# The Planetary Protection Strategy of Mars Sample Return's Earth Return Orbiter Mission


**Dr. Giuseppe Cataldo**

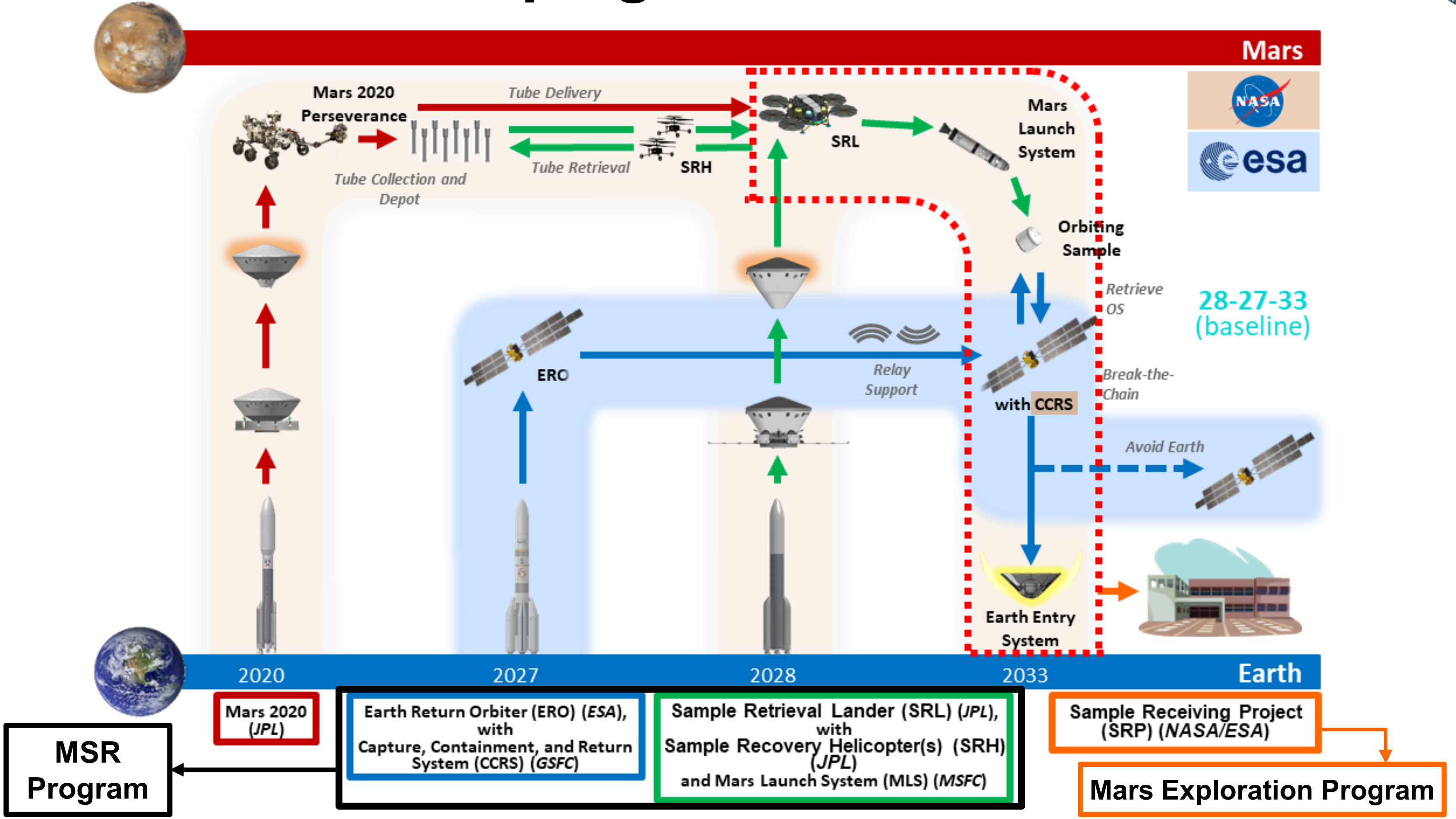
**NASA Goddard Space Flight Center**


**October 4, 2023**

# Outline

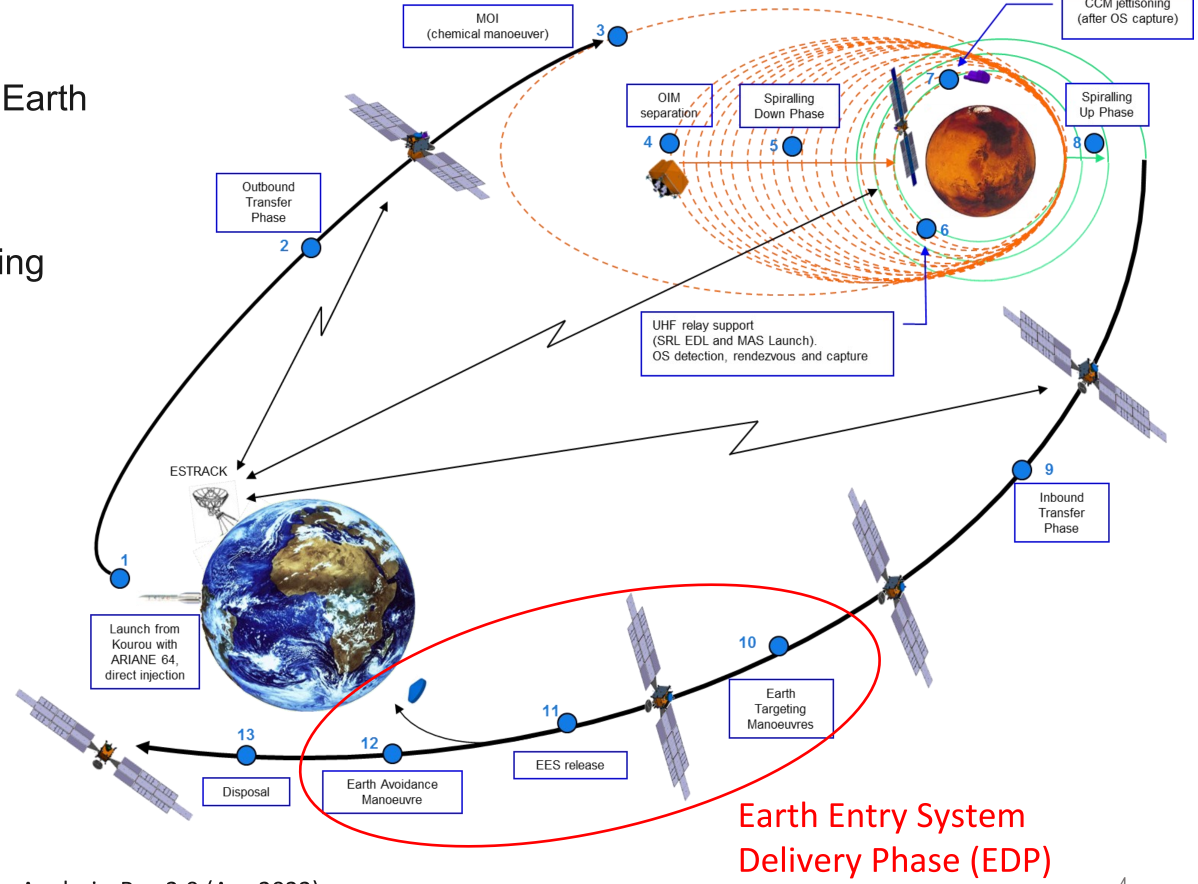
- MSR campaign overview
- ERO mission overview
- ERO spacecraft overview
- CCRS payload overview
- Planetary protection
- Implementation of planetary protection policies
  - ERO
  - CCRS
- Conclusions

# Planned MSR Campaign Architecture Overview



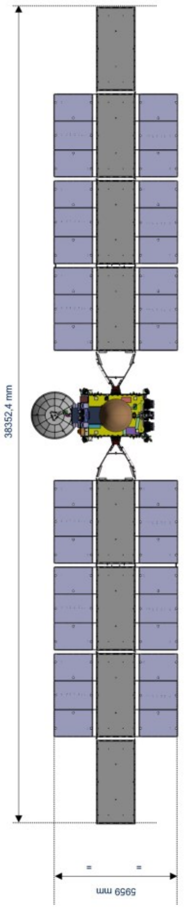
# ERO Mission Overview

- Mission objectives:
  - Capture the OS and bring it back to Earth
  - Relay support for Mars assets
- Nominal mission ("28/27/33"):
  - Launch and near-Earth commissioning [30 days]
  - Outbound transfer with heliocentric parking orbit [3 years]
  - Mars orbit insertion [2 weeks]
  - Spiral down [<1 year]
  - Low Mars orbit (relay support, OS rendezvous, OS containment) [1-1.5 years]
  - Spiral up [<1 year]
  - Inbound transfer [1 year]
  - EES delivery phase [few days]
  - Retirement [few days]




Key document: CReMA, ERO's Consolidated Report on Mission Analysis, Rev 2.0 (Apr 2022)

