Integrated Attitude Control Strategy for the Asteroid Redirect Mission

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Agenda

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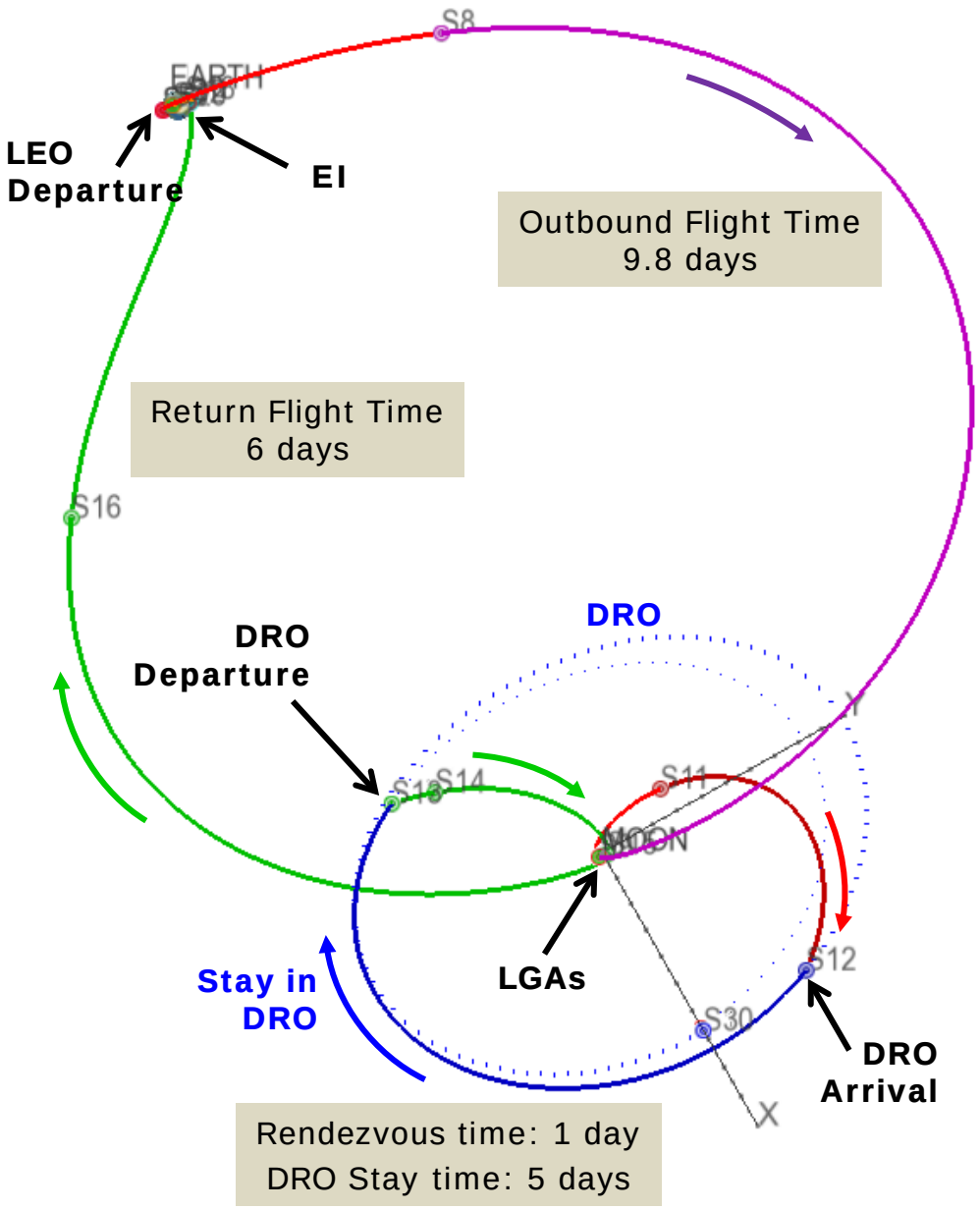
  - Timeline
- Flight Element Configuration Overview
  - Orion/SLS
  - Orion Mission Kits Affecting Integrated Attitude Control
  - Asteroid Redirect Robotic Vehicle (ARRV) Characteristics
- Vehicle-to-Vehicle Communication
- Mated Attitude Reference Frame
- Flight Attitude Constraints
- Integrated Attitude Control Strategy
  - Docking
  - Attitude Maneuvers
  - Undocking
- Conclusions

