Flux Pinning Concepts for On-orbit Capture and Orientation of an MSR Orbiting Sample Container

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California Institute of Technology

Paulo Younse, Laura Jones-Wilson, William Jones-Wilson, Ian McKinley, Edward Gonzales, Boyan Kartolov, Dima Kogan, Chi Yeung Chiu, Eric Olds, and Violet Malyan

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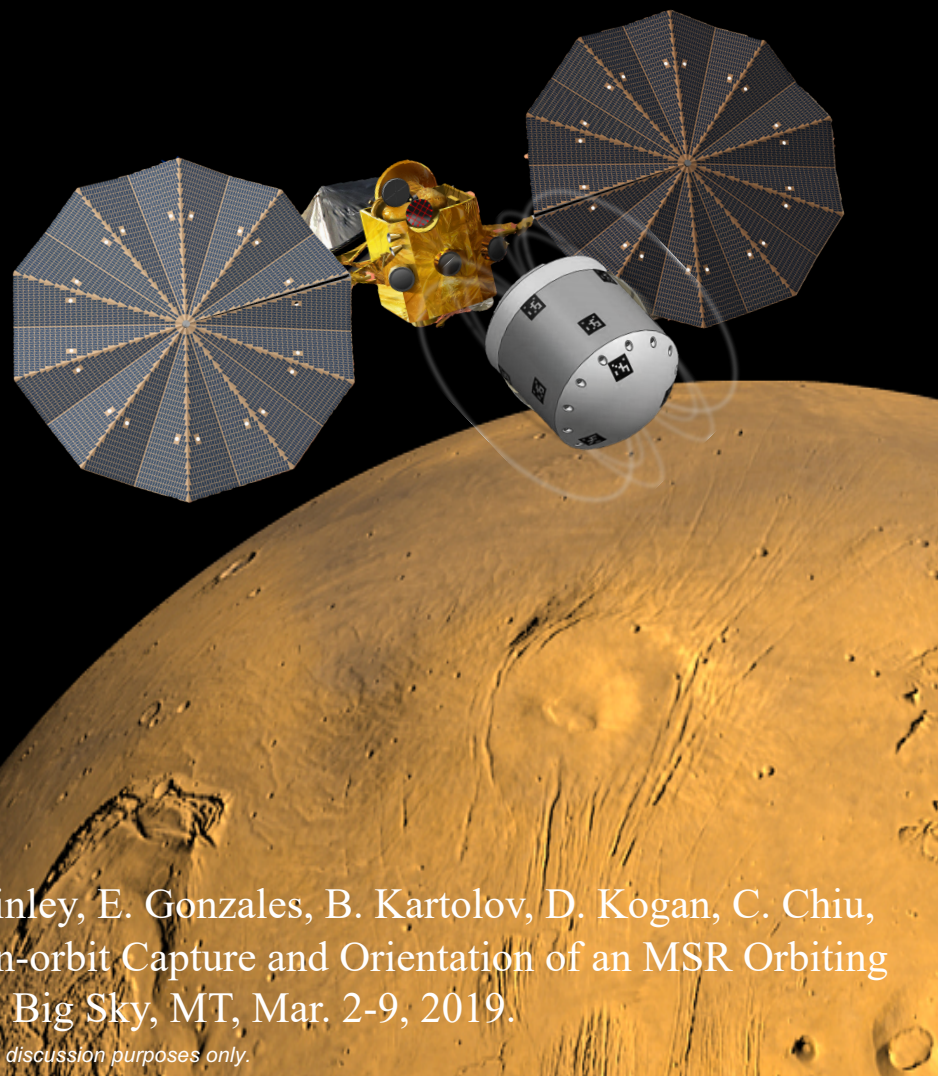

Younse, P., L. Jones-Wilson, W. Jones-Wilson, I. McKinley, E. Gonzales, B. Kartolov, D. Kogan, C. Chiu, E. Olds, and V. Malyan, "Flux Pinning Concepts for On-orbit Capture and Orientation of an MSR Orbiting Sample Container," *2019 IEEE Aerospace Conference*, Big Sky, MT, Mar. 2-9, 2019.

Predecisional: for planning and discussion purposes only.

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Potential Mars Sample Return Campaign

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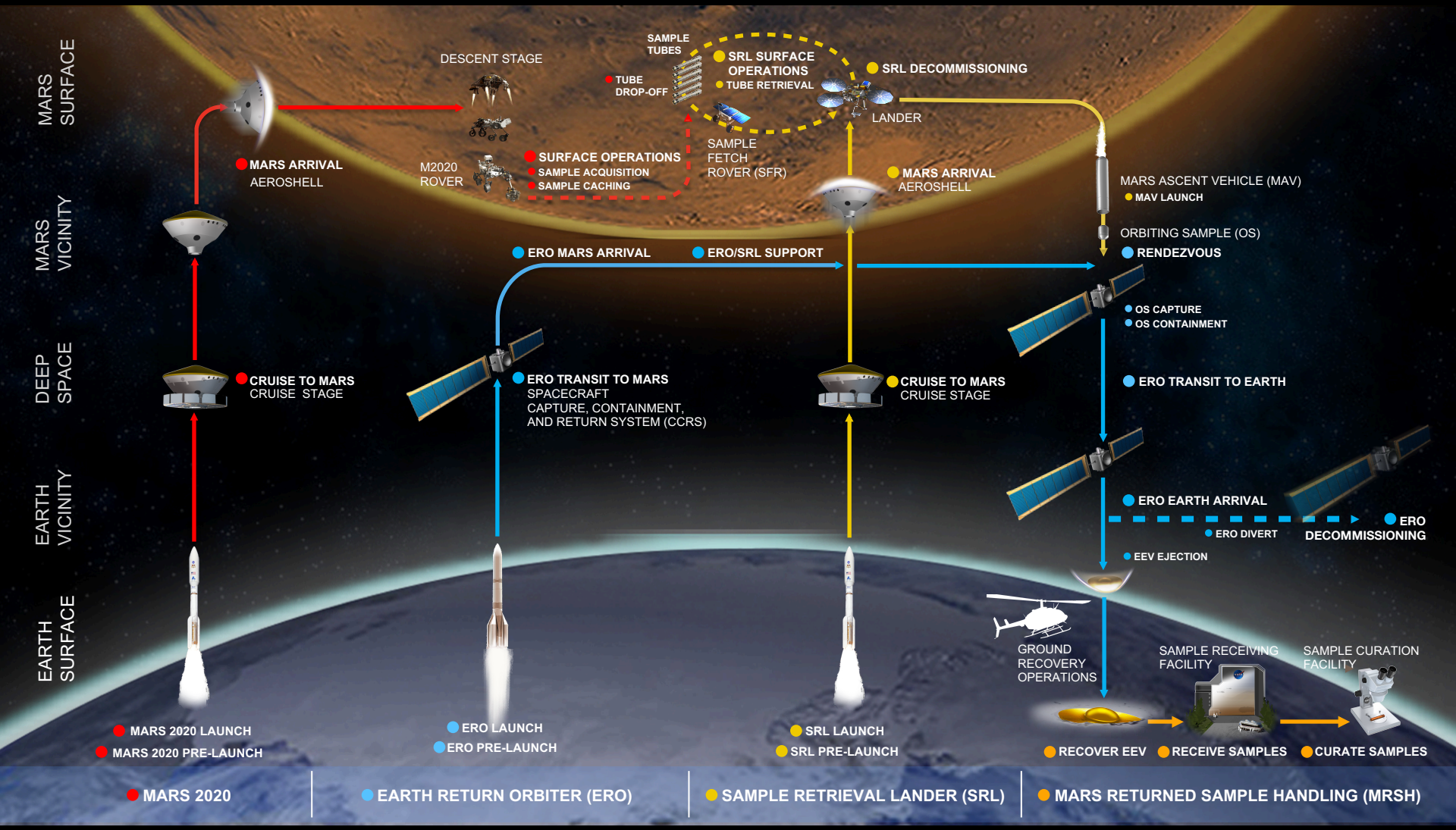

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Potential Mars Sample Return Campaign

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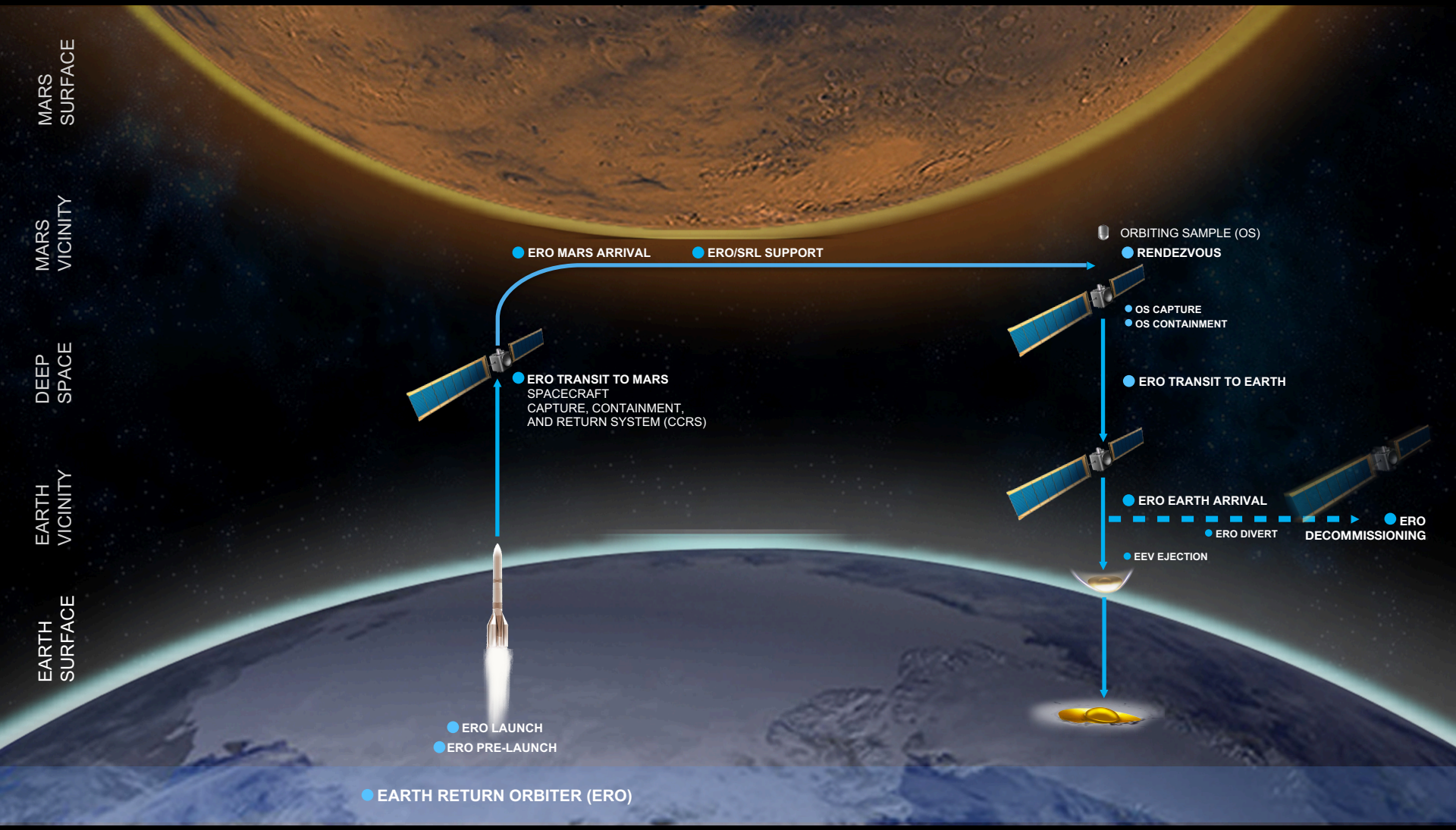

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ERO Mission Concept

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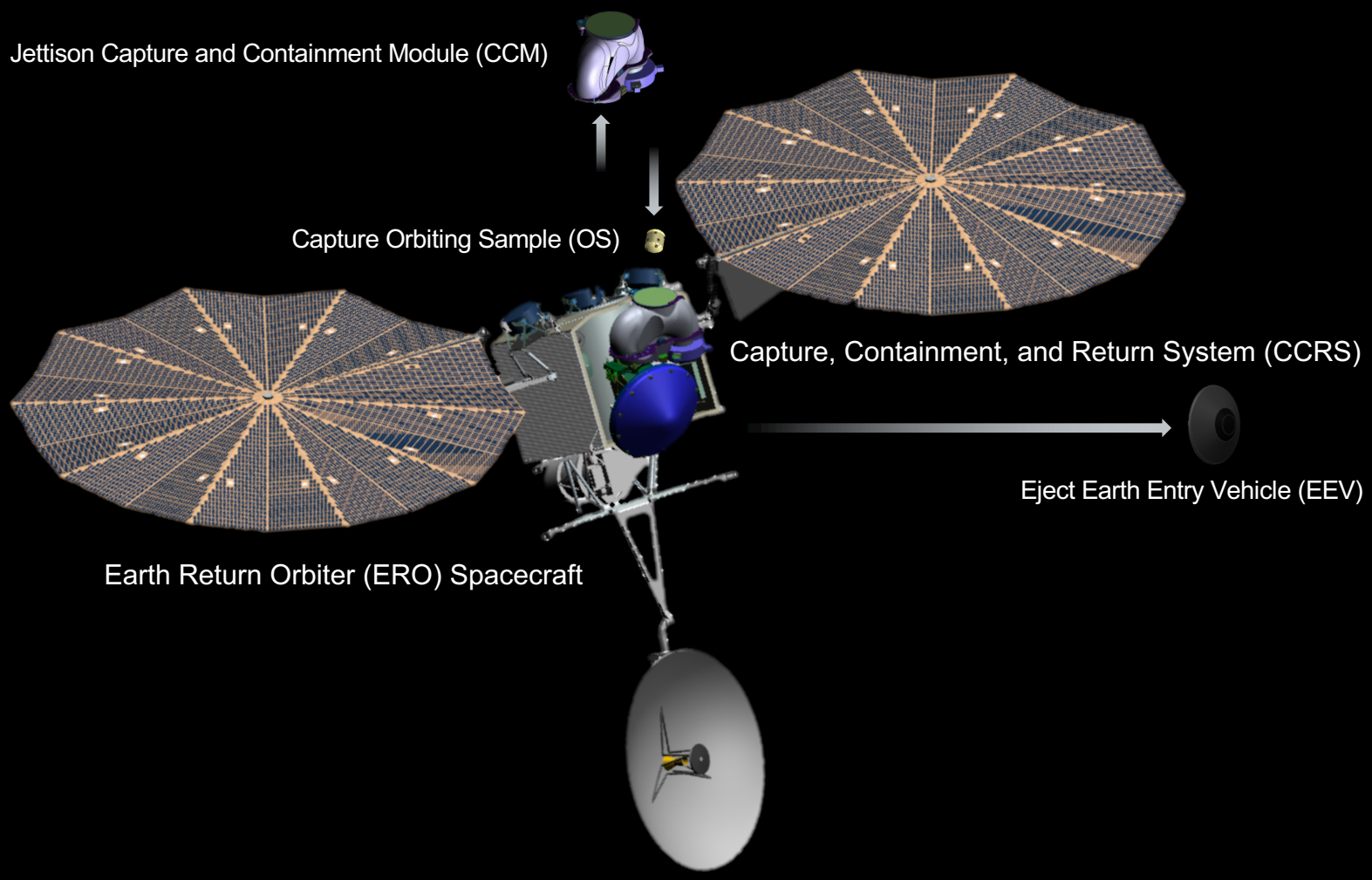

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ERO Mission Concept

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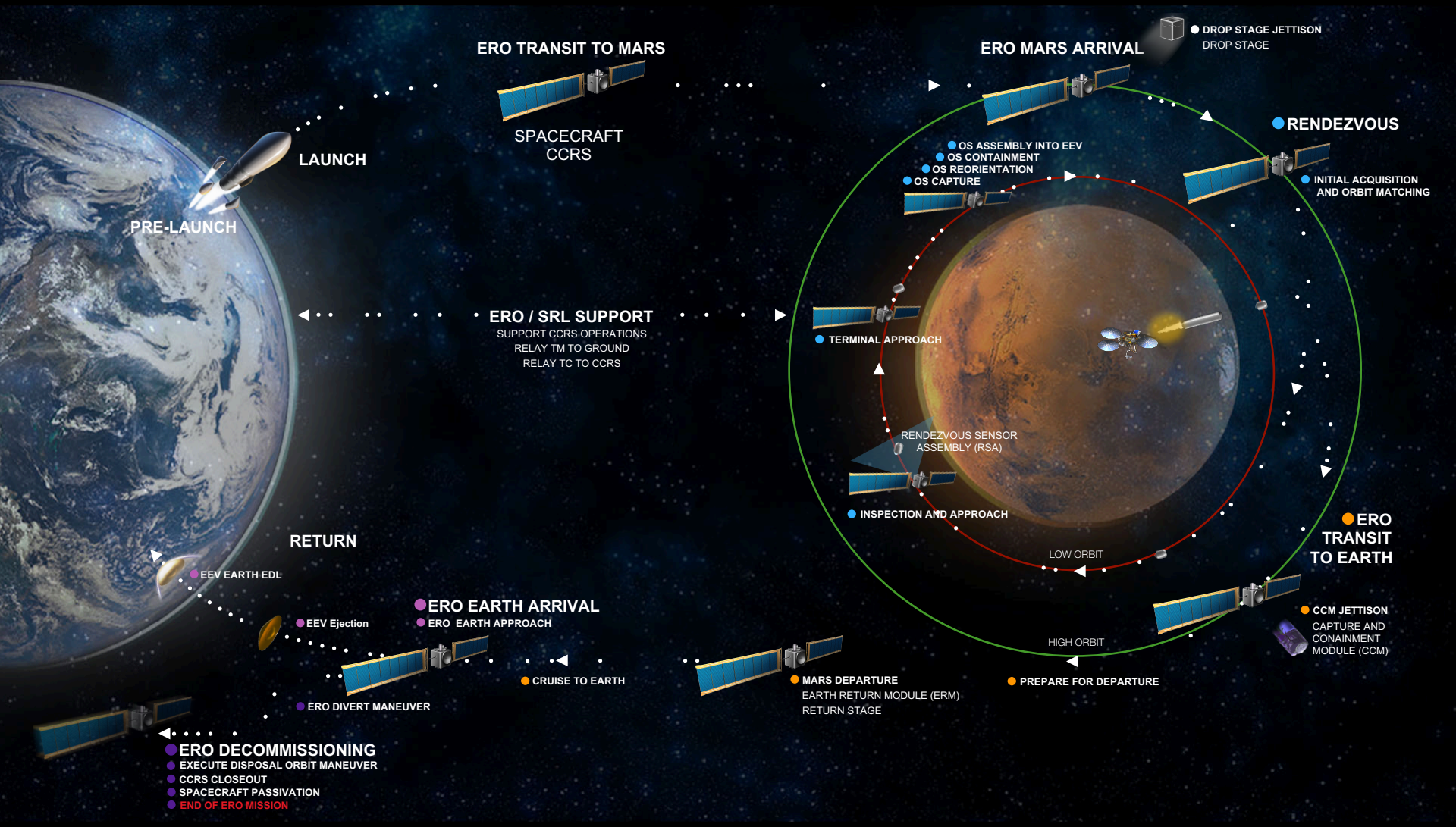