# ERO Spacecraft Overview




## Earth Return Orbiter

*Heritage: BepiColombo, ExoMars*

-> Launch mass: 7.2T
-> Departure mass: 3.6T
-> Return mass: 3T

***High Reliability***

*Heritage: ATV*

2-FT design for safety critical phases

## Communication

***X-Band***

*Heritage: ExoMars TGO*

2-axis steerable HGA & MGA
2 x LGA
2.5Mbits/s @ 1 AU
150kbits/s @ 2.2 AU

***UHF Relay***

*Heritage: ExoMars TGO*

2 x UHF
2 Mbits/s

## RDV Sensor Suite

**2 x Narrow Angle Cameras**

*Heritage: Faintstar*

**2 x LiDAR**

*Heritage: ATV*

## Solar Array

Deployable 2 x 72m²
Power: 42 kW

*Heritage: ENEO*

## Return Module

**5 x RIT-2X EP Thrusters**

T = [130mN; 290mN]
Isp = 4000 s
I = 47 MNs
Xe = 1203 kg

*Heritage: BepiColombo TDA*

**LEROS 10N Thrusters**

Bi-Prop = 271 kg

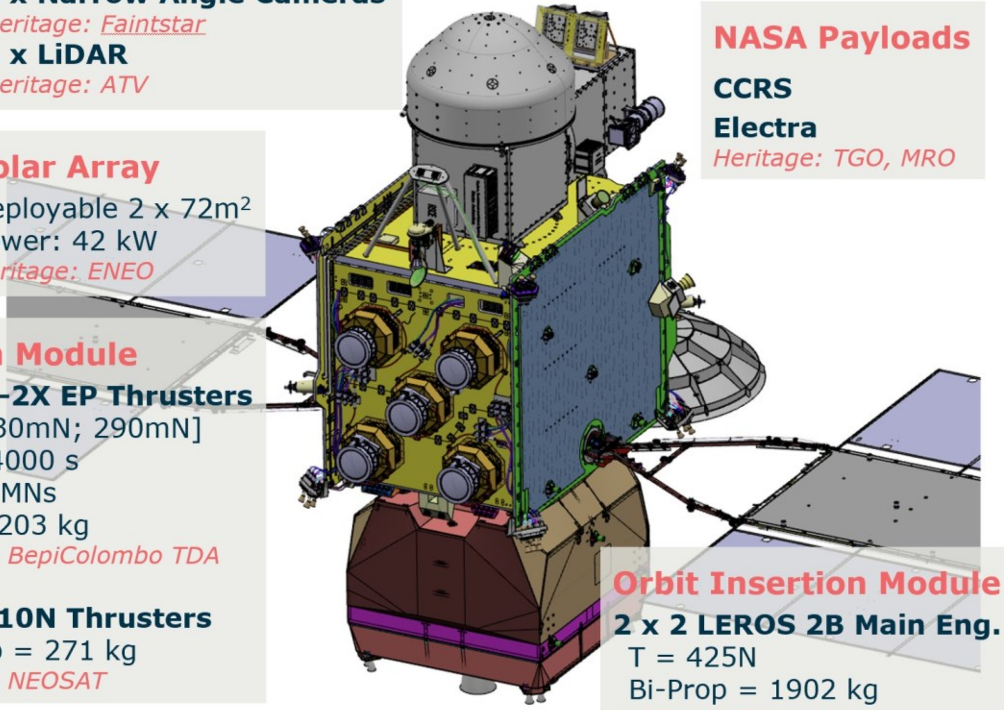
*Heritage: NEOSAT*

## NASA Payloads

**CCRS**

**Electra**

*Heritage: TGO, MRO*



## Orbit Insertion Module

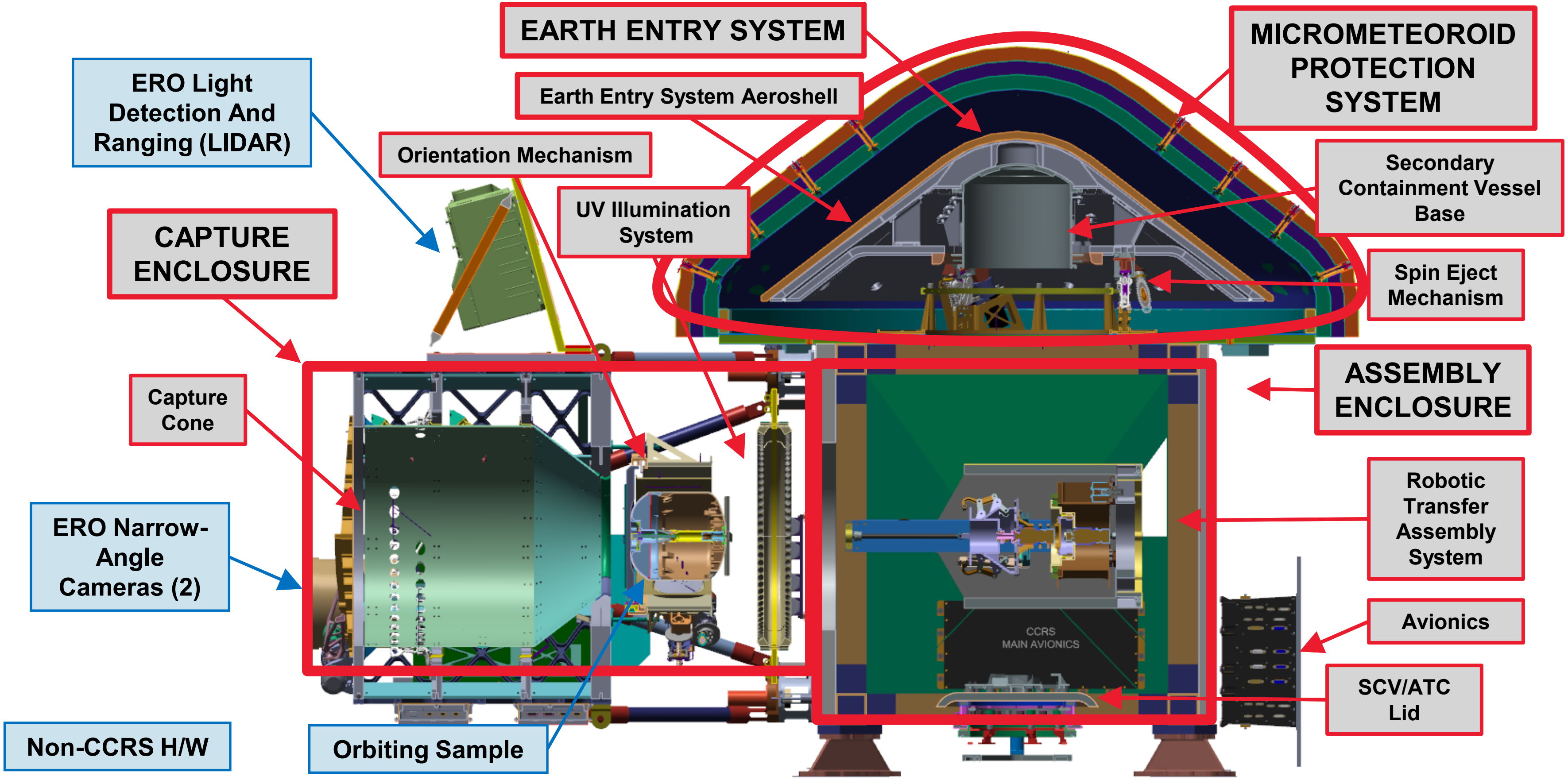
**2 x 2 LEROS 2B Main Eng.**

T = 425N
Bi-Prop = 1902 kg

*Heritage: NRL Mitex*

Credit: Airbus Defence and Space

# CCRS Payload Overview



# What is Planetary Protection?

**FORWARD PLANETARY PROTECTION (FPP)**

From NASA Procedural Requirement NPR 8715.24:

