures

“I think dust is probably one of our greatest inhibitors to a nominal operation on the Moon”
Apollo 17 Commander Gene Cernan

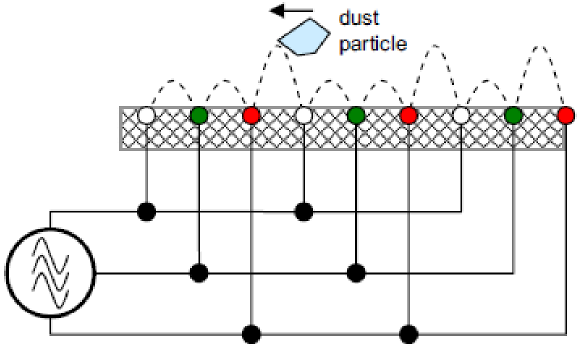
KEY STRATEGIES FOR TAS

/// Prevention

- Wear-resistant materials and surface treatments
- Development tests with dust during projects' earliest phases

/// Design countermeasures

- Barriers for sensitive items protection (covers for mechanisms, sealed bearings)
- Dust-repellant coatings or electrodynamic fields
- Oversizing for solar arrays and radiators

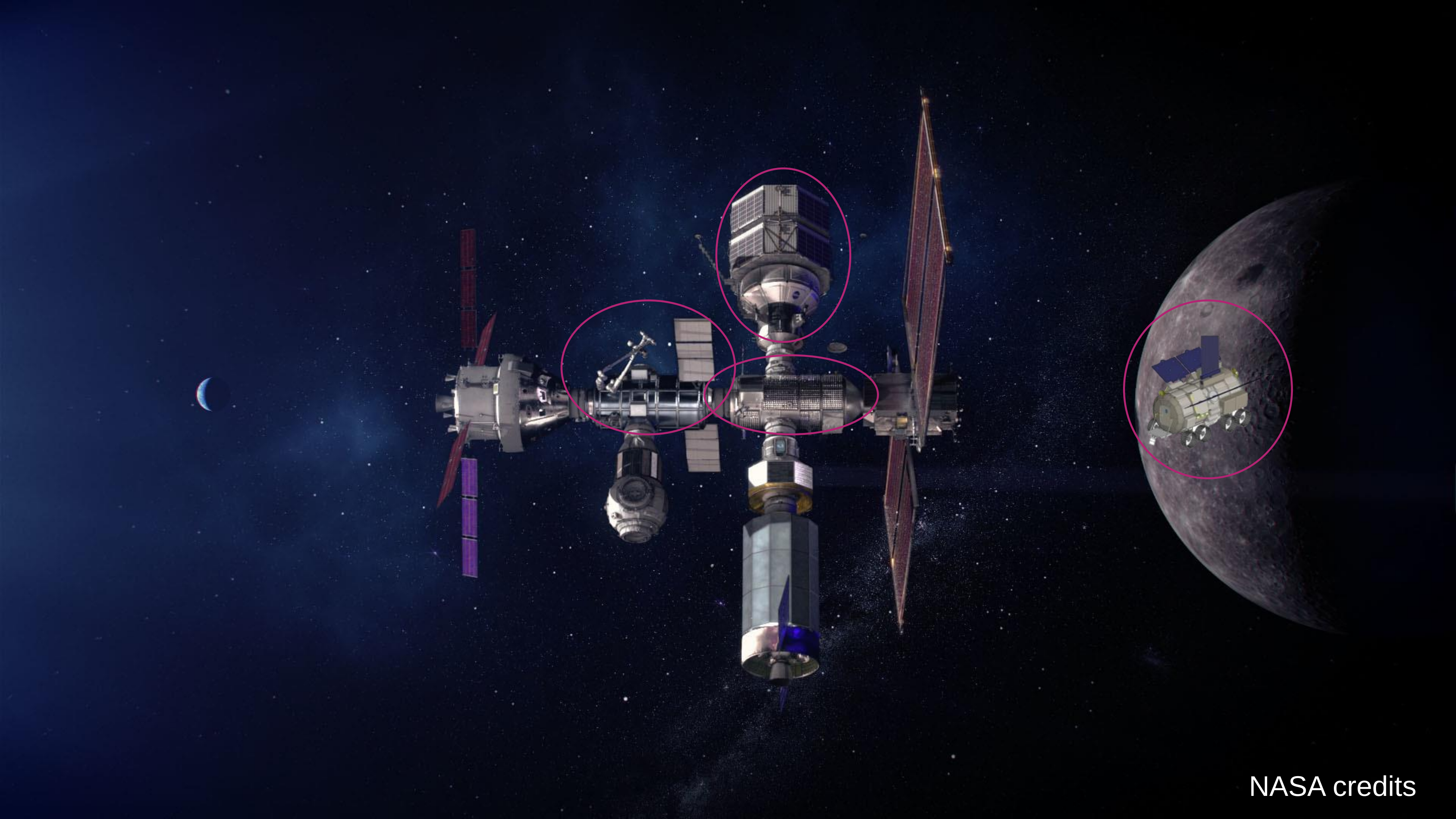


/// Cleaning methods

- Most suitable technologies wrt efficacy, crew time, compatibility with the substrate