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ERO Mission Concept

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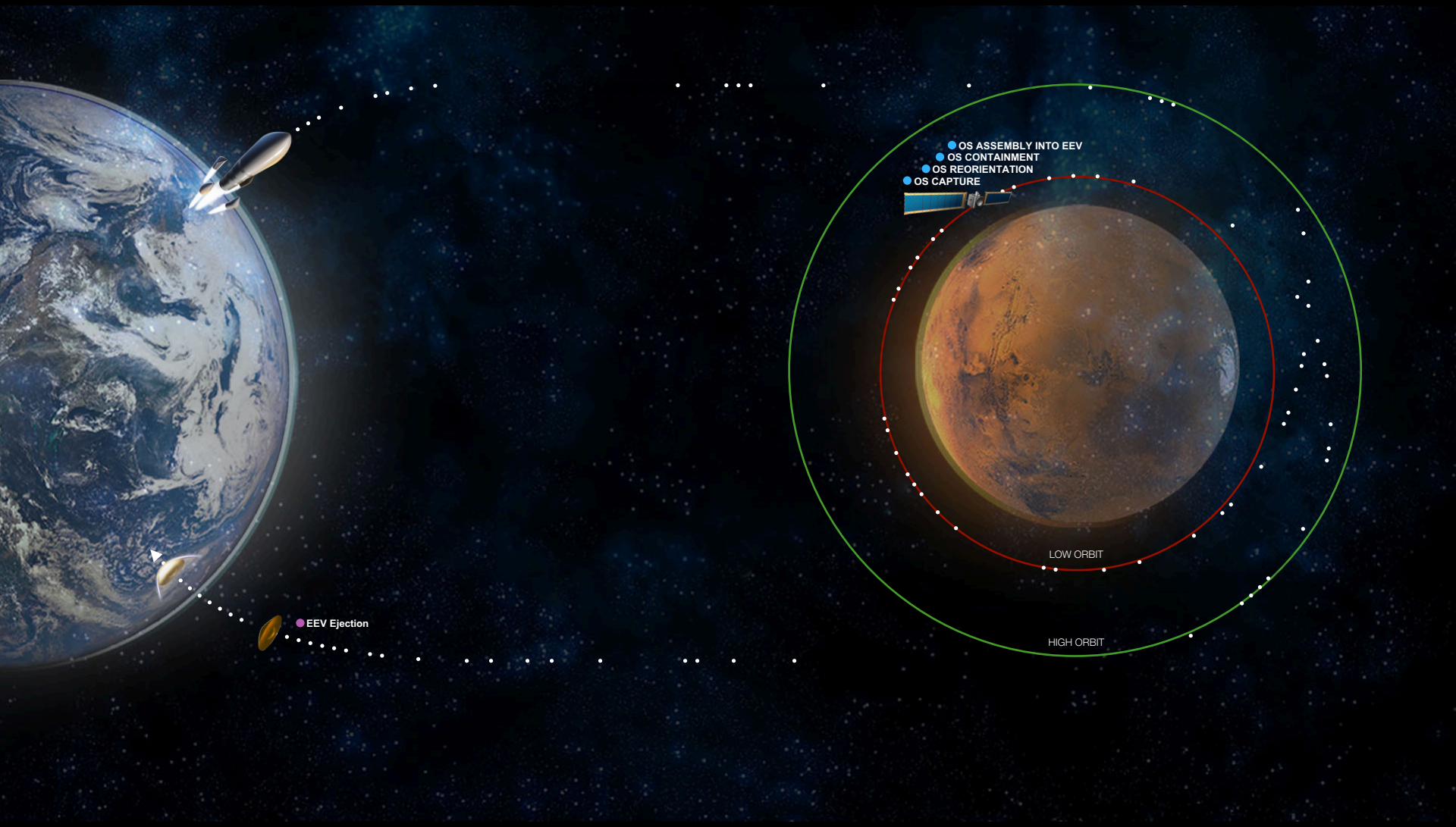

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Capture, Containment, and Return System

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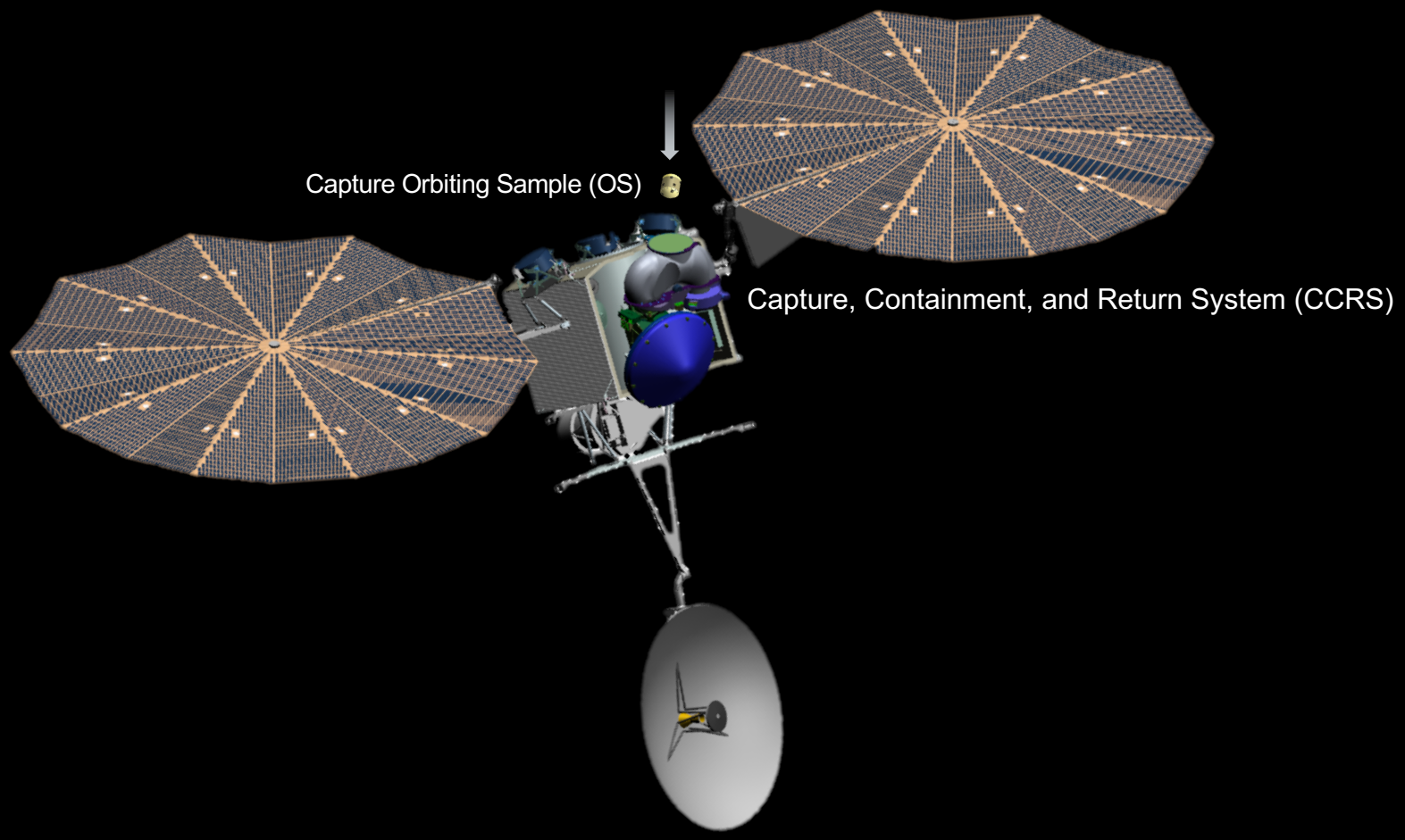

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Capture, Containment, and Return System

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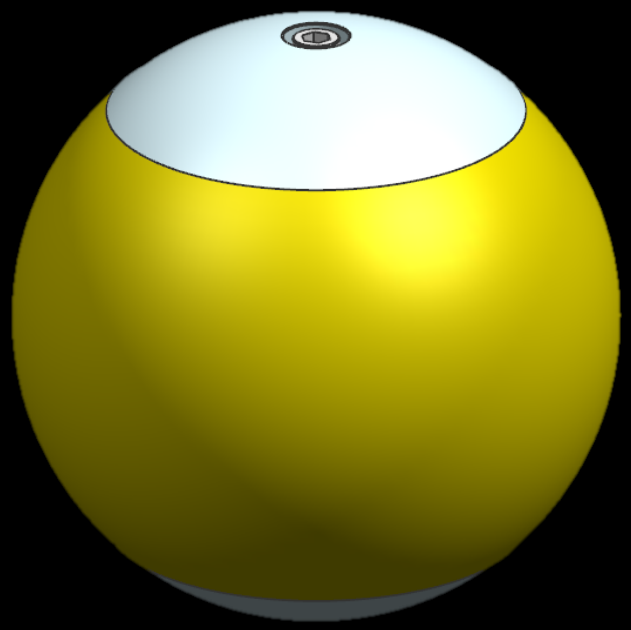
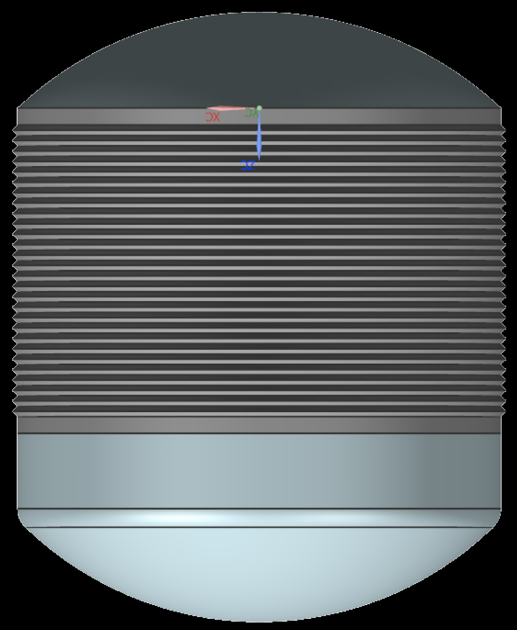
Orbiting Sample (OS)



Spherical OS



Non-spherical OS

Capture, Containment, and Return System

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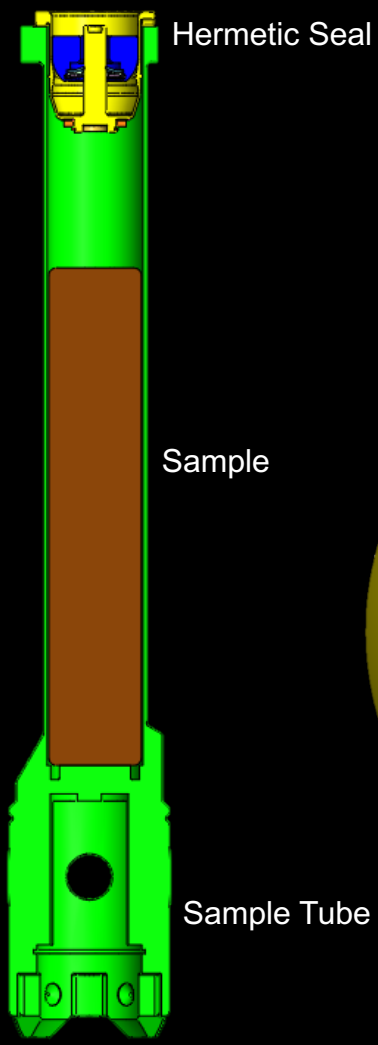

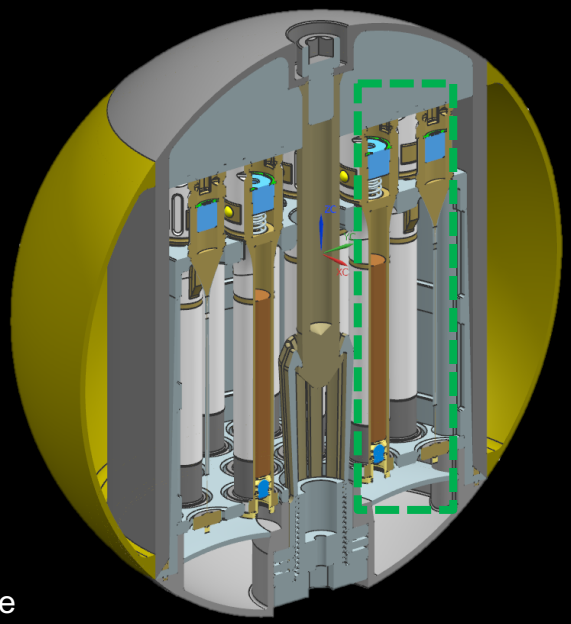

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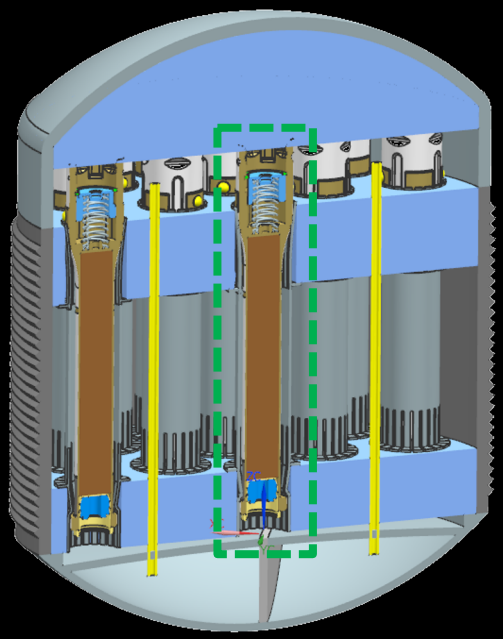

Non-spherical OS

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Capture, Containment, and Return System

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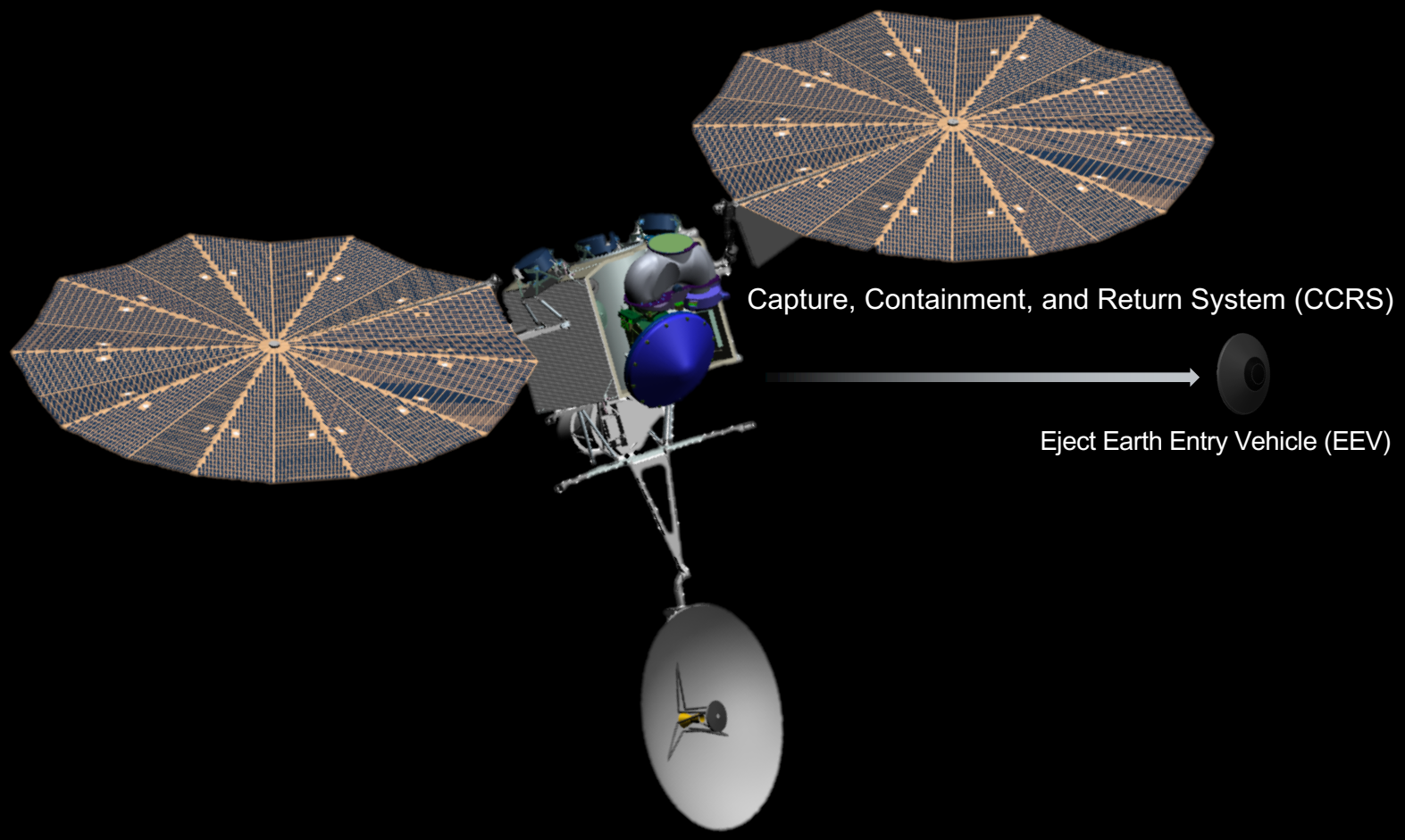

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Capture, Containment, and Return System

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Earth Entry Vehicle (EEV)