“Planetary protection is the practice of **protecting solar system bodies** from harmful contamination by terrestrial materials to enable scientific exploration and **protecting the Earth-Moon system** from possible harmful extraterrestrial contamination that may be returned from other solar system bodies.”

**BACKWARD PLANETARY PROTECTION (BPP)**

Also see:

1. *Article IX, UN Space Treaty* (UNOOSA 2017, Report of the Committee on the Peaceful Use of Outer Space, 60th Session, A/72/20, United Nations, New York)
2. *Planetary Protection Policy*, Committee on Space Research (COSPAR), 2021

# ERO Planetary Protection Categorization

| FPP Cat. | BPP Cat. | Element | Bioburden Cleanliness* | Execution |
|---|---|---|---|---|
| III | N/A | ERO Orbit Insertion Module | N/A | Jettison after Mars Orbit Insertion maneuver. |
| III | V(r) | ERO Rendezvous Sensor Suite<br>CCRS Capture Enclosure | N/A | Separates from ERO for disposal in either a Mars or heliocentric orbit. |
| | | ERO Return Module<br>CCRS Assembly Enclosure<br>CCRS Micrometeoroid Protection System | N/A | Disposed with ERO in a heliocentric orbit that avoids Earth for at least 100 years. |
| | | CCRS Earth Entry System | N/A | Sterilization and containment to break the chain of contact, anomaly detection, robust and redundant containment through entry, descent and landing. |

- Per NASA-ESA MOU, CCRS will comply with NASA FPP requirements at delivery to ESA for integration and perform to NASA BPP standards as an element of the MSR Program during flight.