  - Compressed air or vacuum
  - Soft brushes and wipes

Soft Teflon bristles brush

Foam brush



NASA credits

WORK IN PROGRESS FOR ON-ORBIT MODULES – ESA I-HAB

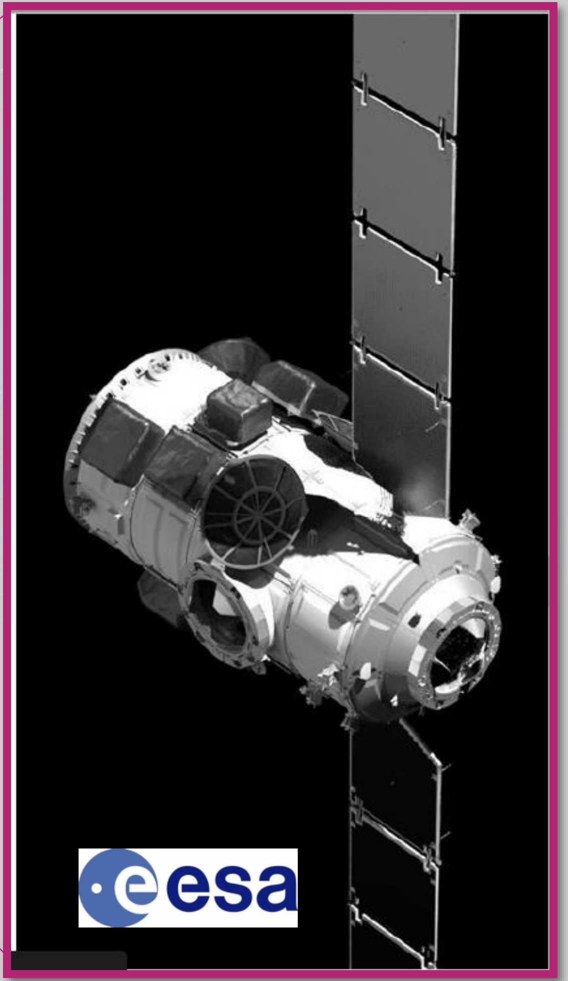
///PROLONGED EXPOSURE to LOW LEVELS OF DUST

EXTERNAL SURFACES

- Material characterization and proper selection
- Radiators oversizing
- Docking mechanisms dust testing
- Mechanical barriers
  - Labyrinths upstream mechanisms
  - Debris panels for EPS units/Harness
  - EVA-replaceable connector savers for GERIs

INTERNAL SURFACES

- Design towards easy mantainability
- Sealed interfaces (e.g. IP/MIL rated covers)
- Cleaning protocols
- Airborne dust control thru ECLS