Capture, Containment, and Return System

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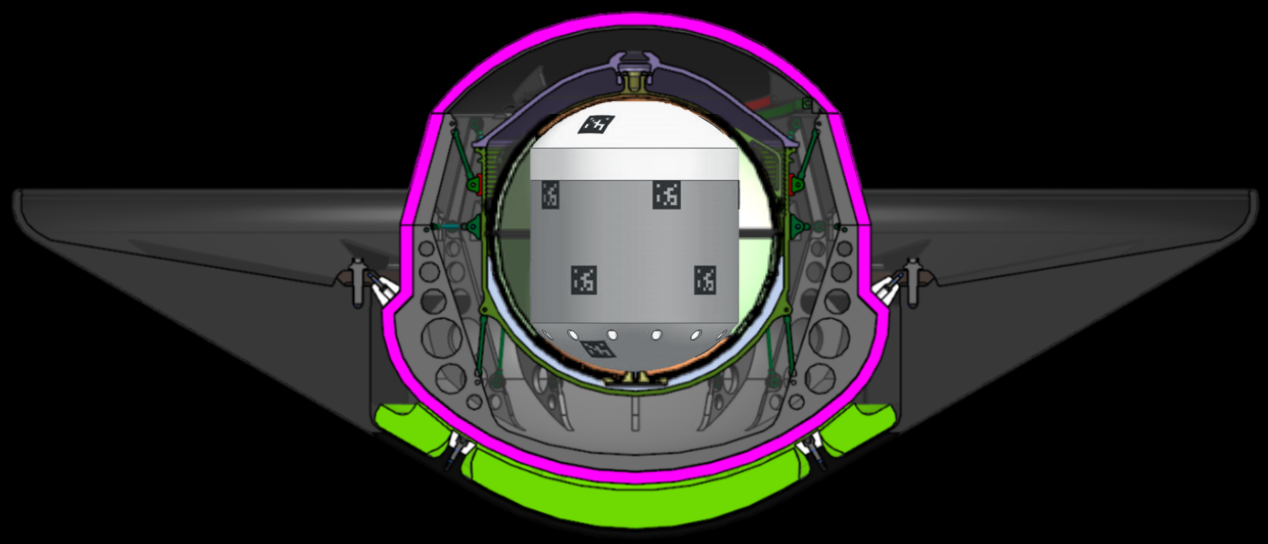

Capture, Containment, and Return System

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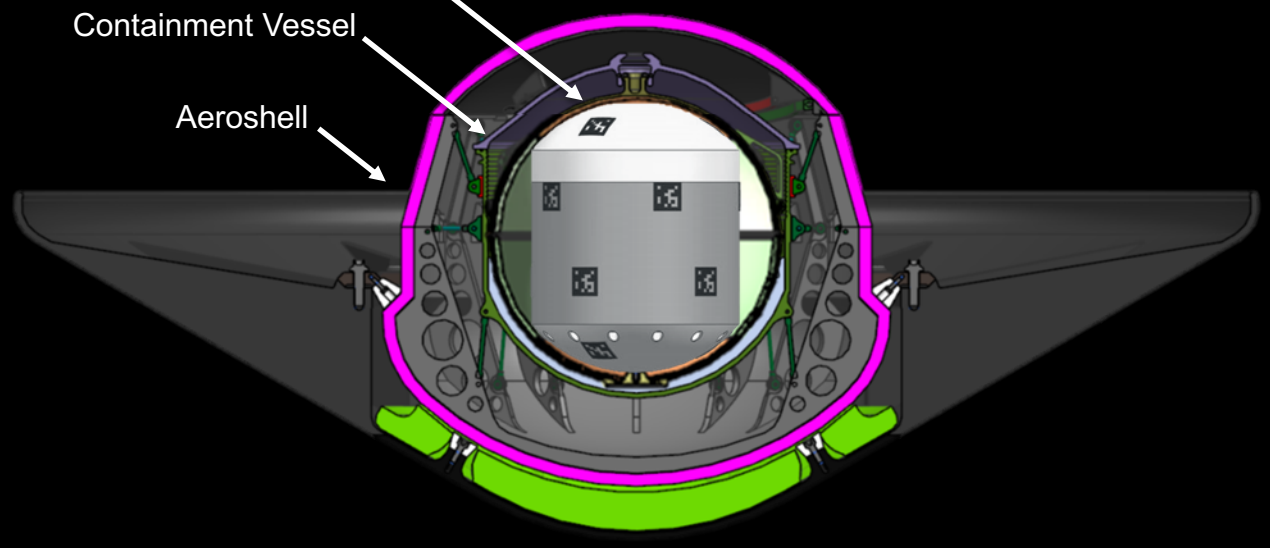

EEV

Capture, Containment, and Return System

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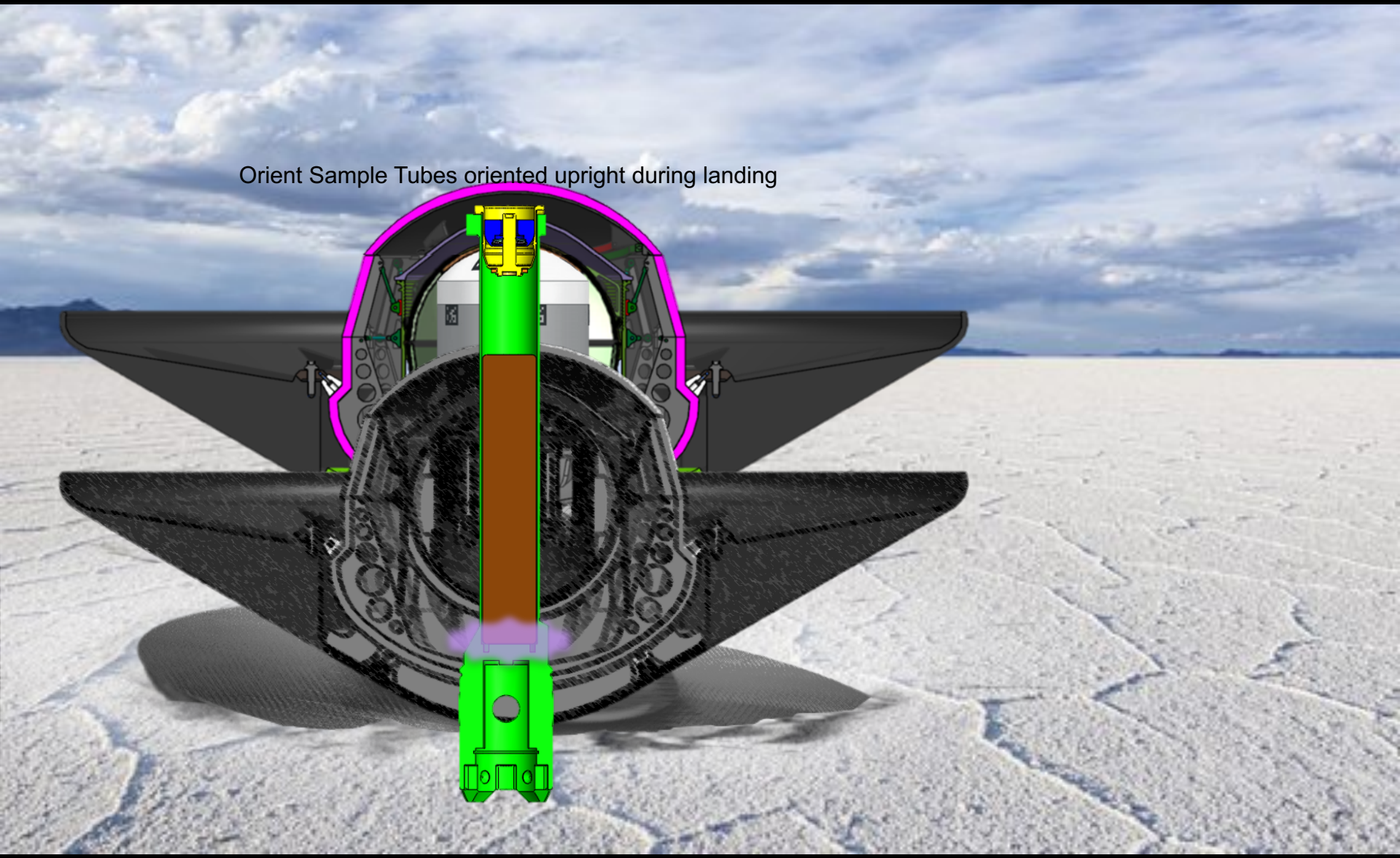

Capture, Containment, and Return System

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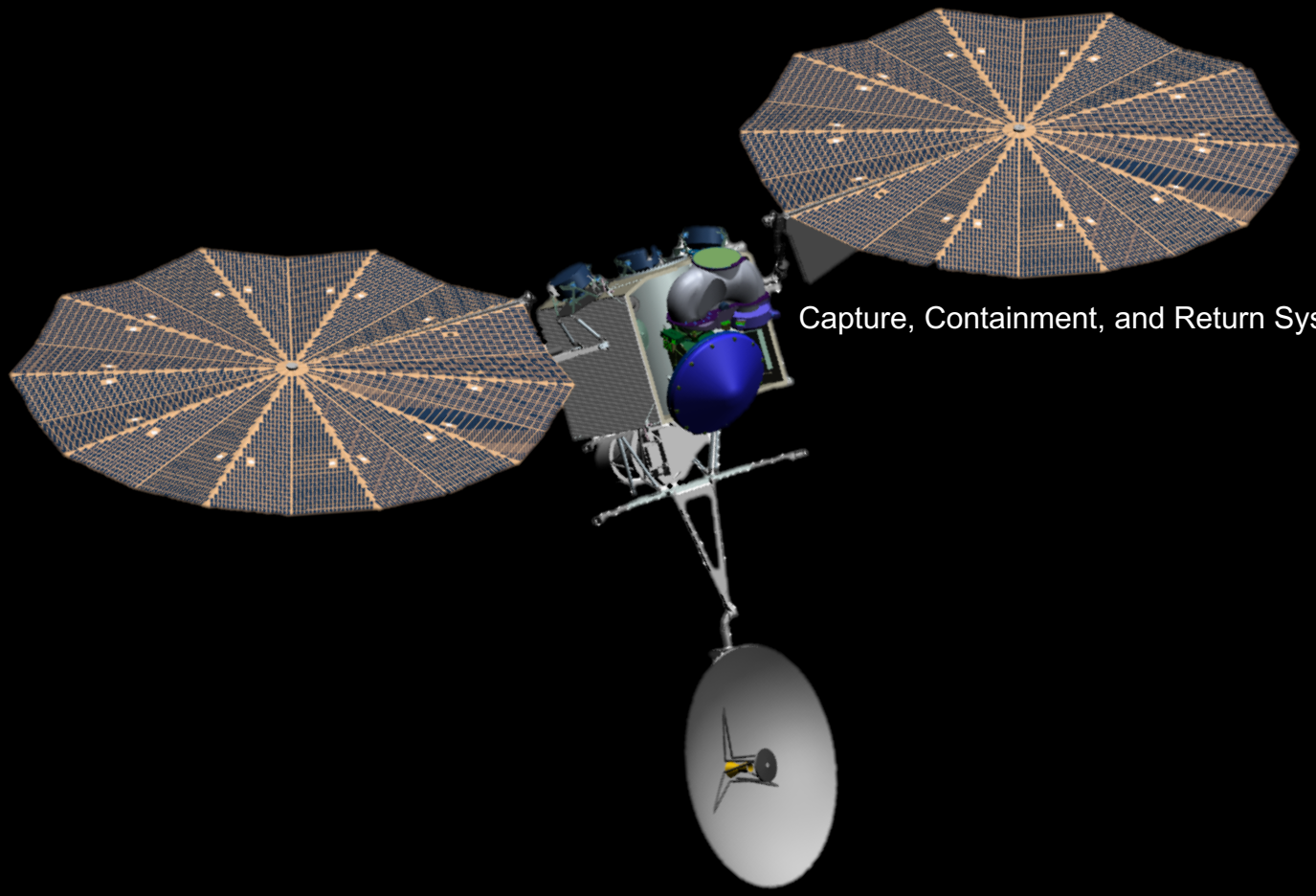

Capture, Containment, and Return System

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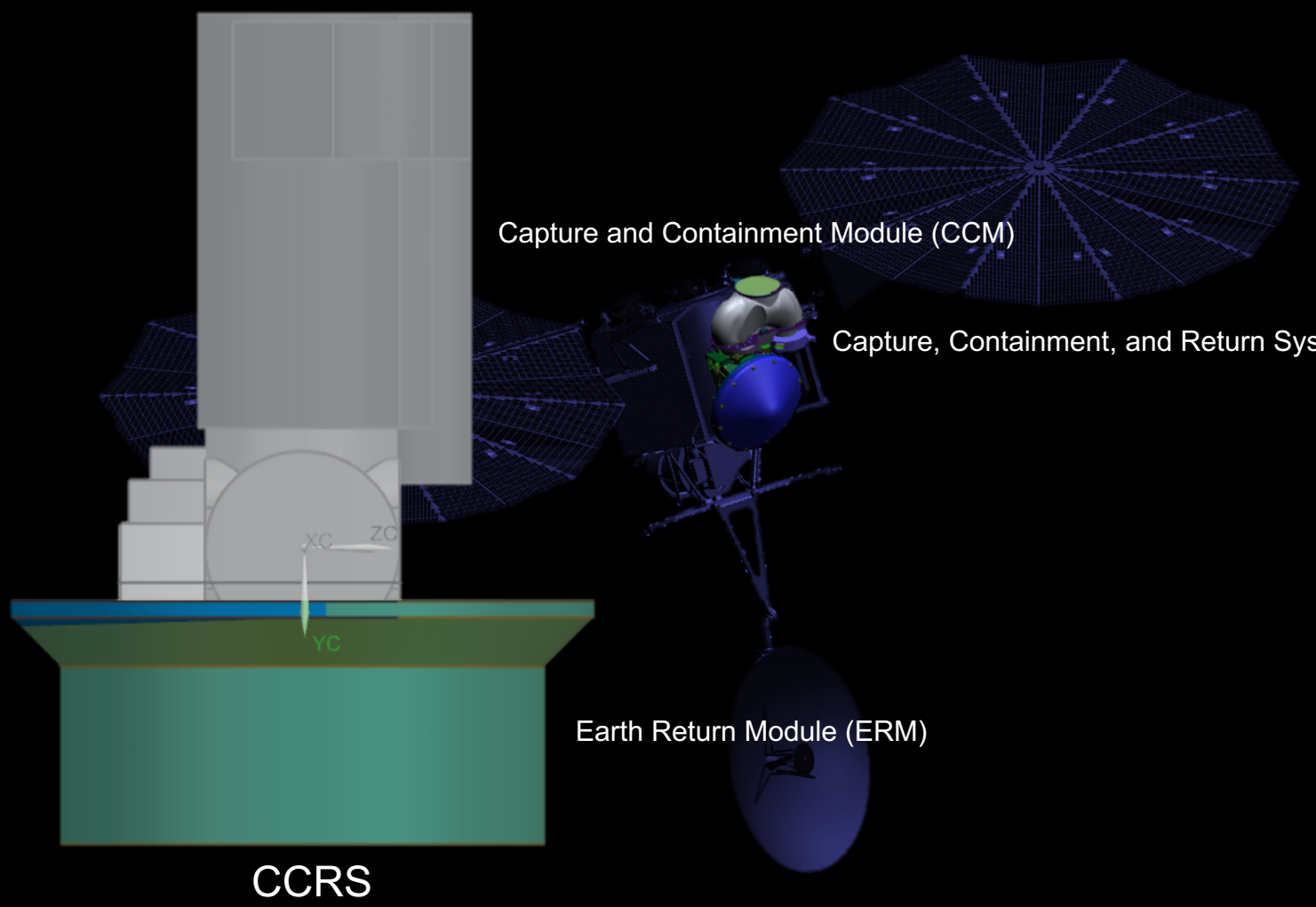

Capture, Containment, and Return System

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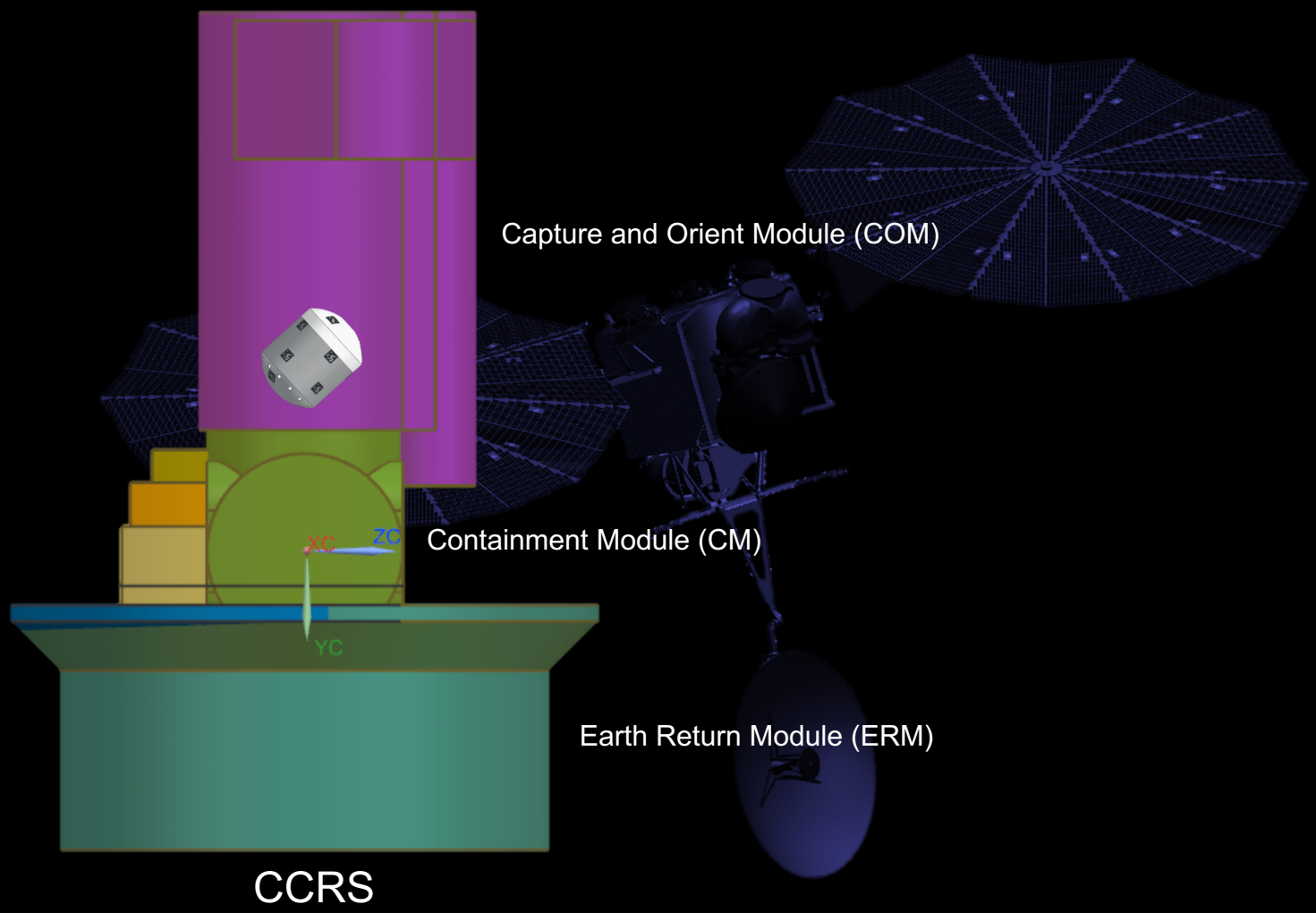