* ERO plans orbits to be stable for longer than the required impact avoidance period or be limited in duration such that the probability of spacecraft failure during execution remains below impact probability requirements (<1% impact probability for the first 20 years after launch, <5% impact probability for the 30 years thereafter) consistent with COSPAR PP guidelines.

  - ERO requirements include **compatibility with bioburden assessments** to ensure a bioburden-based compliance path is possible if mission success considerations result in Mars orbital parameters that exceed allowable Cat. III impact probabilities.

# ERO Forward Planetary Protection Implementation

**Guidelines**
ERO follows ECSS requirement derived by COSPAR Planetary Protection guidelines.

**Deterministic approach**
ERO's FFP approach relies on optimized orbit selection for the time spent in Mars's sphere of Influence keeping bioburden compatibility assessment as a contingency measure.

**Mars impact avoidance**
The ERO spacecraft and mission is designed to avoid impacting Mars for a probability which would be lower then:
1% for the first 20 years after launch from Earth,
5% for the following 30 years.

**Jettisoned Elements**
All the jettison events happen in orbits selected for their orbital decay properties which ensure no contact with Mars is possible within the bounds of the FPP requirements

**Probabilistic approach**
Critical hardware failure leading to a loss of spacecraft control, including failure due to micrometeoroid impacts, are assed to ensure that the probability of contacting Mars is minimised – especially during mission phases in which ERO resides in orbits that are subject to natural degradation in less than the required duration.

# ERO Backward Planetary Protection Implementation

**ERO a is Cat. V restricted Earth Return Mission**

**Design specification on safety-critical functions**

Function that can lead to the risk of releasing unsterilized material from Mars into the terrestrial environment.

**Probabilistic safety target**

Potential contamination of the Earth biosphere must be avoided with a probability of less than 1 in a million

**Earth Avoidance Maneuver**

Key compliance and risk reduction apparatus to ensure ERO can be diverted from an Earth Impacting trajectory

**Fault tolerance**
Functions required to perform such an Earth Avoidance Manoeuvre are dual fault tolerant, including operations

**Trajectory**
Strategy to minimise time spent on an Earth impacting trajectory (a few days)

**Operational**
Monitoring of ERO's fault tolerance state is in place to provide in-flight input for key decisions making

**Software**
All software used to perform safety critical functions are developed following the highest possible safety standards

**Long term considerations**
Disposal manoeuvre post EAM that will put the spacecraft in a heliocentric orbit for 100 years

**Ground segment**
Special measure are in place to ensure 24/7 double ground station coverage

**Security**
Dedicated measure in place to ensure authorised communication between ERO and ground

**Probabilistic Risk Assessment**
Assessment performed with tools used by nuclear industry

**Review cycle**
External experts' involvement during entire development phase to review, advise and ensure compliance to PP requirements and appropriate adherence to guidelines.

# CCRS Forward Planetary Protection Implementation

**Compatibility with bioburden assessment** through compliance to ERO-CCRS interface requirements

**Assembly, integration and testing in an ISO-8 or better cleanroom**
This requirement is based on accepted surface biological levels found in ordinary ISO-8 cleanrooms and allows a bounding estimate for the biological load in the absence of assays.
For machining and fabrication taking place outside of clean environments, the contamination control implementation plan would provide details on the transition between fabrication and assembly for each subsystem.

Final disposition of CCRS hardware not returned to Earth based on **trajectories**, in either Mars or heliocentric orbit, established and maintained by ERO that satisfy both Cat. III requirements for FPP and Cat. V(r) requirements for BPP.

**Inventory for all organic materials** present on the payload in amounts greater than 1 kg.
The goal of this inventory is to aid in determining future scientific impacts if the mission inadvertently contacts Mars.

**Archive 50 g of organic materials** that are present on the payload in amounts greater than 25 kg.
Archived materials would be collected from those processed for flight (e.g., machined, cured, treated, etc.).
Archival through the end of mission would be managed by the MSR sample curation facility.

# CCRS Backward Planetary Protection Implementation

**BREAK THE CHAIN** OF CONTACT BETWEEN MARS & EARTH

**Active, surface-to-surface (Mars-to-Earth)** process to satisfy BPP goals by prohibiting uncontrolled transmission and release of **extraterrestrial material of concern** into Earth's biosphere.

- BPP is about defining and achieving the appropriate risk posture.
- BTC is an implementation-focused part of it, mandated by NASA HQ.