Nominal ARCM Overview

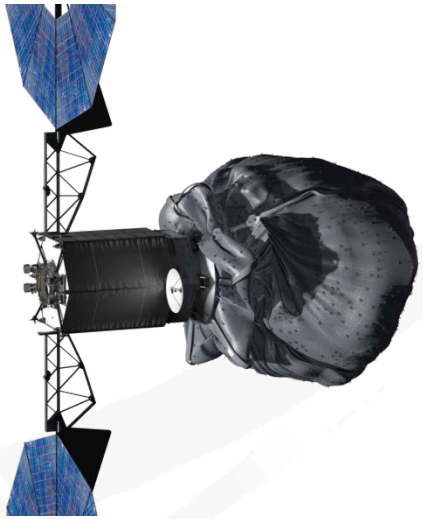


- **Outbound**
  - **FD01 – Launch/TLI**
  - **FD02-FD05 – Outbound Trans-Lunar Cruise**
  - **FD06 – Lunar Gravity Assist**
  - **FD07-FD09 – Lunar to DRO Cruise**
- **Joint Operations**
  - **FD10 – Rendezvous**
  - **FD11 – EVA #1**
  - **FD12 – Suit Refurbishment, EVA #2 Prep**
  - **FD13 – EVA #2**
  - **FD14 – Contingency/Departure Prep**
  - **FD15 – Departure**
- **Inbound**
  - **FD16 – DRO to Lunar Cruise**
  - **FD17 – Lunar Gravity Assist**
  - **FD18-FD21 – Inbound Trans-Lunar Cruise**
  - **FD22 – Earth Entry and Recovery**

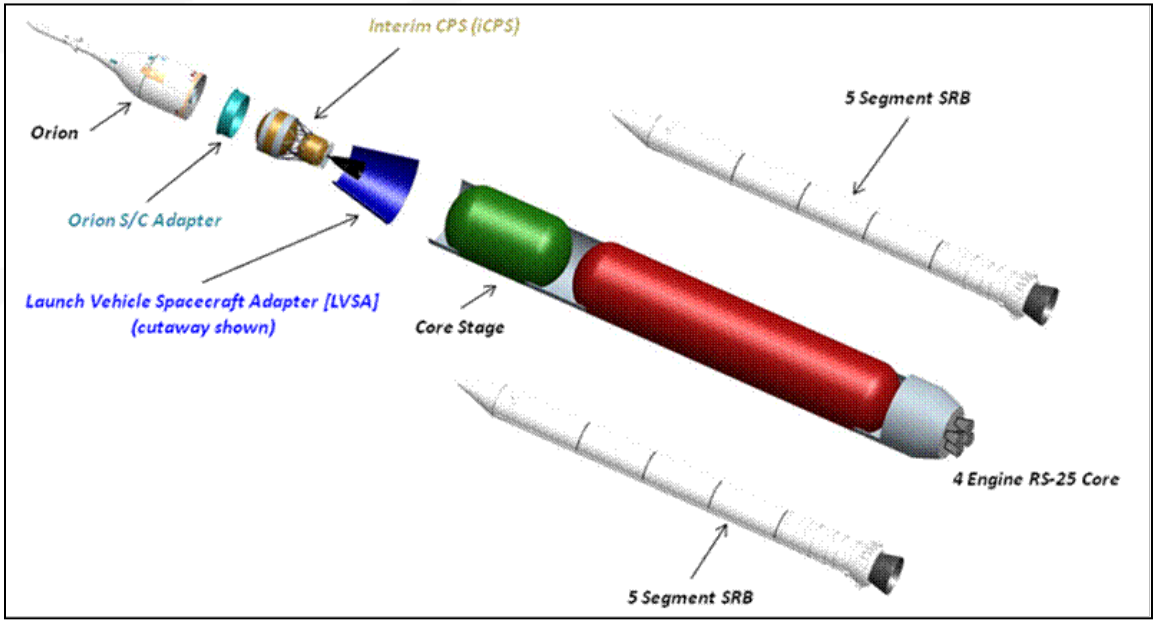
Mission Duration and timing of specific event will vary slightly based on epoch variation.