Capture, Containment, and Return System

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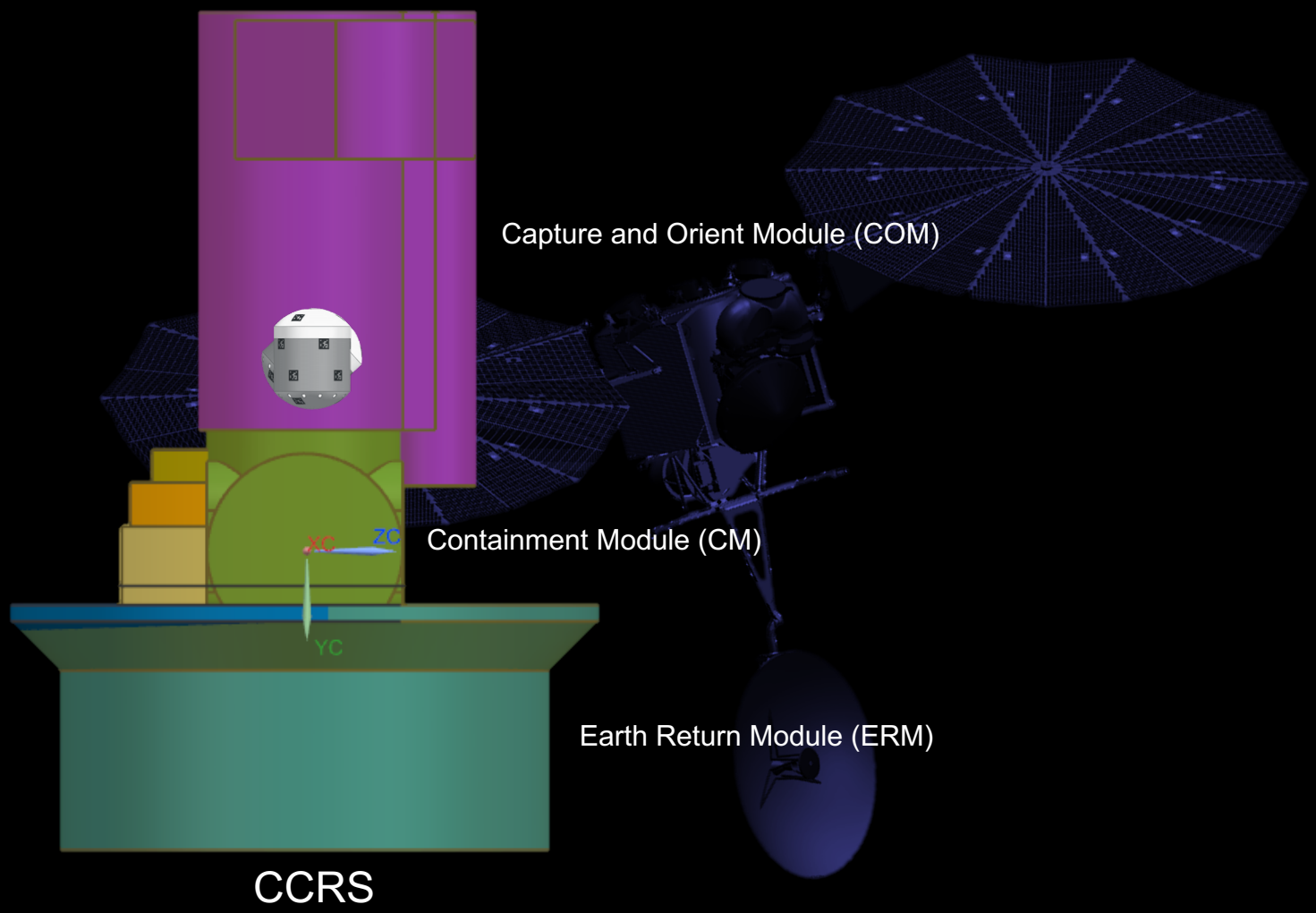

Capture, Containment, and Return System

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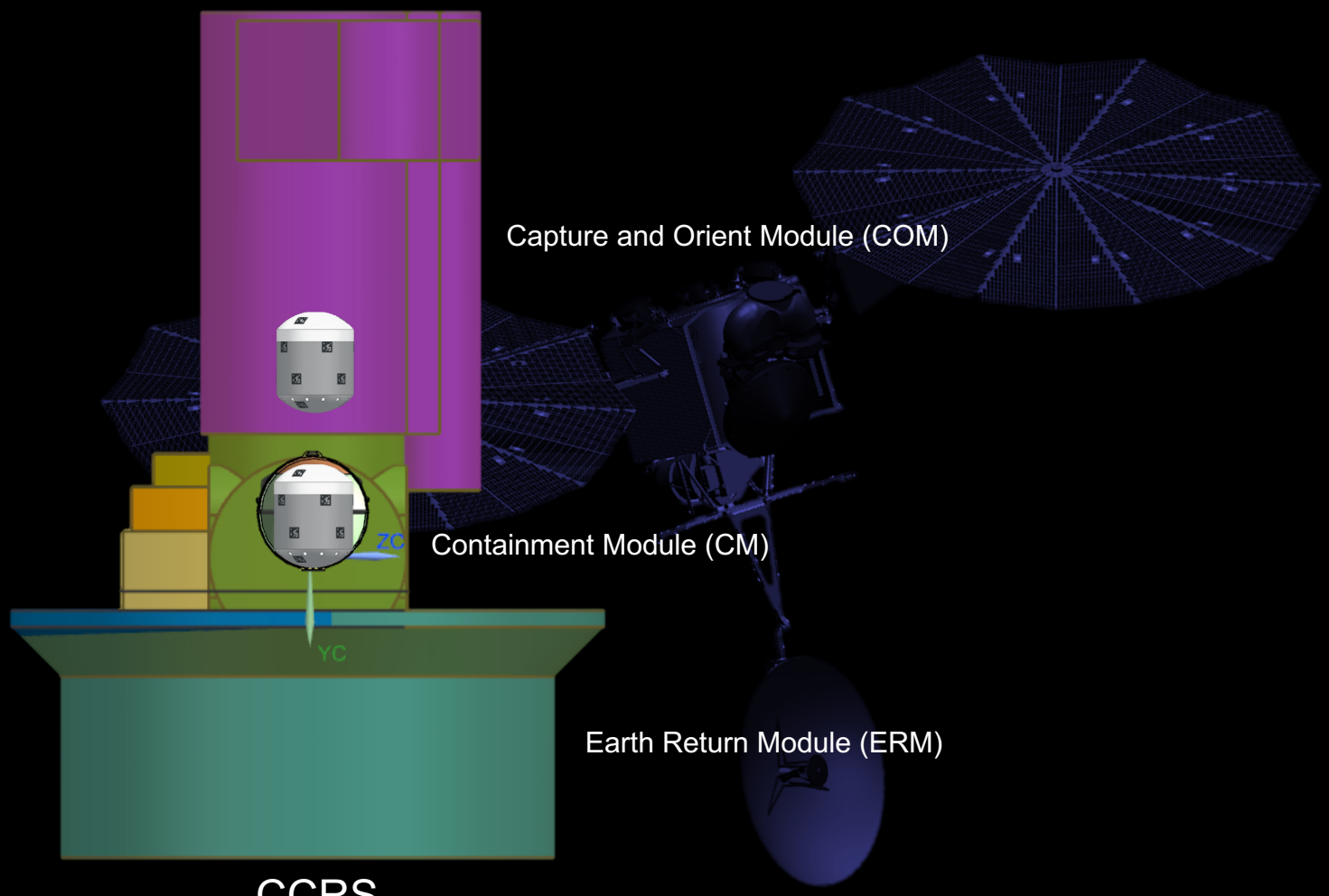

CCRS

Capture, Containment, and Return System

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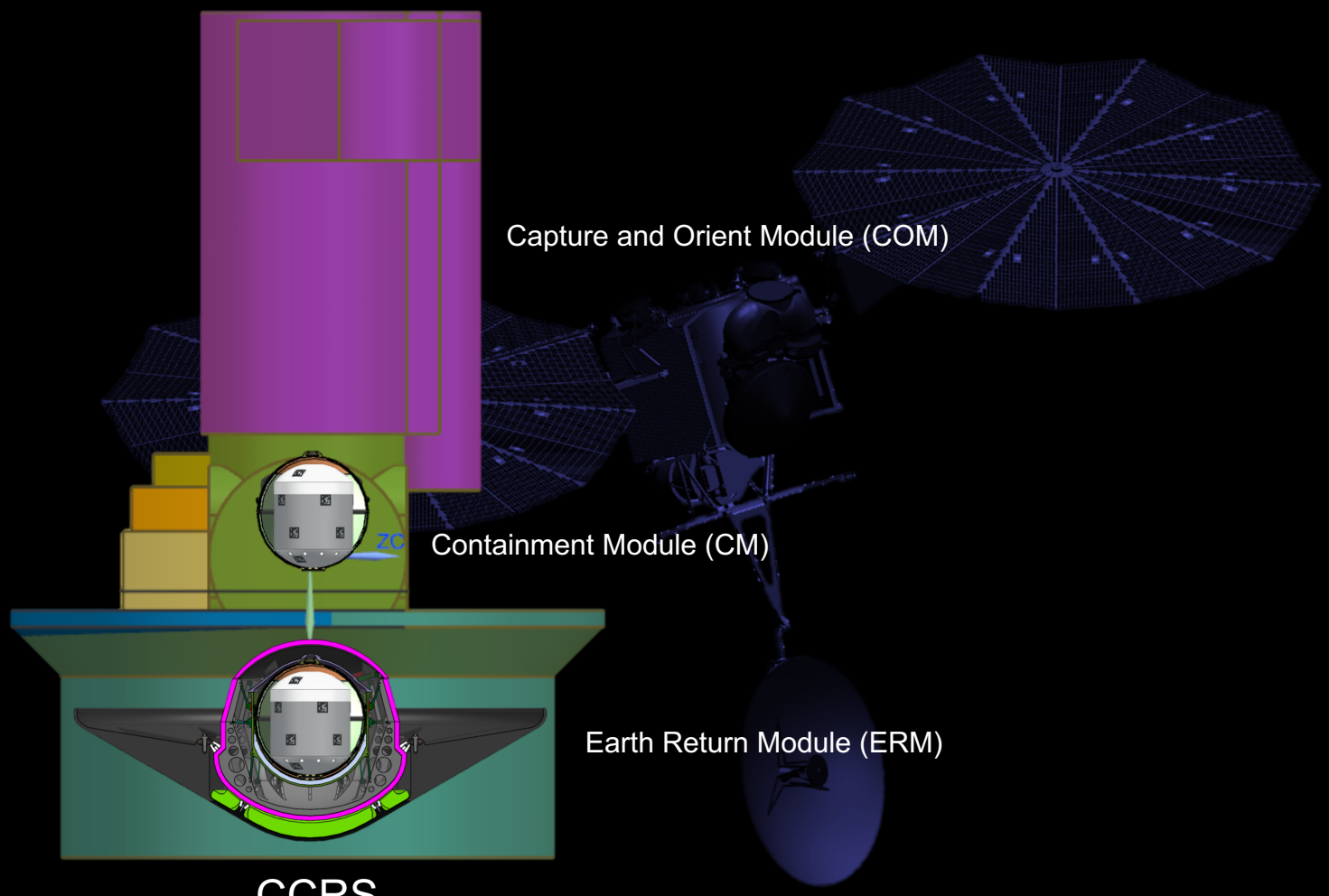

CCRS

Capture, Containment, and Return System

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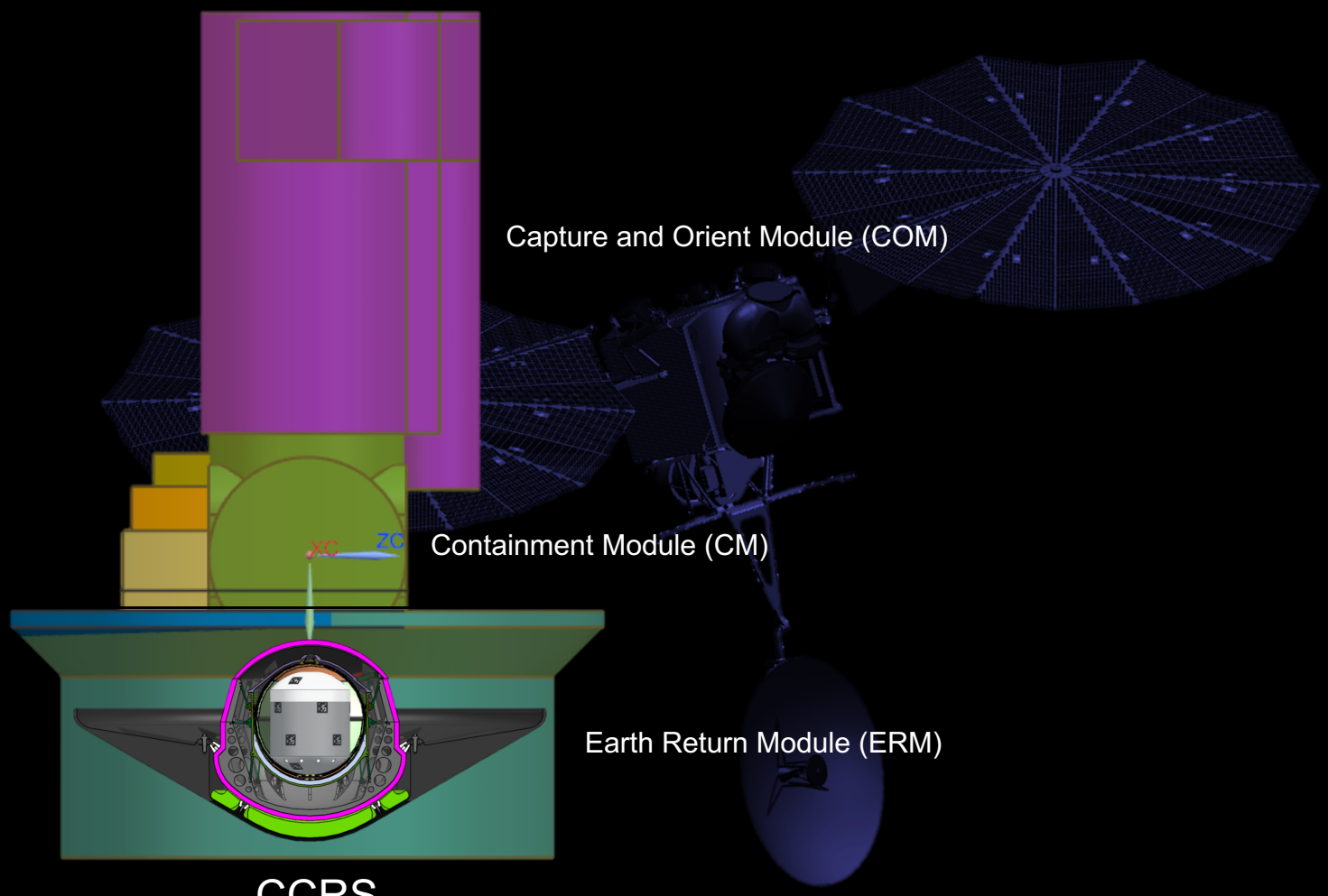

CCRS

Capture, Containment, and Return System

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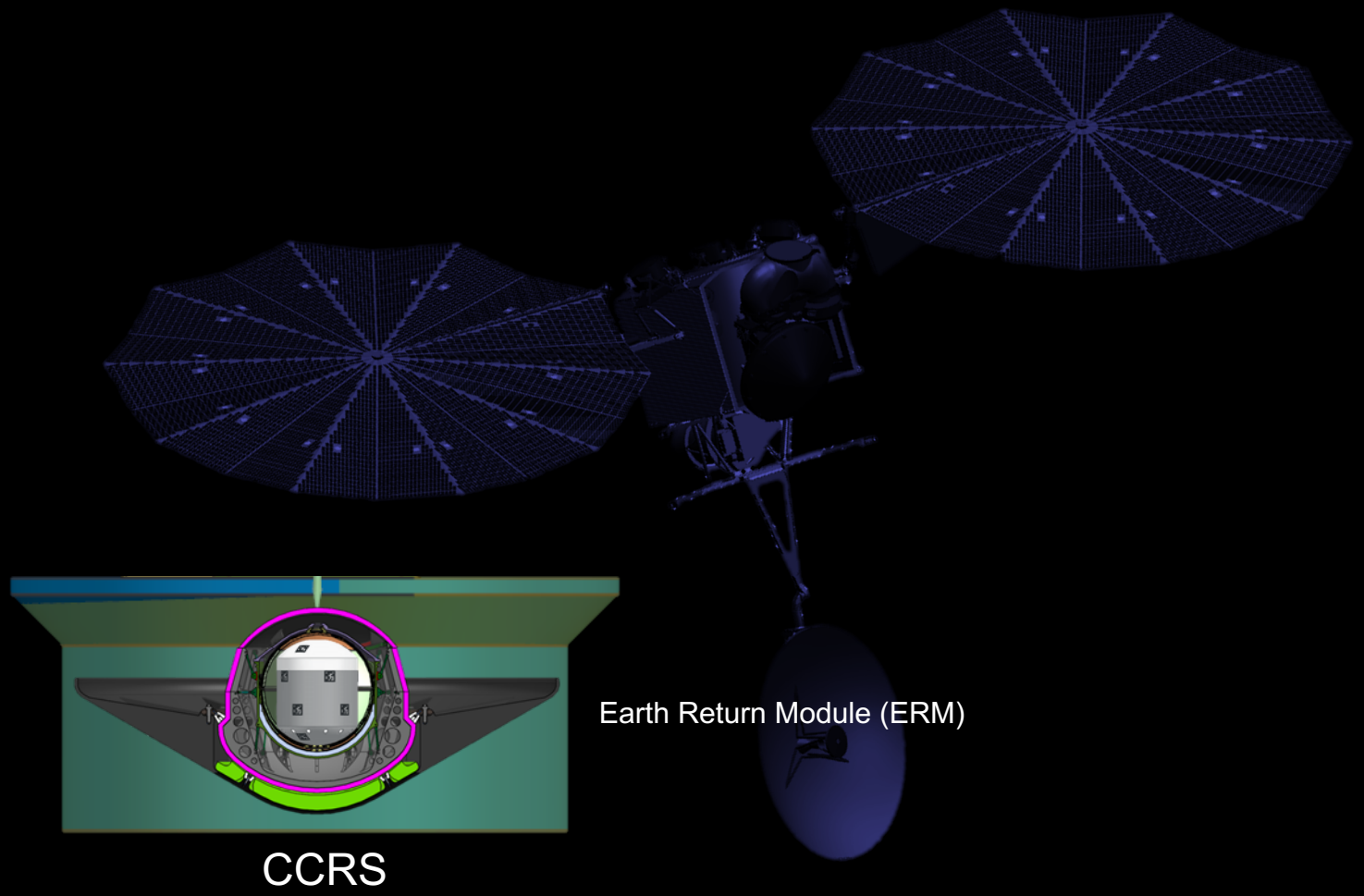