**PARTICLE CONTROL ("Leave behind")**

- Adhesion
- Transmission
- Emission

**STERILIZATION ("Inactivation")**

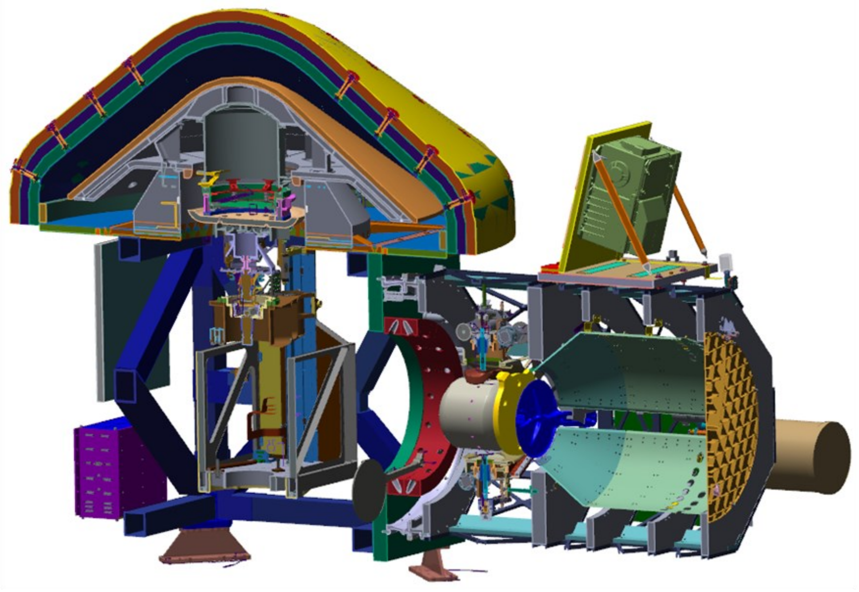
- Natural (solar UV)
- Engineered (active UV illumination)

**CONTAINMENT ("Lock up")**

- Sealing
- Encapsulation
- Isolation
- Blocking

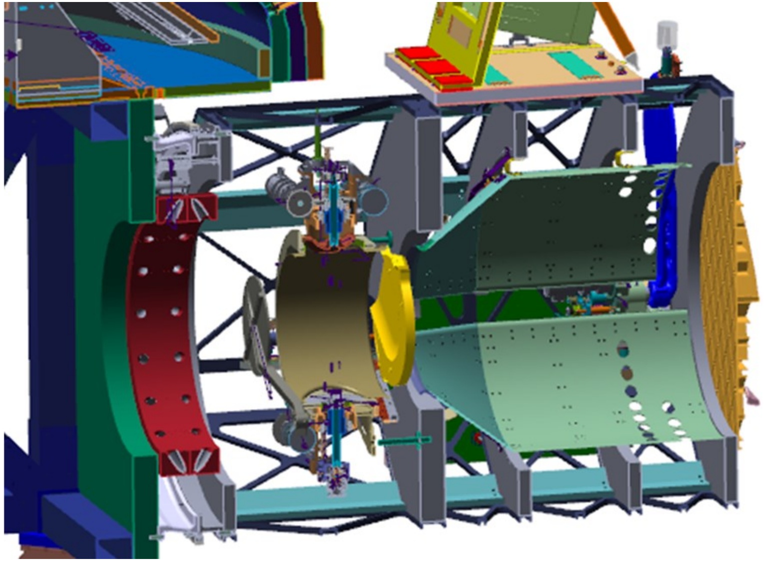
# Particle control

- CCRS directly controls the particle paths:
  - By minimizing by design gaps that could lead to undesired lines of sight (i.e., gap size, number of bounces, etc.)
  - Through mitigation strategies (e.g., MLI as barriers)