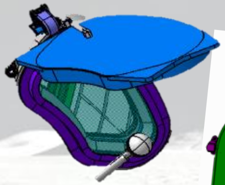


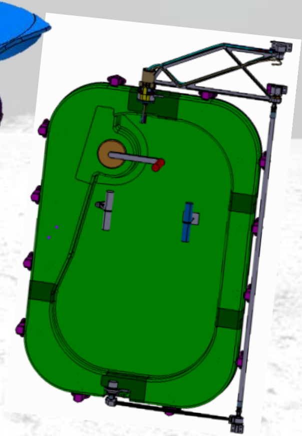
WORK IN PROGRESS FOR SURFACE HABITAT – ASI MPH

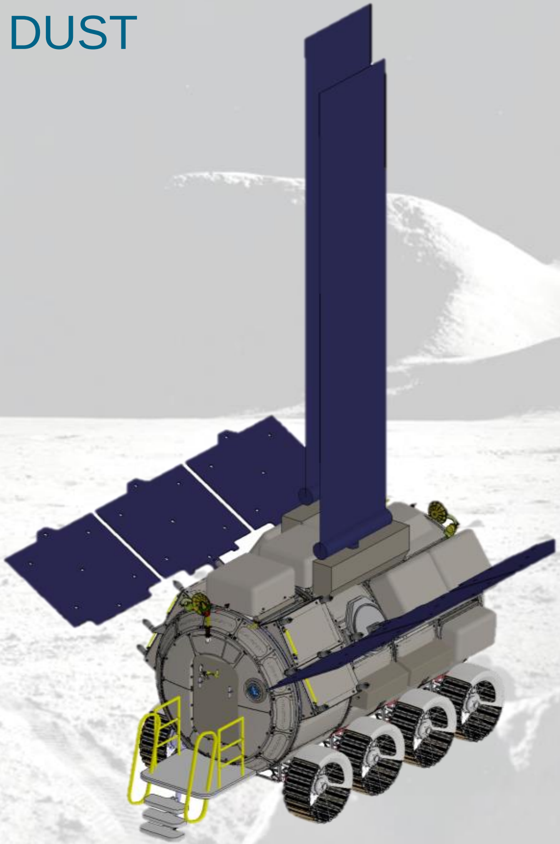
///LONG-TERM EXPOSURE AND HIGHER LEVELS OF DUST

/ COMBINATION OF PASSIVE AND ACTIVE MEASURES

- Most suitable materials and processes
- Dust-resistant seals and bearings
- Mechanical barriers
  - MMOD panels
  - Window Shutters
  - EVA Door cover for mechanisms protection
- Electro Dynamic Shield (EDS)
- Dust Removal System in the airlock
- Air revitalization inside the habitat
- Operational constraints
- Strict and regular cleaning protocols







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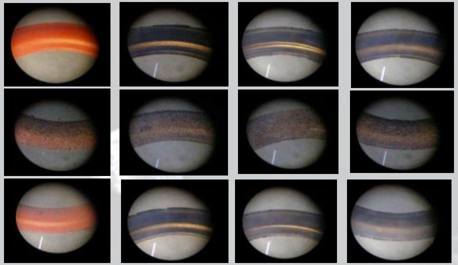
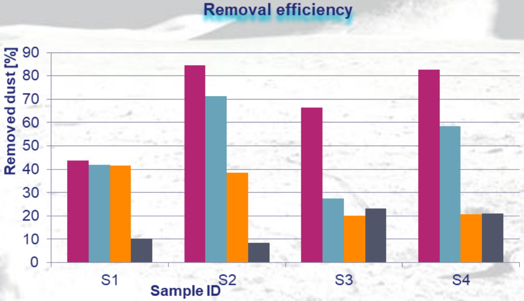
WORK DONE – ASI MPM (2021)