Capture, Containment, and Return System

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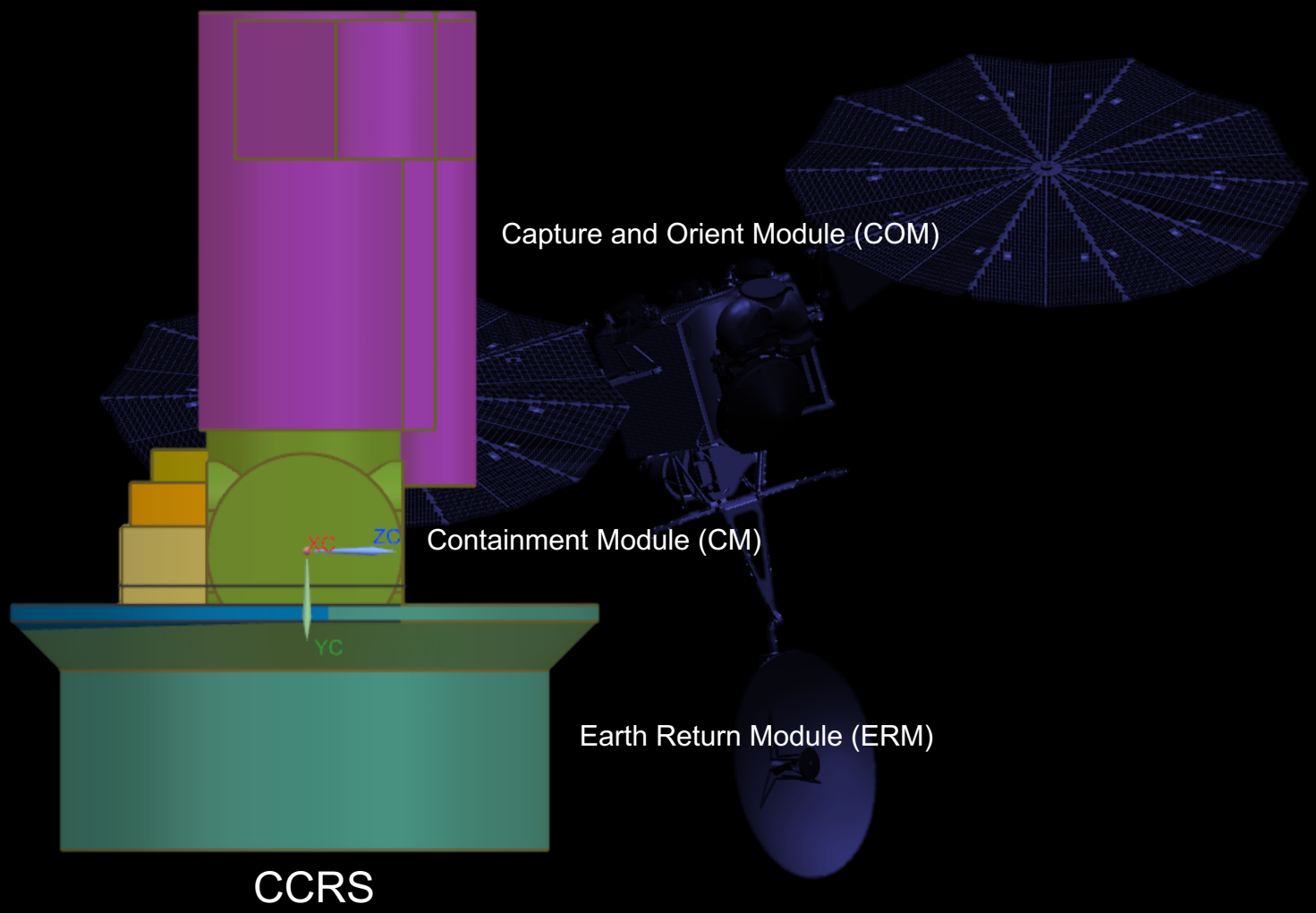

Capture and Orient Module

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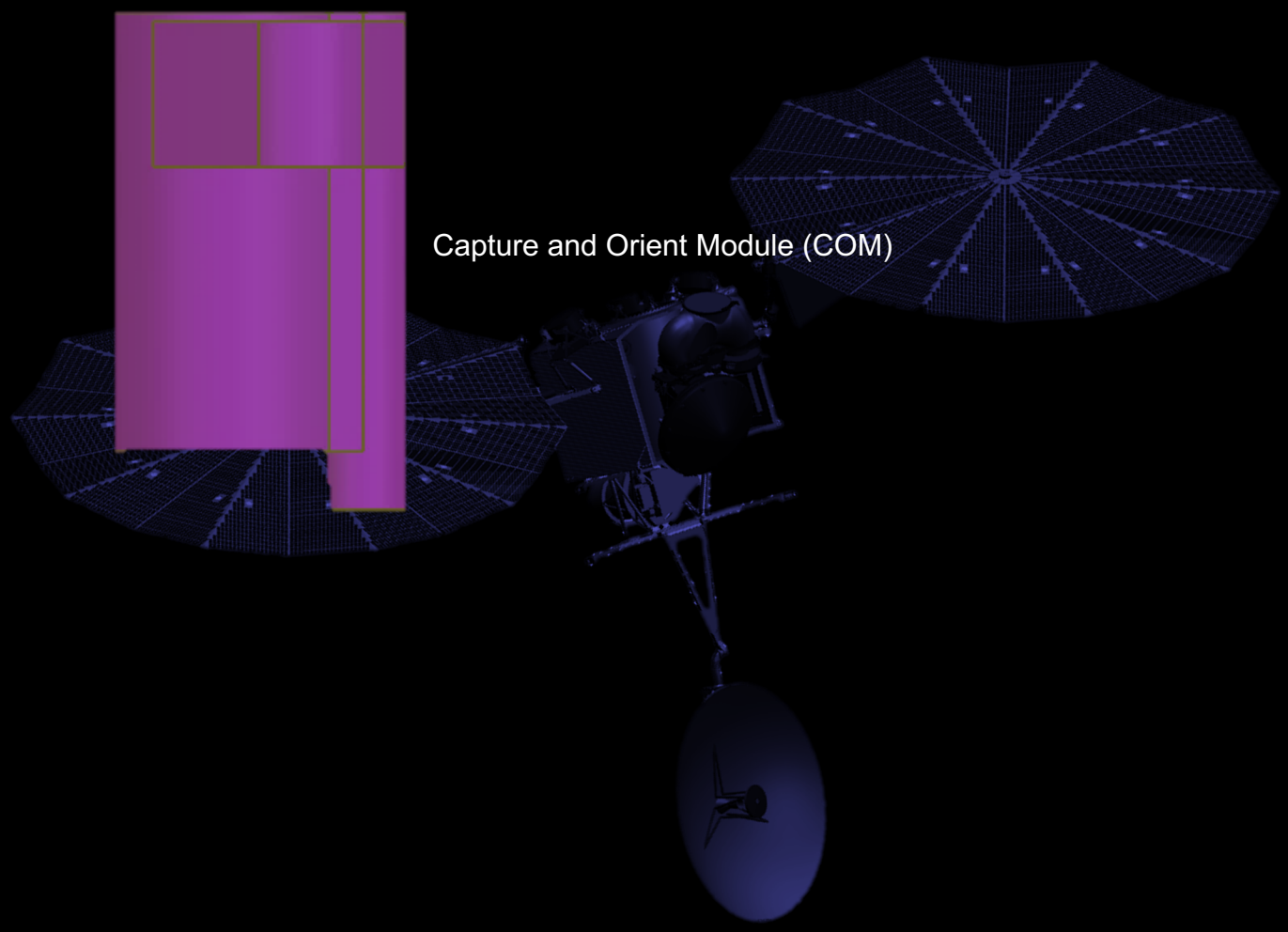

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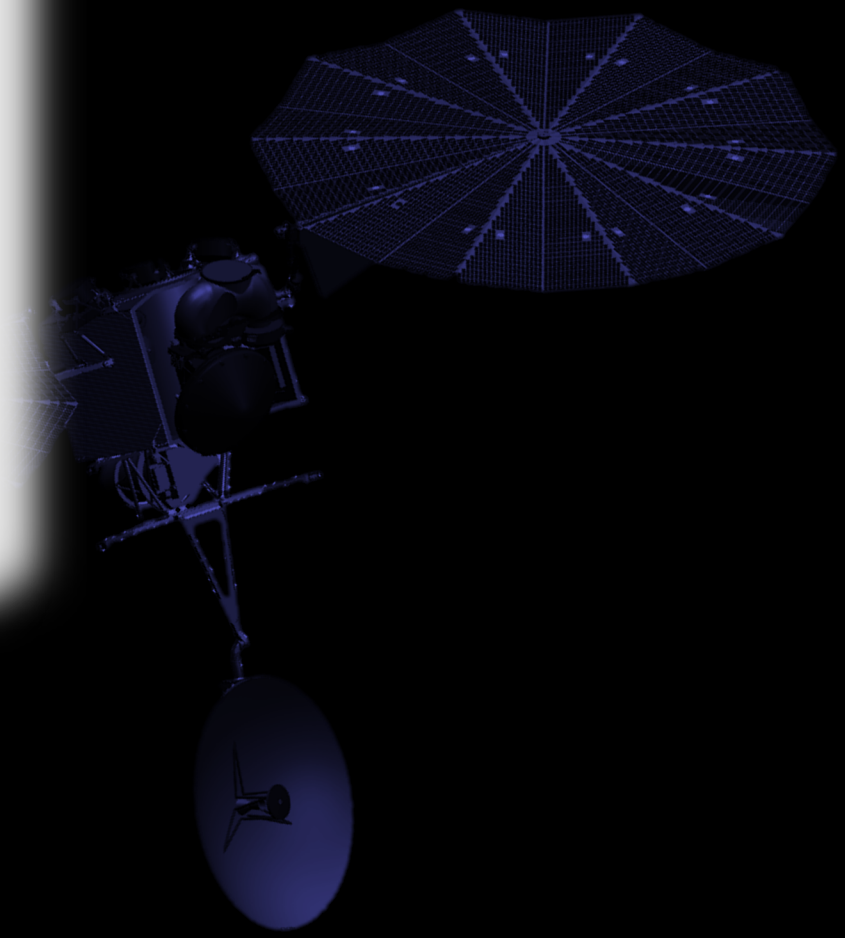

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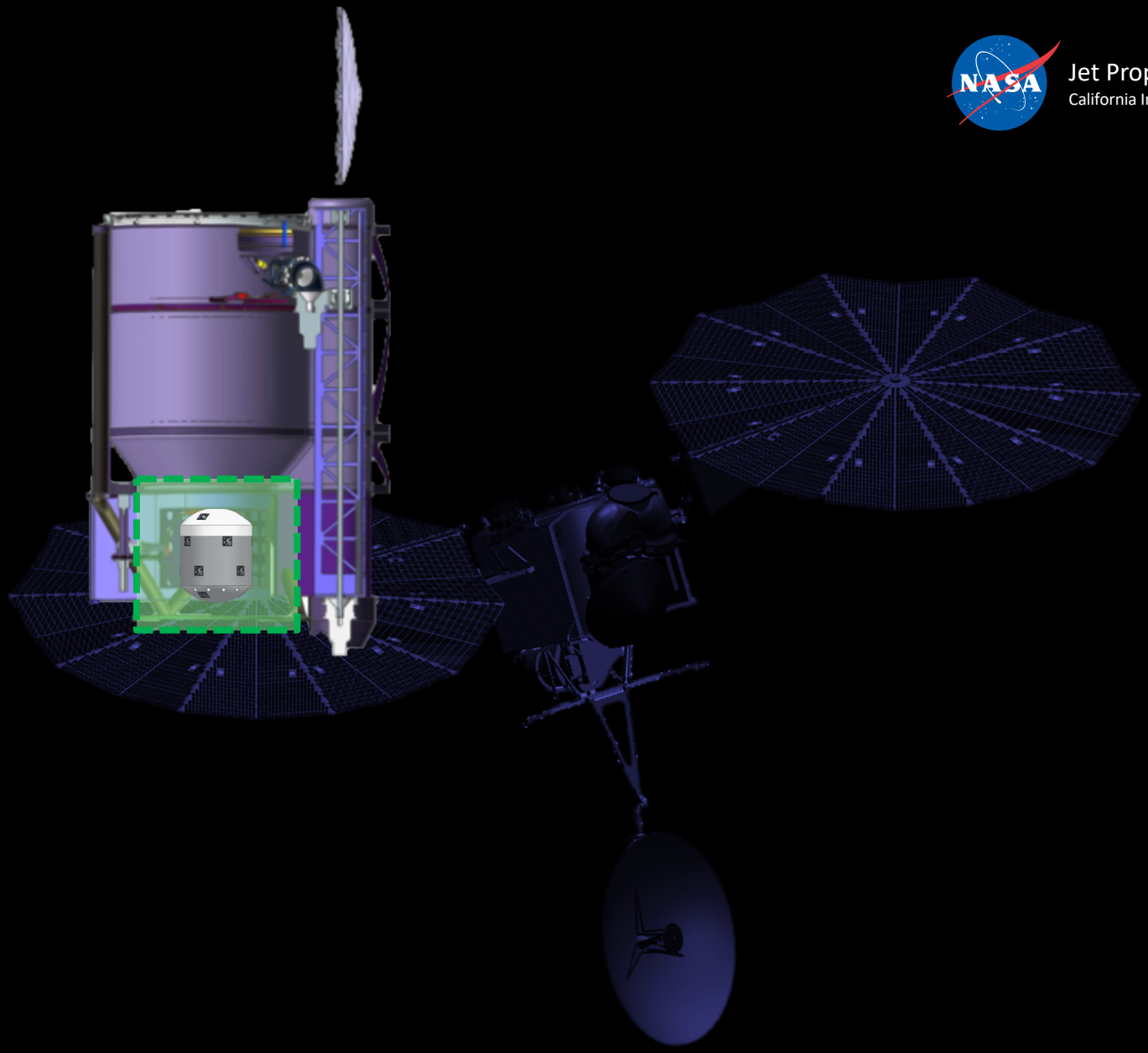

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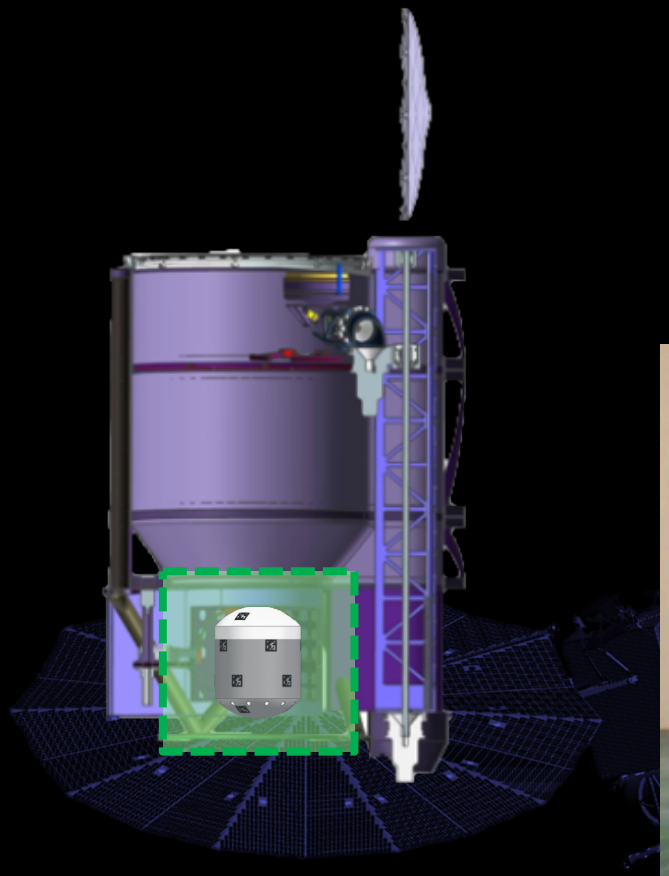
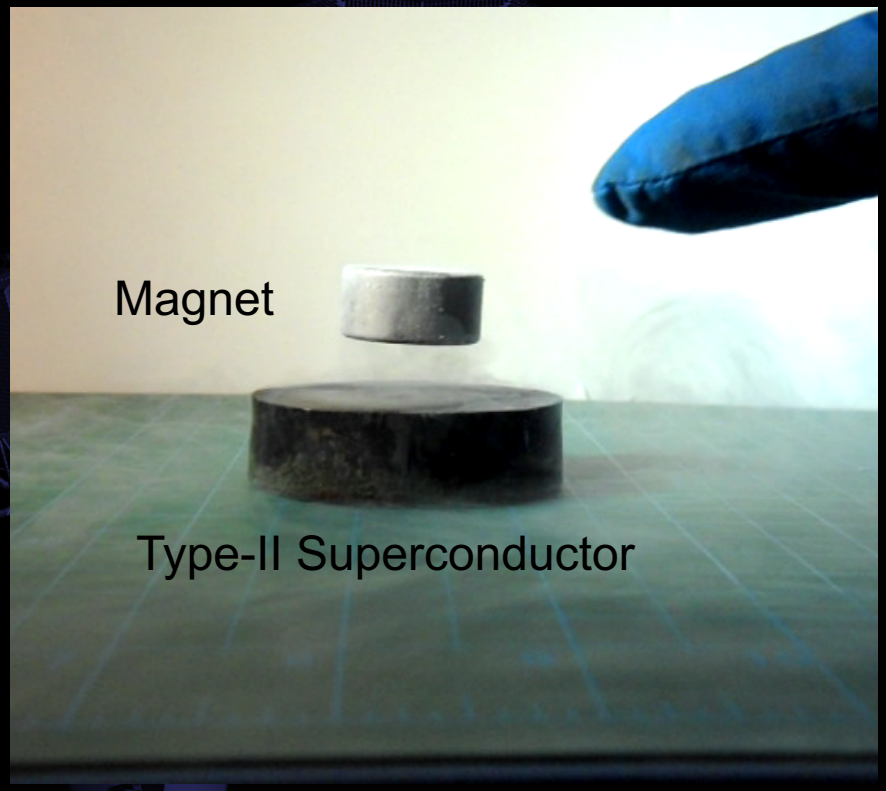