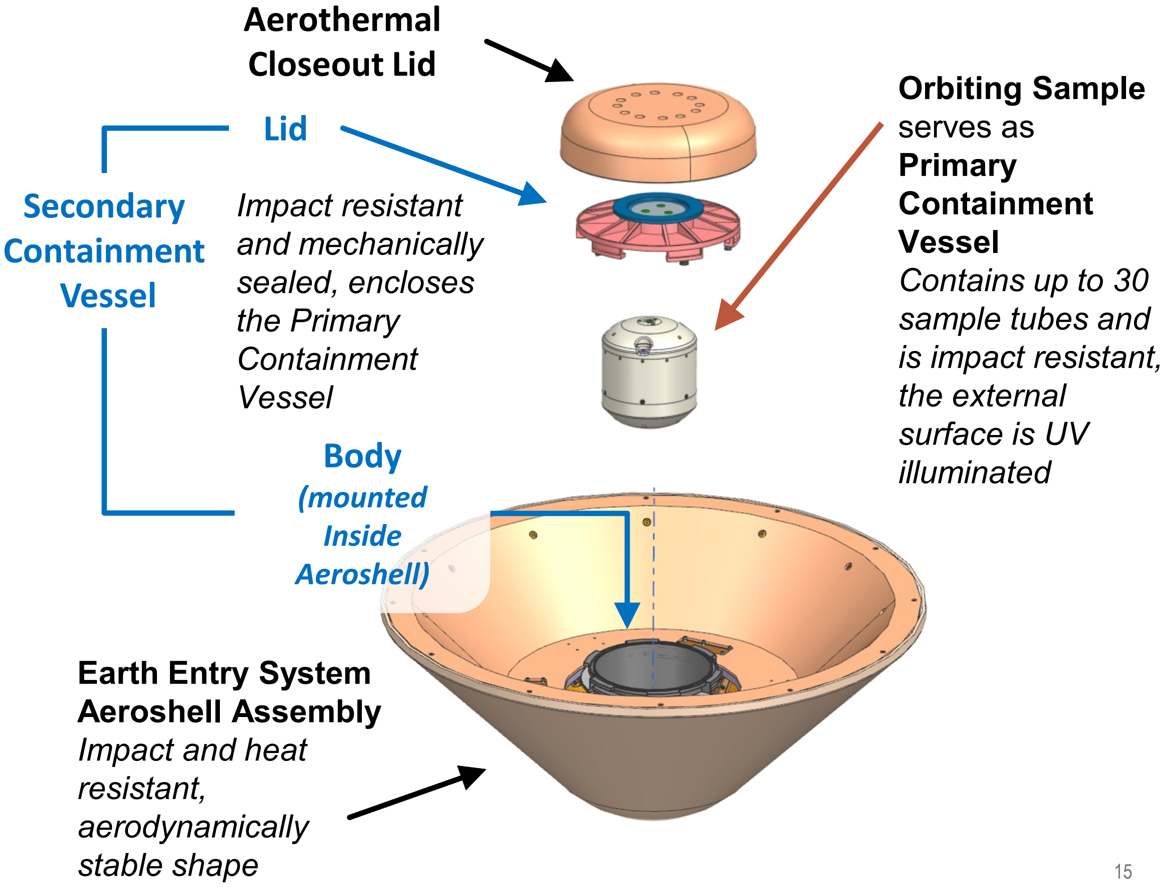
# Sterilization

- CCRS is required to deliver a minimum UV flux and dose to the outer surface of the OS and therefore will build a UV illumination system capable of providing both.
- <u>Verifying the efficacy of UV sterilization for potentially hazardous Mars particles falls under MSR Program's responsibilities.</u>



# Containment Assurance

- Containment in redundant vessels is completed in Mars orbit
- After UV illumination, the Orbiting Sample is sealed inside a Secondary Containment Vessel
- The nested Orbiting Sample and containers are then placed inside the Earth Entry System



# Robust protective measures are being designed to protect Mars and Earth's biosphere

### Assessing the risks

Sampling location and conditions present an **extremely low likelihood** of presence of hazardous biological material

### Safety first

Securely contain all unsterilized Mars material returned to Earth

→

### Break the chain of contact

between Earth and Mars

### Orbital trajectory management

The EES would be **pointed away** from Earth until a few days before the planned landing, allowing a final decision to be made about proceeding with Earth entry using all available information collected during the entire mission

### Highly reliable design

- Materials to tolerate extreme conditions
  - High velocities: ~43 000 km/h and forces: ~125 g
- No parachute
- Robust design and testing of the cone-shaped vehicle and its components

### Care upon landing

*Treat as if they could be hazardous*

Adopt procedures based upon the proven principles and techniques used by hazardous material response teams.

# Acknowledgments

- Co-authors:
  - – Lorenz Affentranger ESA ESTEC
  - – John Hall ESA ESTEC
  - – Brian Clement JPL
  - – Daniel Glavin NASA GSFC
  - – Bruno Sarli NASA GSFC
  - – Christine Szalai JPL

- The entire ERO-CCRS team from both sides of the Atlantic

Any questions?