/// HERITAGE ON DESIGN DEVELOPMENT FOR MOON MISSIONS

Hatch

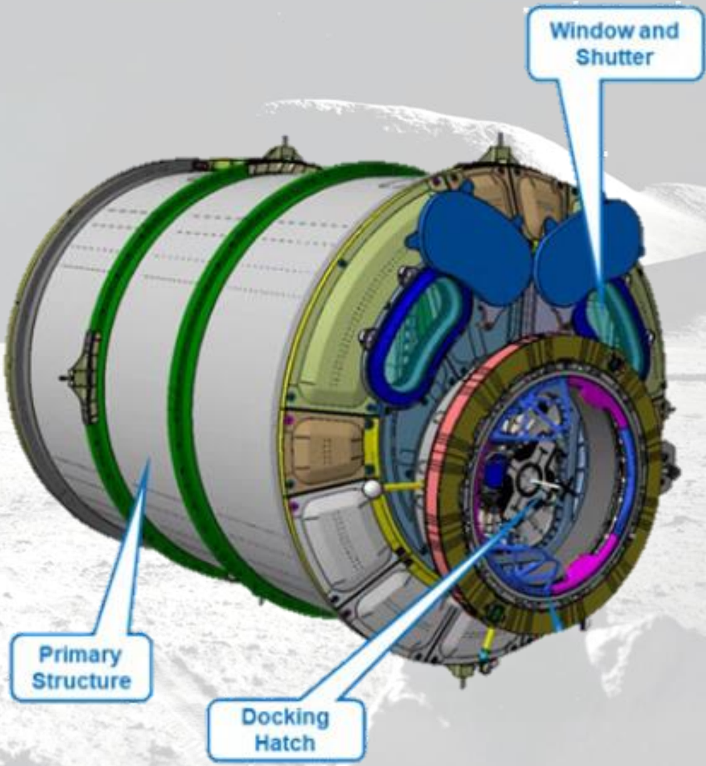
- Seal material characterization
  - Silicone
  - Ethylene Propylene Rubber
  - Fluorocarbon
  - Nitrile Rubber
- Seal cleaning methods
  - Soft brushing
  - wet wiping
  - N2 fluxing
  - sticky tape.
- EVA Door – cover efficiency
- Mechanisms – sealed bearings





Window

- Optical coatings compatibility
- Shutter mechanism cycling
- Assembly testing to study dust effects



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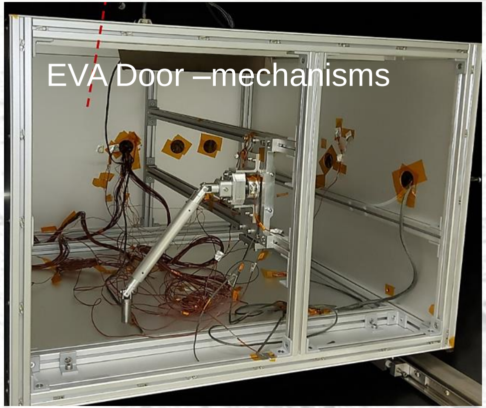
WORK DONE – ASI MPM

/// HERITAGE ON DUST TESTING

- Purpose:
  - To demonstrate compliance with functional and performance requirements after exposure to thermal-vacuum conditions and lunar dust simulant
- Test approach:
  - Test article contamination (LHS-1 dust simulant)
  - Depressurization to <5 E-04 mbar (initial target pressure)
  - Thermal cycling (- 60/+70 degC)
  - Return to ambient conditions
  - Test Article post-evaluation
- Results:
  - Window: scratches, small decrease of optical properties
  - Slight increase of mechanisms friction during lifetest
- Lessons learned:
  - Window: need of EDS coating
  - Mechanisms: new desing to keep a low actuation force