Magnetic Flux Pinning



Flux Pinning Magnet Arrangements on OS

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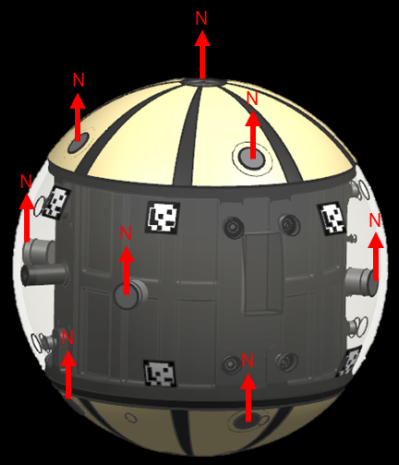
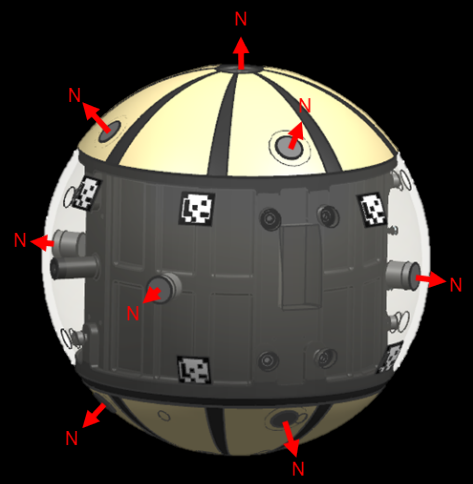
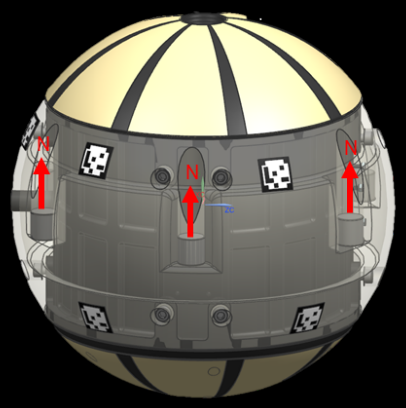


Icosahedron extended dipole magnet arrangement



Icosahedron isotropic magnet arrangement



Equatorial ring magnet arrangement

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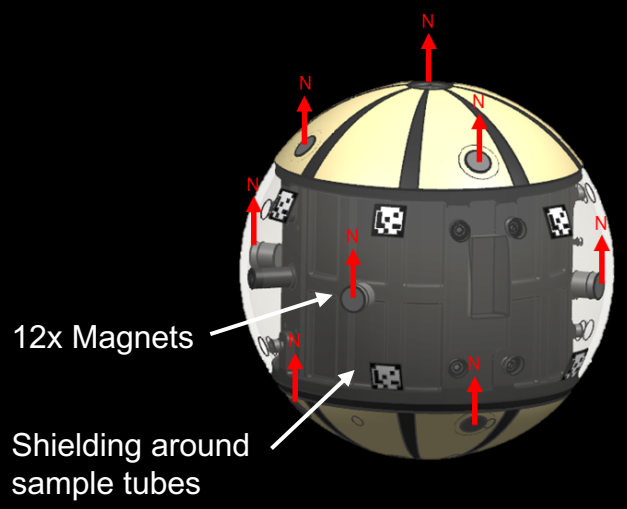
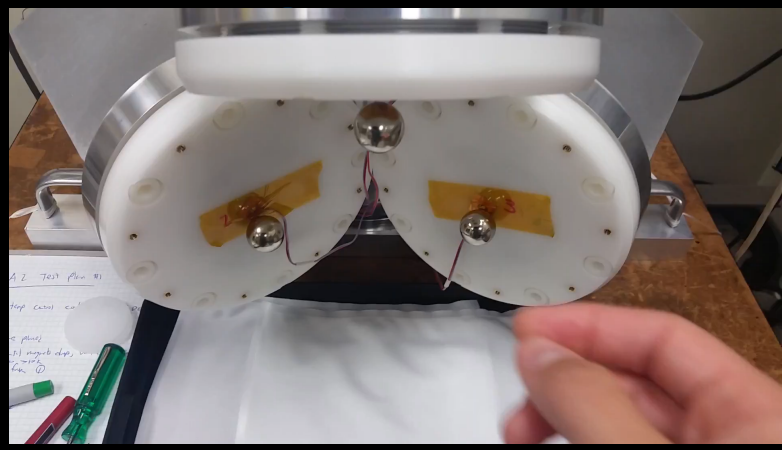
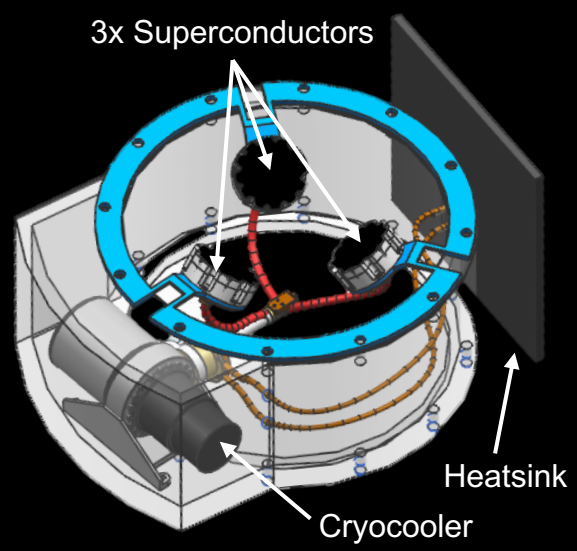
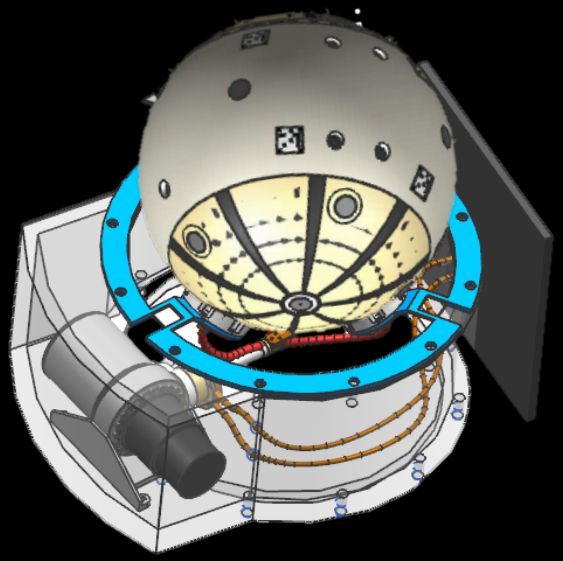
Icosahedron extended dipole magnet arrangement





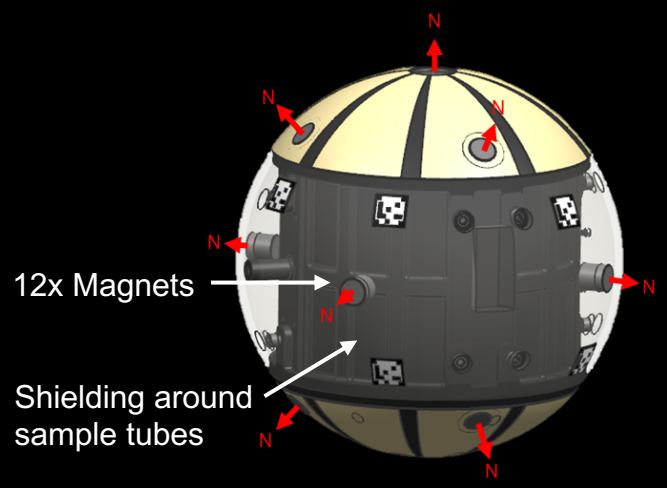


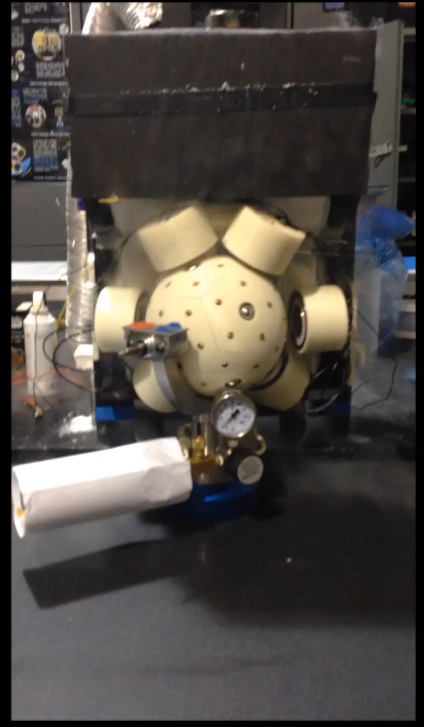
Flux pinning assembly

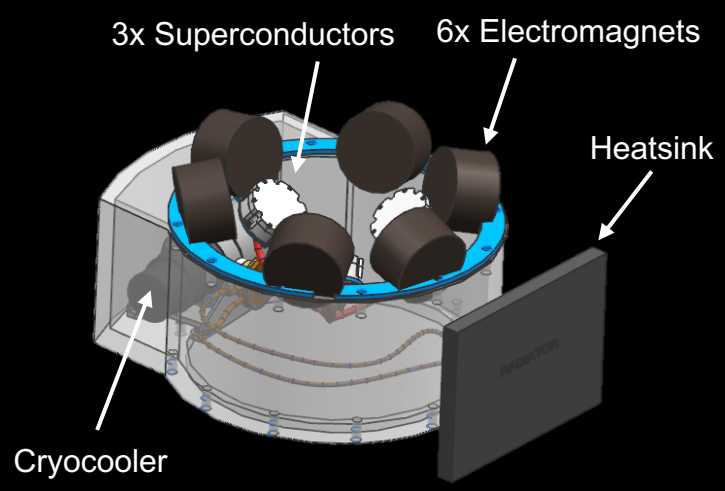


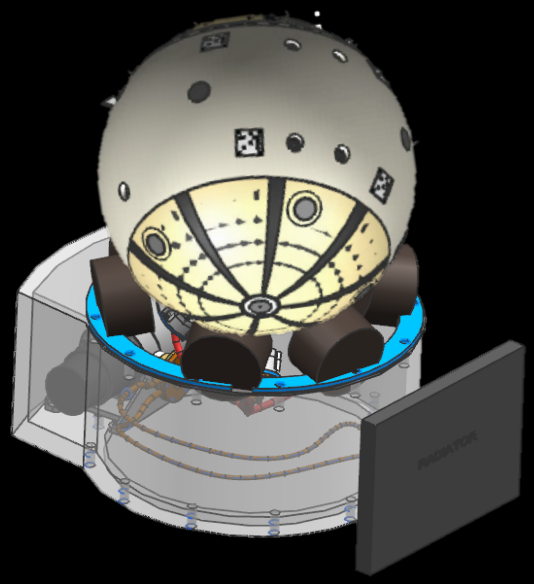
Predecisional: for planning and discussion purposes only.

Icosahedron isotropic magnet arrangement









Flux pinning assembly

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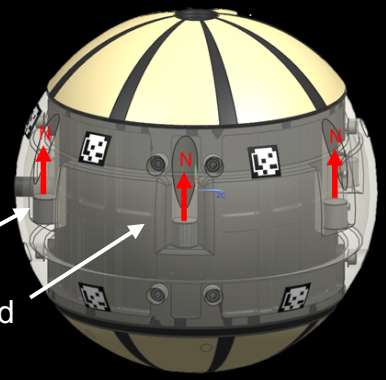
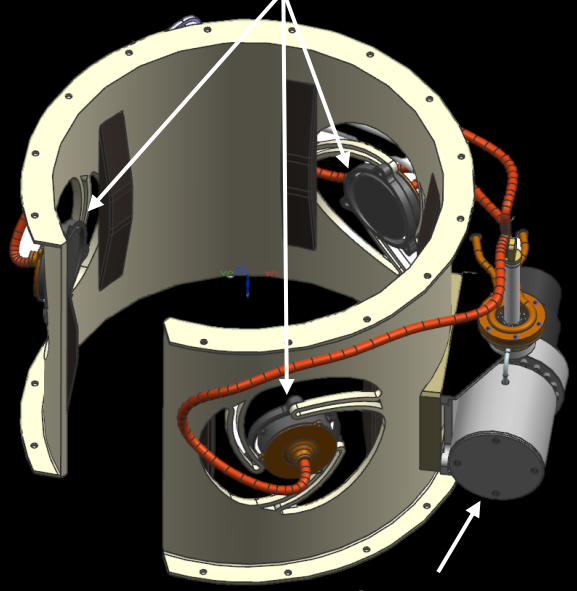
Equatorial ring magnet arrangement



6x Magnets

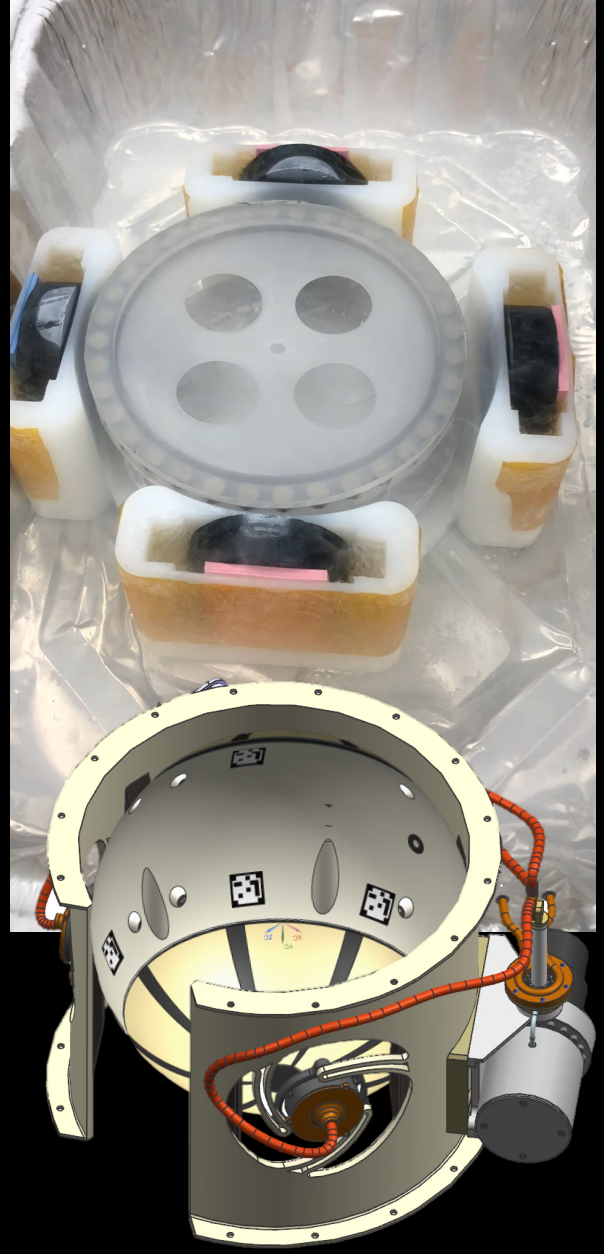
Shielding around sample tubes

3x Superconductors



Cryocooler

Flux pinning assembly



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Alternative Non-spherical OS Configurations

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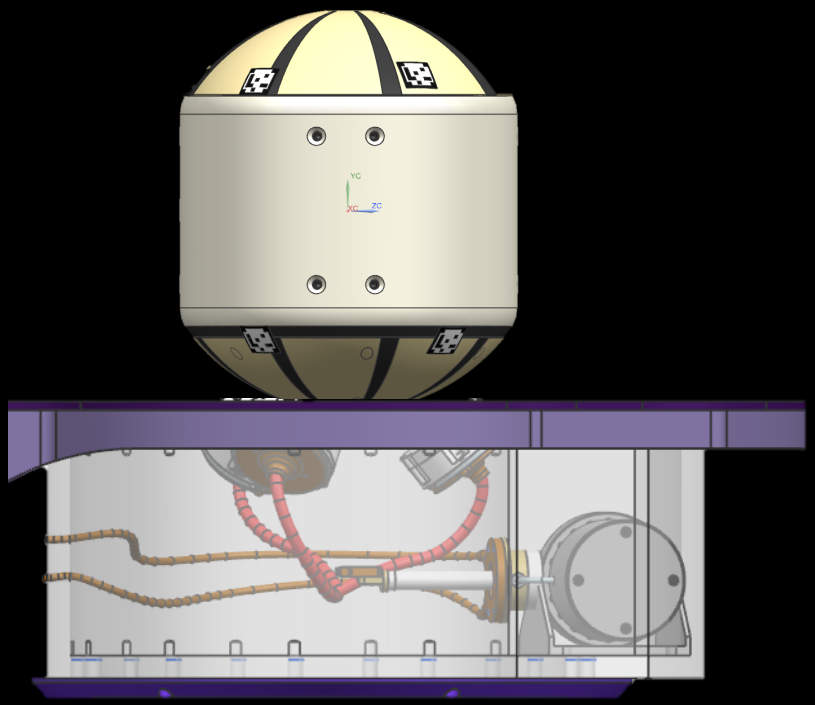
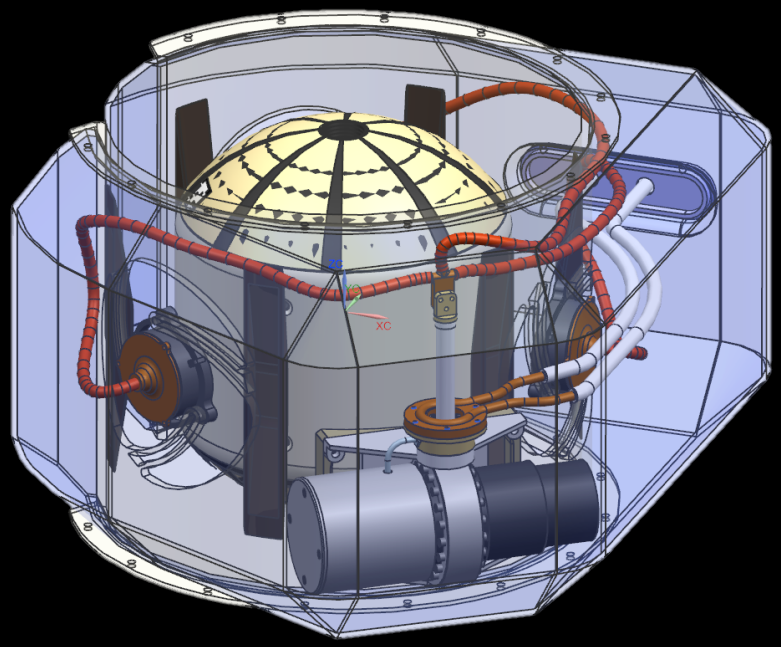