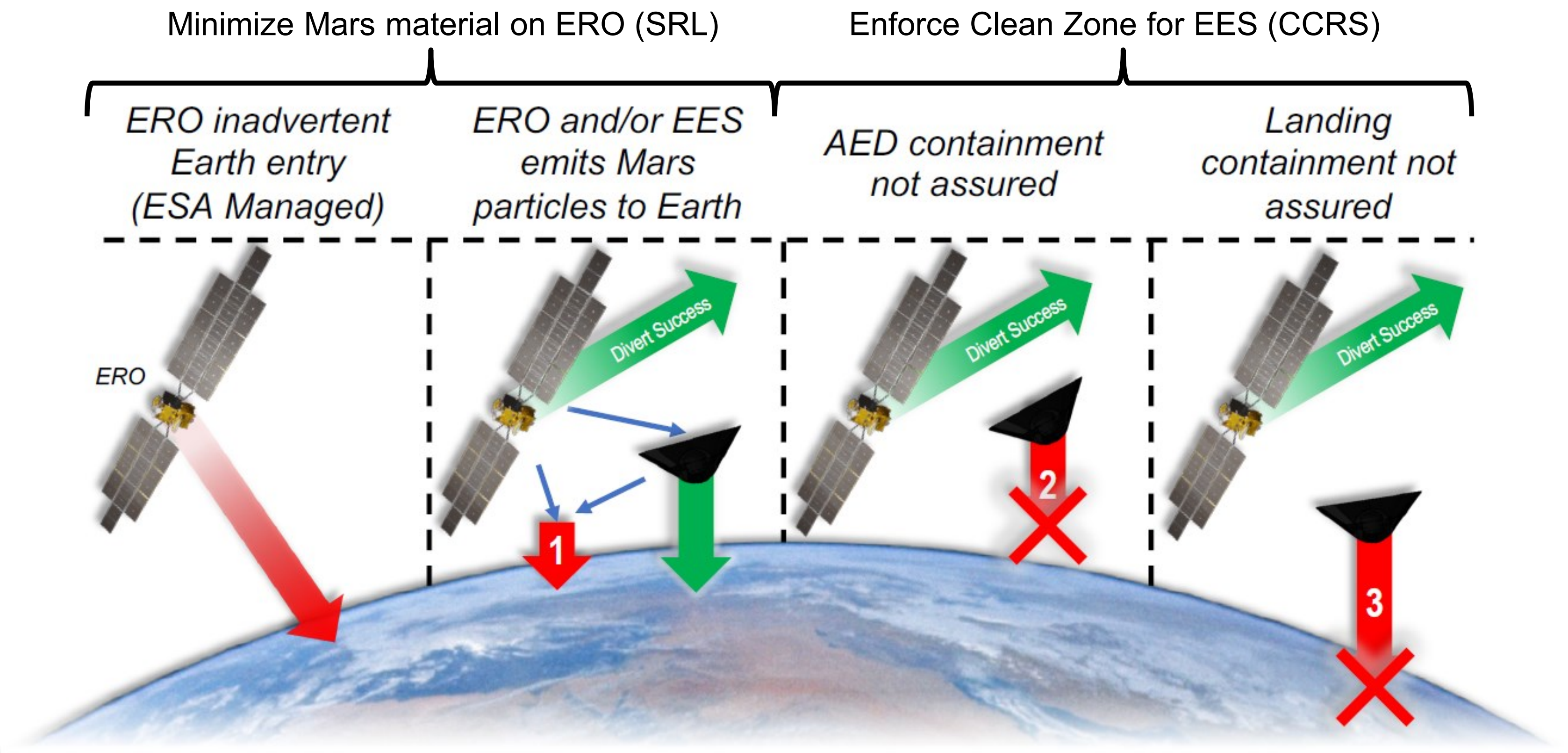
Reach out at
Giuseppe.Cataldo@nasa.gov
@g_cataldo

Learn more here:

# Back-up

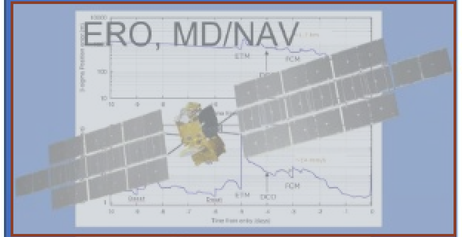
# Particle Control

- There are 5 primary paths of Mars material that can enter Earth's biosphere
- End-to-end, physics-based, analytical framework developed to track particles on hardware

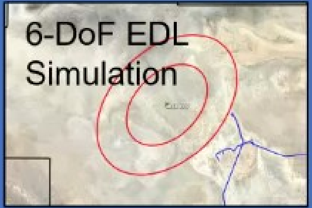


# Containment Assurance – The Pillars

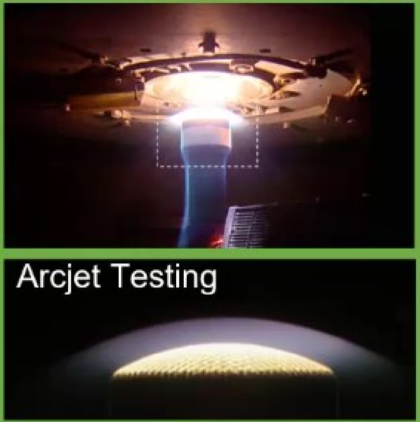
## Targeting is Successful








## Survives Entry Environments





Ballistics Testing

## Aerodynamics as Expected




## Survives Landing Loads