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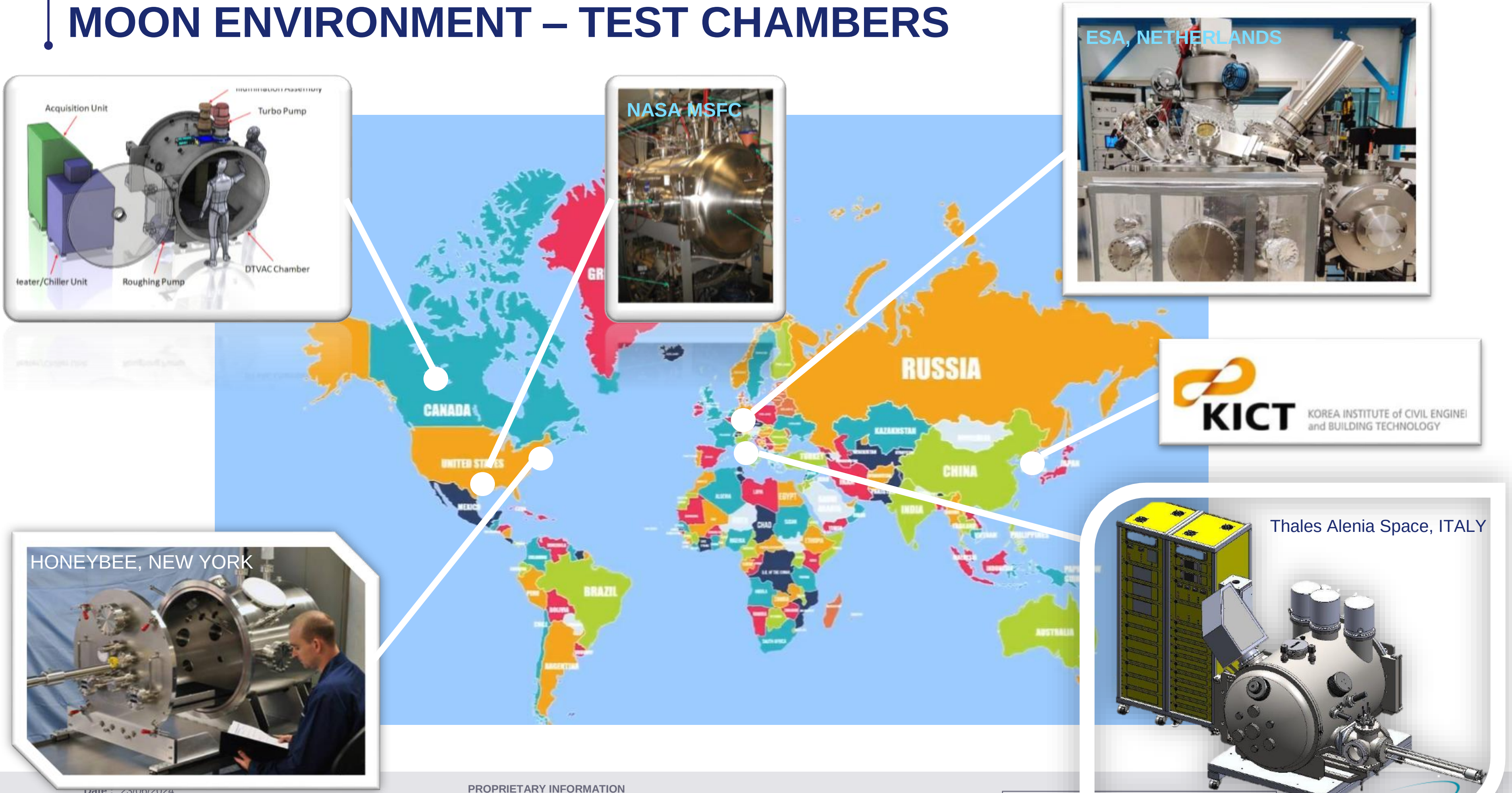
MOON ENVIRONMENT – TEST CHAMBERS



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NEW UPCOMING MOON ENV TEST CHAMBER – TAS ITALY

Vacuum Pumping System	Vacuum level	< 5×10^{-5} Torr (< 5×10^{-7} Torr, w/o dust)
Vacuum chamber	Internal dimensions (L×D)	127x110 cm
Sample Holder (Test Rig)	Thermal conditioning (LN2)	-150 to +200°C
Cloud Forming Mechanism	Bunker capacity	250mL
	Type of actuator	Stepper-Motor
Vacuum-UV Radiation Source	Type of VUV Source	Deuterium Lamp
	Wavelength range	115-200nm
Near-UV Radiation Source	Wavelength	200-400nm
VIS source	Wavelength	400-700nm
IR source	Wavelength	700-2500nm
Data Acquisition	Type of monitoring system	Optical camera
Outgassing controlled source	Knudsen cell	Via interlock

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TO BUILD A BETTER, SUSTAINABLE LIFE ON EARTH
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