Icosahedron extended dipole magnet arrangement



Equatorial ring magnet arrangement

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Flux Pinning Modeling

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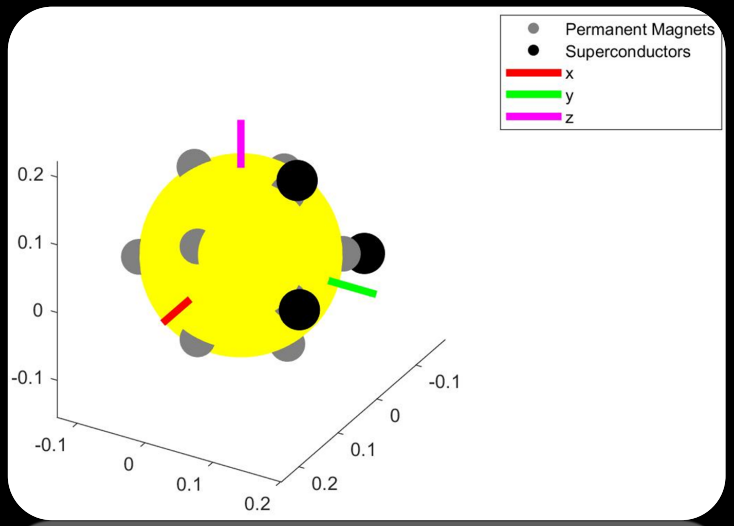

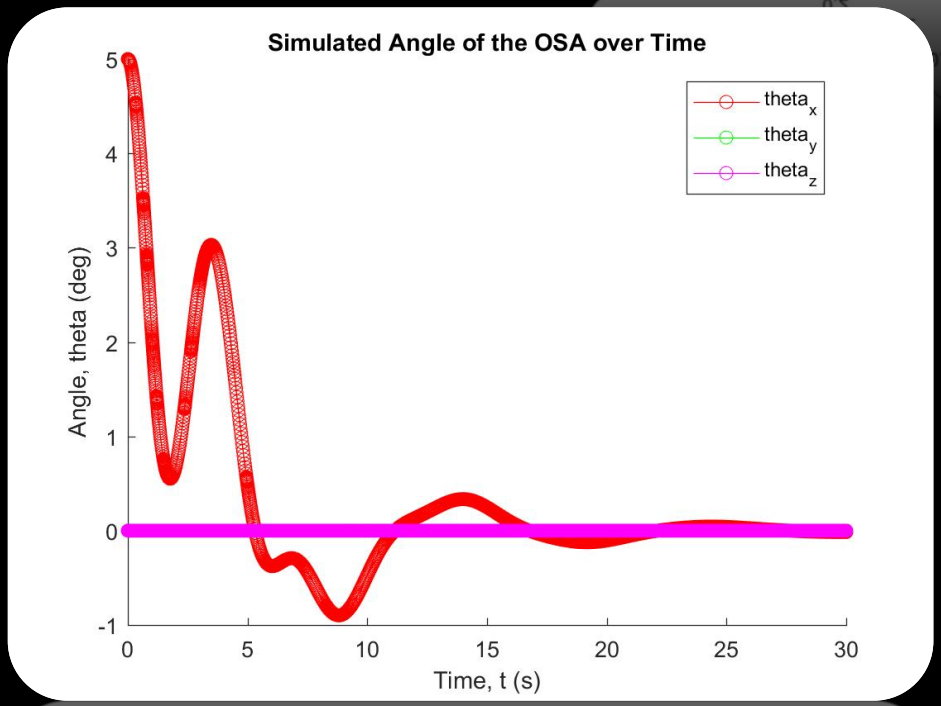

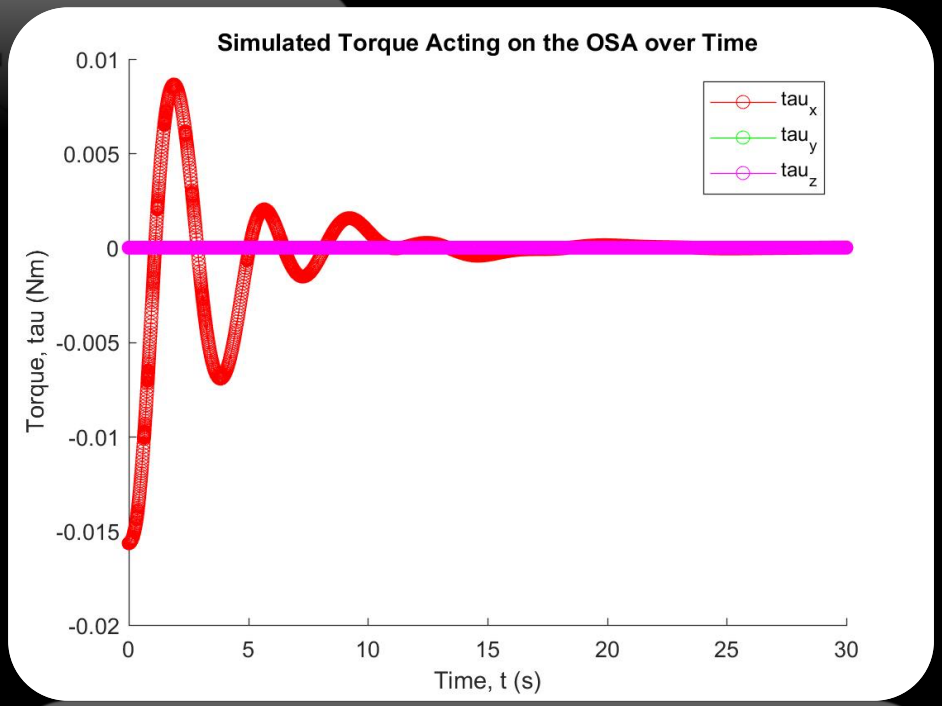

Magnetic Modeling

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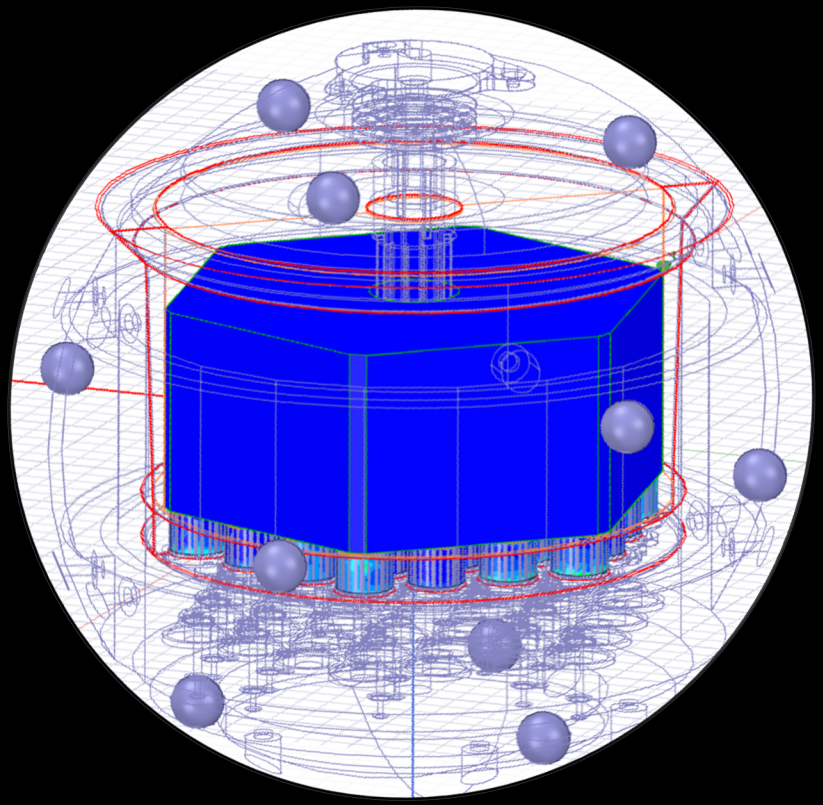
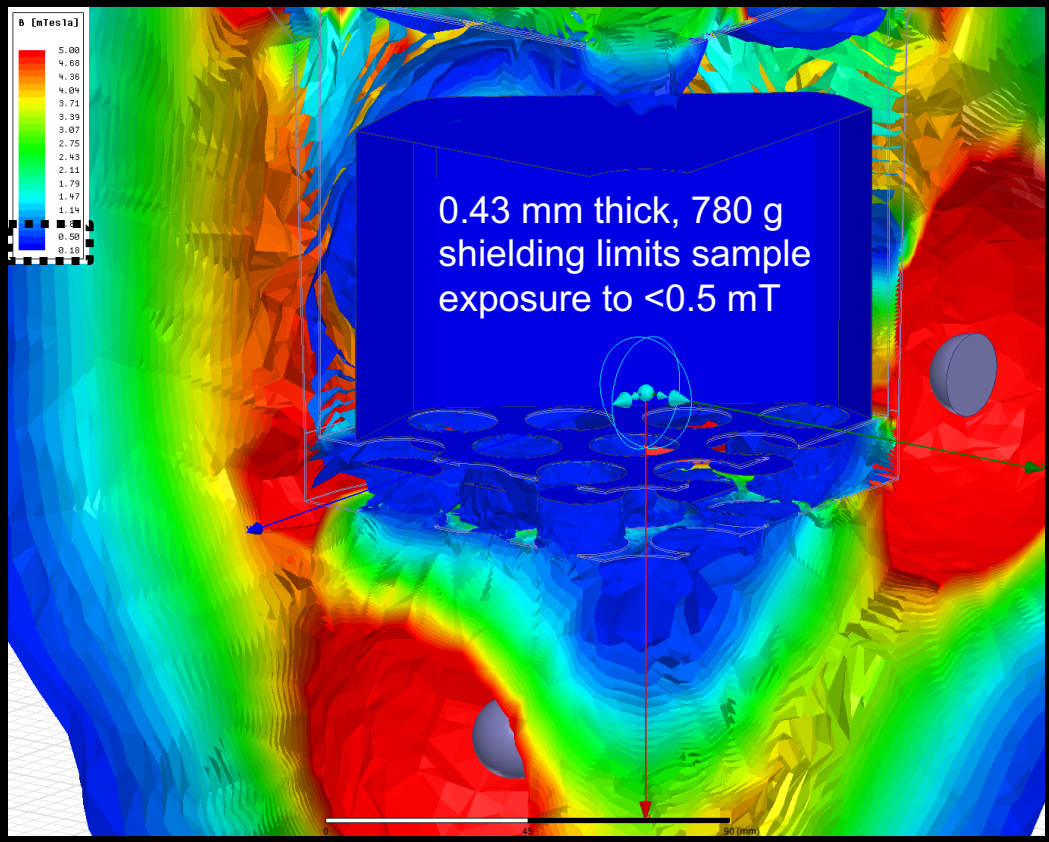
Shielding analysis for the icosahedron isotropic magnet arrangement





Microgravity Testing

Microgravity Testing

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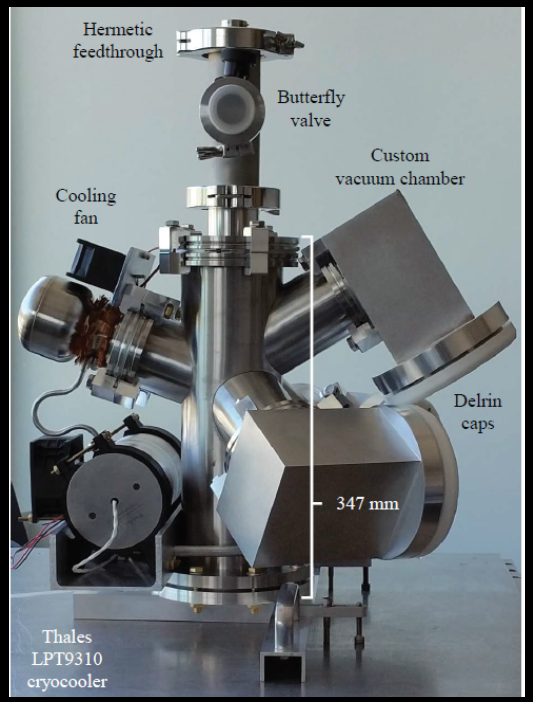
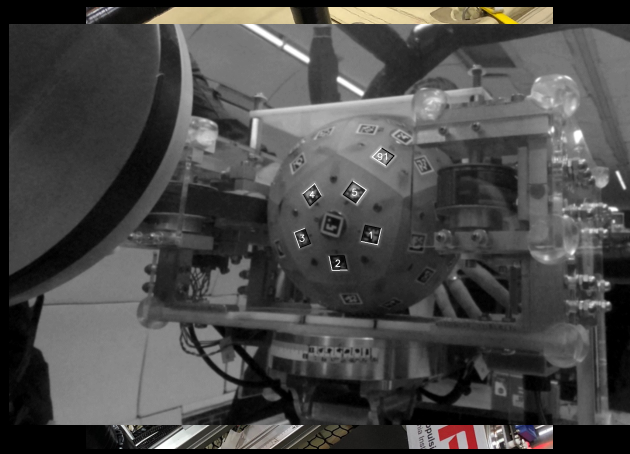


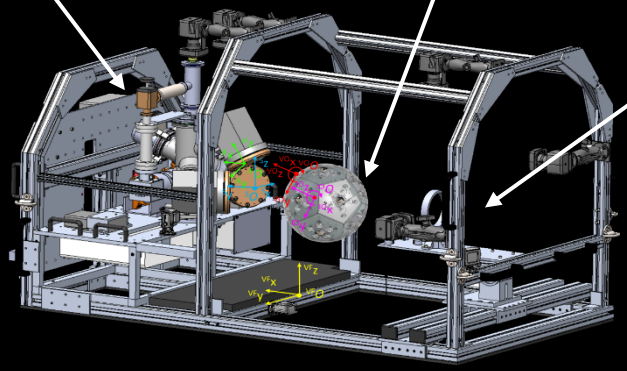
Sample Return Orbiter Analogue (SROA)

McKinley, I., C. Hummel, and L. Jones-Wilson, "A Flight-Traceable Cryogenic Thermal System for Use in a Sample-Capture Flux-Pinned Interface," *IEEE Aerospace Conference*, Big Sky, MT, Mar. 2-9, 2019.

Orbiting Sample Analogue (OSA)



OSA Launcher



Test Frame

Zhu, F., M. Dominguez, L. Jones-Wilson, and M. Peck, "Flight-Experiment Validation of the Dynamic Capabilities of a Flux-Pinned Interface as a Docking Mechanism," *IEEE Aerospace Conference*, Big Sky, MT, Mar. 2-9, 2019.

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Microgravity Testing

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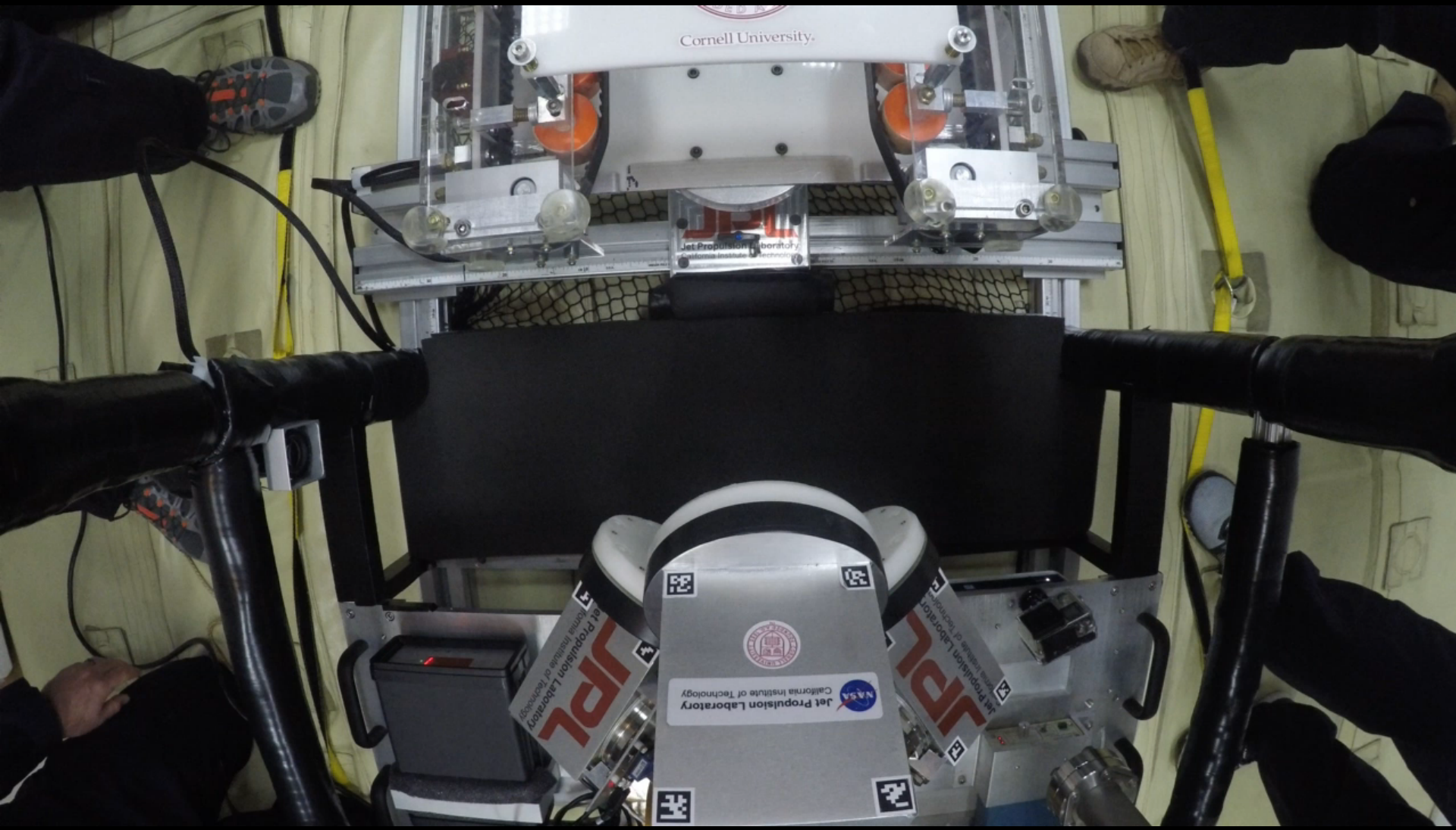

OS Tracking

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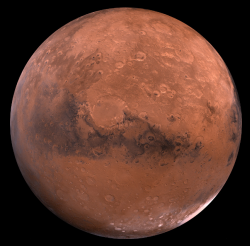
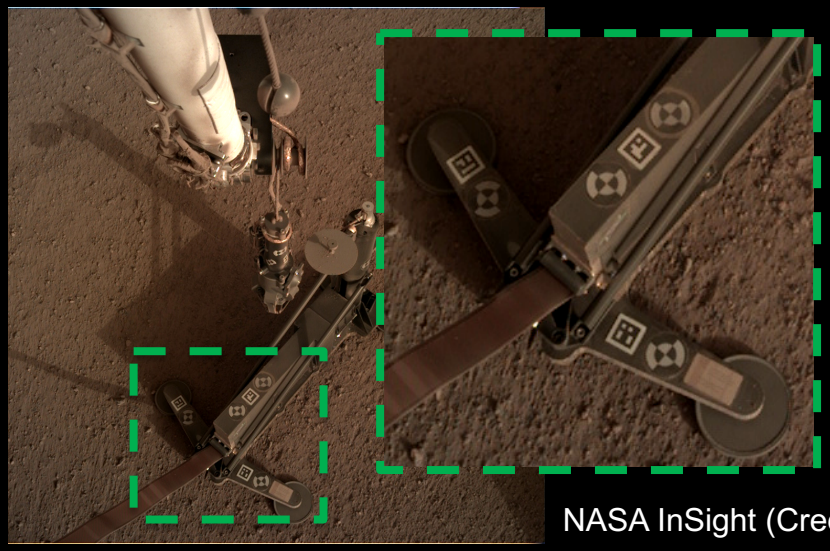
California Institute of Technology



Mars



NASA InSight (Credit: NASA JPL)

AprilTags on surface of OSA

AprilTags on faces of SROA

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OS Tracking

3D Scanning with Blue LED Fringe Projection

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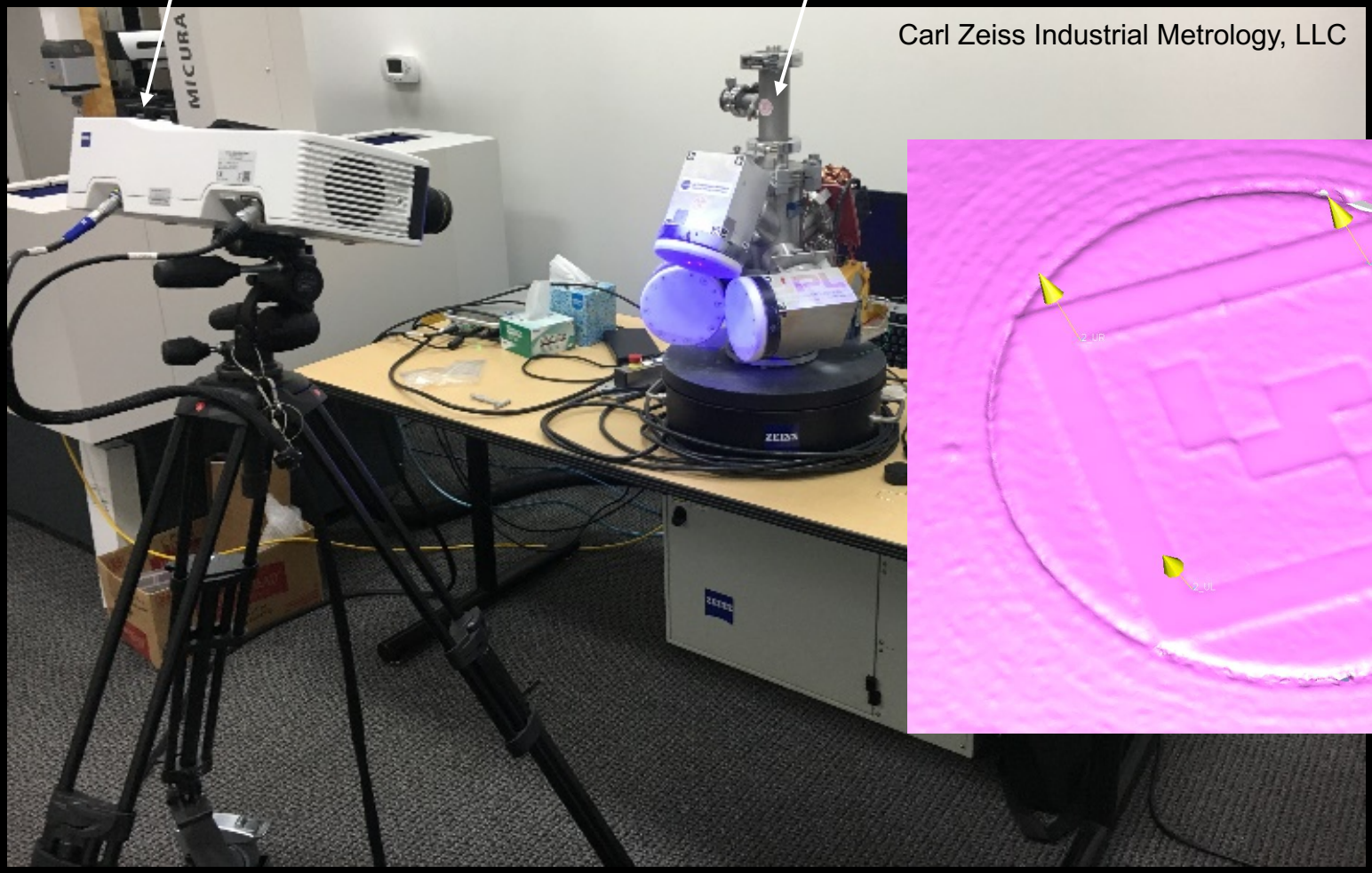

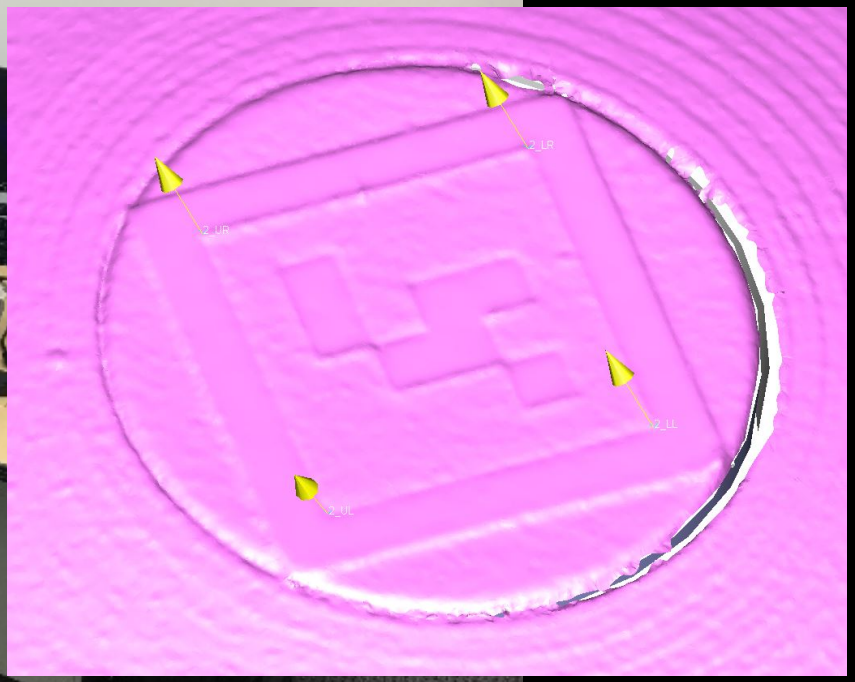

10 microns resolution

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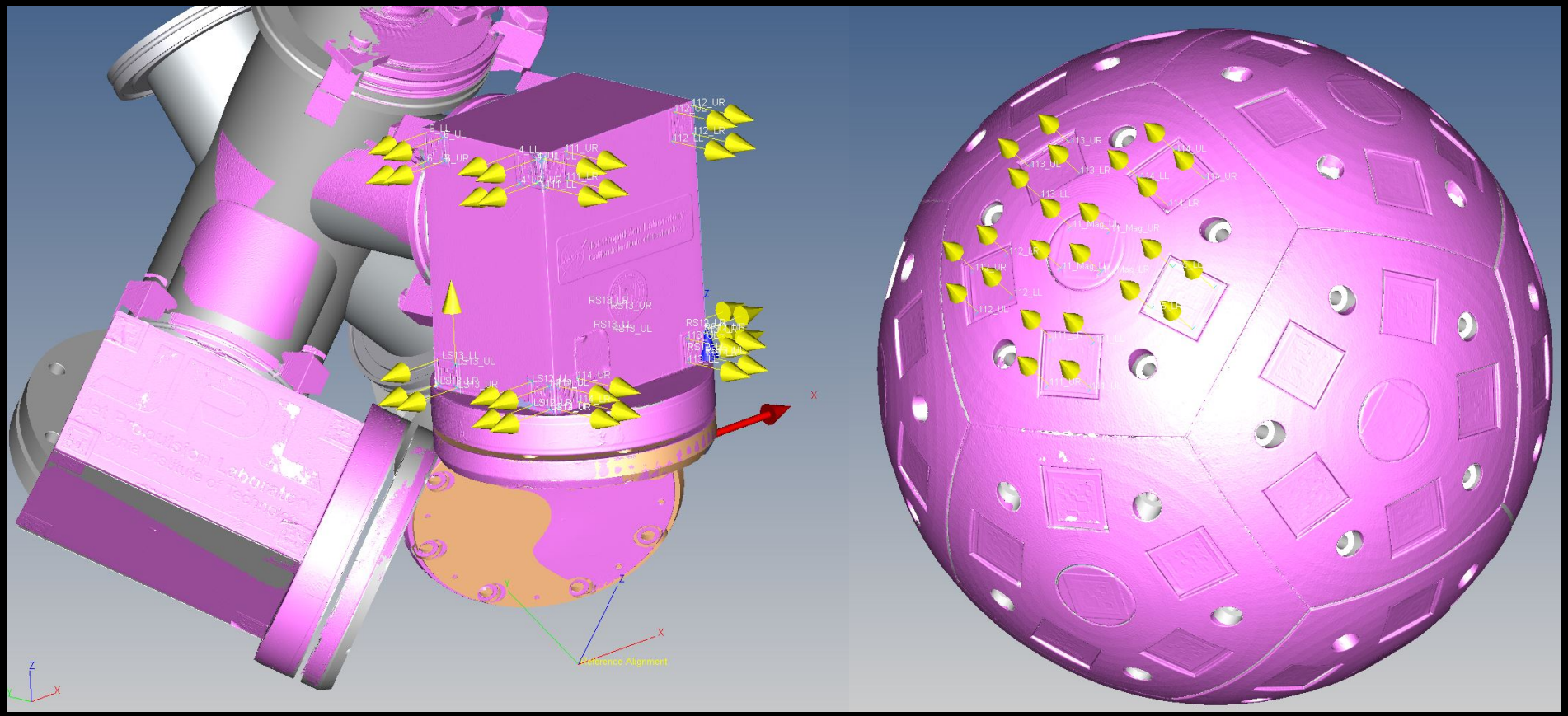

OS Tracking

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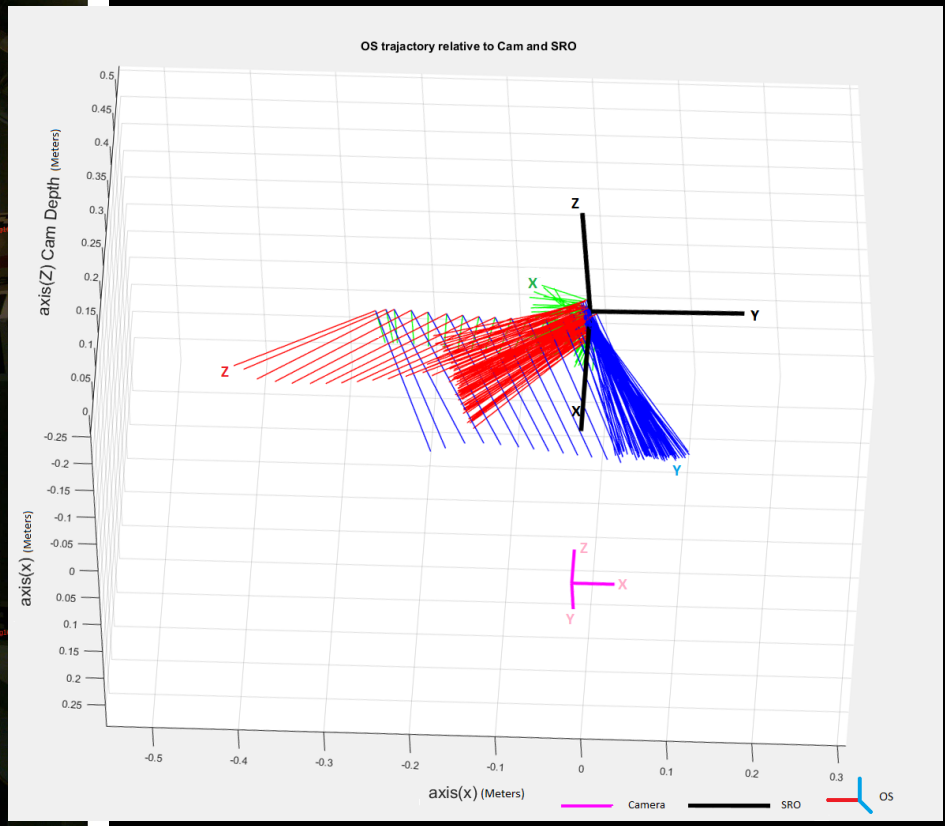
AprilTags tracking from microgravity OS capture testing video



Plot of OS position and orientation relative to testbed reference frame (estimated ~1 mm uncertainty)

Summary

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- Flux pinning is a feasible technology for implementing on-orbit capture and orientation of an Orbiting Sample (OS) container for potential Mars Sample Return (MSR)
  - Pluses: passive, non-contact capture and orientation
  - Minuses: additional OS mass for magnets and shielding
- Flux pinning modeling and simulation can be used to predict OS capture behavior, settling time, and torques
- Magnetic modeling can be used to design effective shielding to ensure sample exposure remains within acceptable limits
- Prototype testing demonstrated flux pinning in microgravity
- A vision system using AprilTag fiducials tested on a free-floating OS in micro-gravity demonstrated feasibility of using computer vision to perform OS tracking and pose estimation
- Architecture trades currently in work for capture and orient technologies as part of the ongoing Mars Sample Return study

Thank you!

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Paulo Younse, Laura Jones-Wilson, William Jones-Wilson, Ian McKinley, Edward Gonzales, Boyan Kartolov, Dima Kogan, Chi Yeung Chiu, Eric Olds, and Violet Malyan

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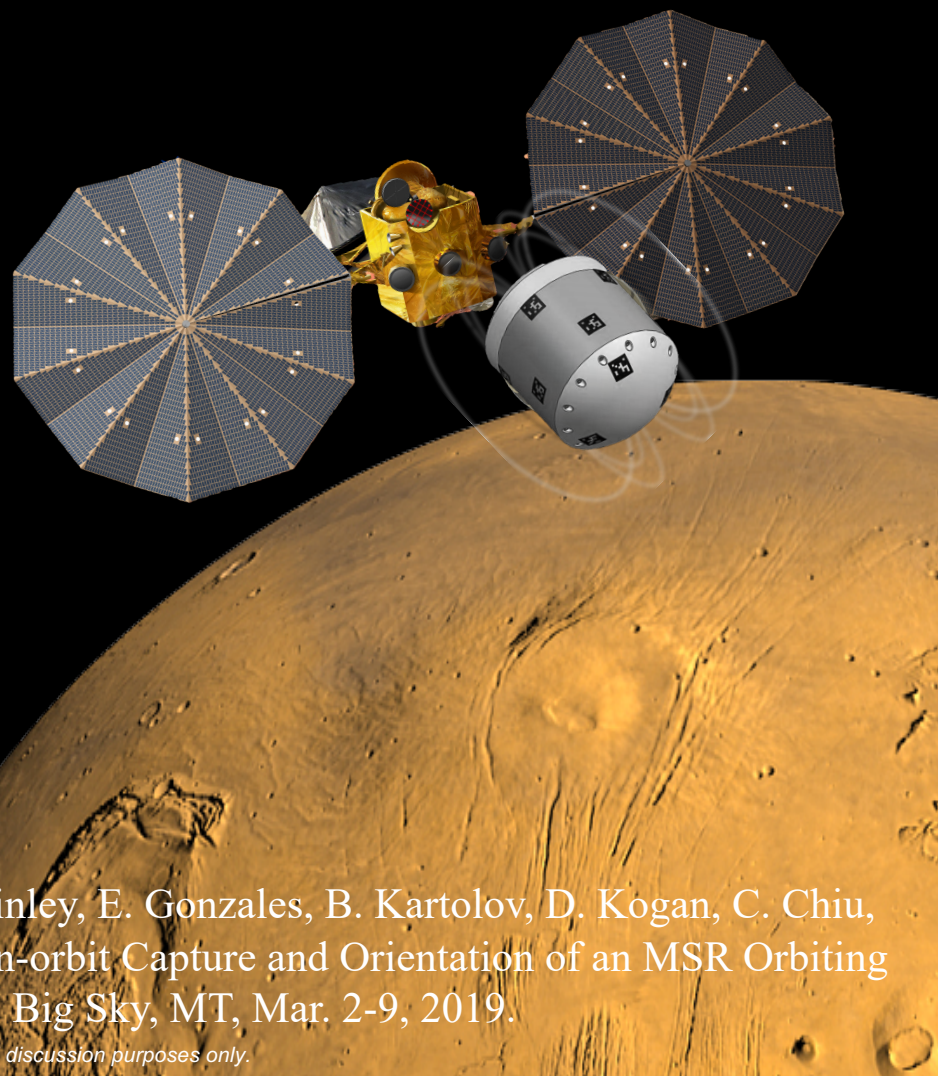

Younse, P., L. Jones-Wilson, W. Jones-Wilson, I. McKinley, E. Gonzales, B. Kartolov, D. Kogan, C. Chiu, E. Olds, and V. Malyan, "Flux Pinning Concepts for On-orbit Capture and Orientation of an MSR Orbiting Sample Container," *2019 IEEE Aerospace Conference*, Big Sky, MT, Mar. 2-9, 2019.

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