Flight Element Configuration Overview

- **Asteroid Redirect Vehicle** (ARV) with the captured asteroid in a Distant Retrograde Orbit (DRO) near the moon



- **Orion** with 2 crewmembers launched on a **Block 1 SLS** (with iCPS)
  - Based on EM-2 configuration, augmented with mission kits

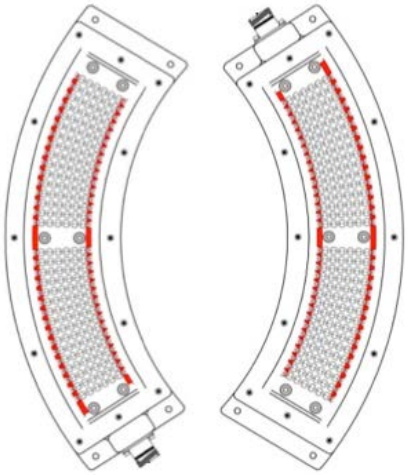


Orion Mission Kits Supporting Integrated Attitude Control

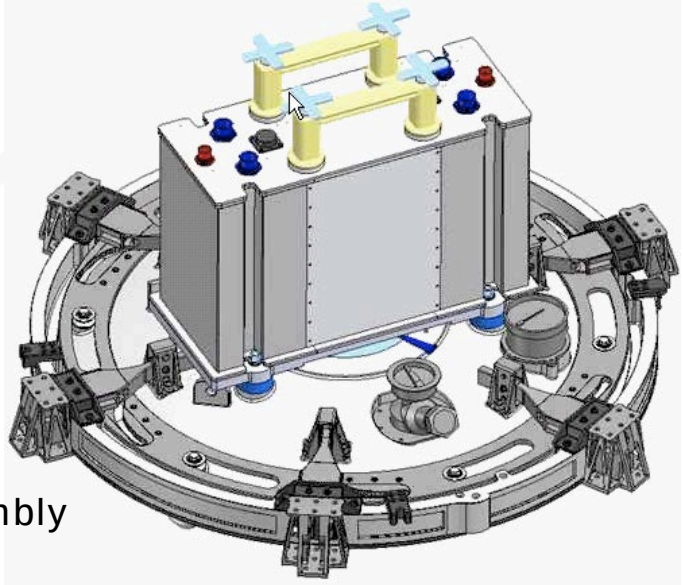
Relative Navigation Kit

- Laser Optical Camera Instrument (LOCI) system that will be mounted on the Orion docking hatch
  - 2 Vision Navigation Sensors provide range and bearing from 6 km and relative position and attitude from 15 m to docking
  - 2 Docking Cameras provide relative bearing from 3-4 km to docking and situational awareness for the crew during docking
- Docking lights on the exterior side of the docking hatch provide target lighting

LOCI mockup



Docking Lights assembly

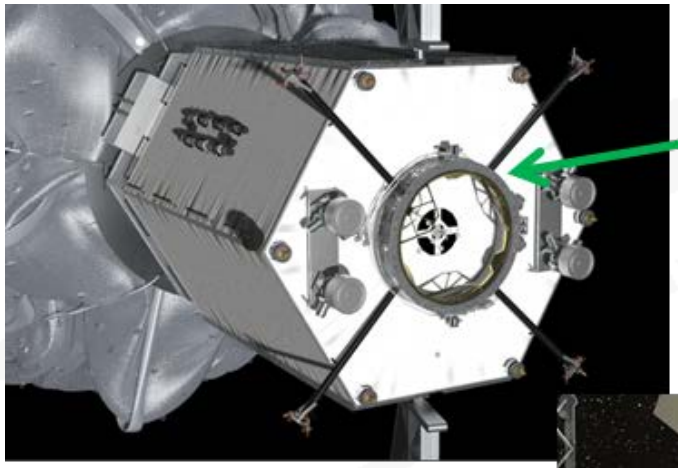


LOCI mounted to docking hatch

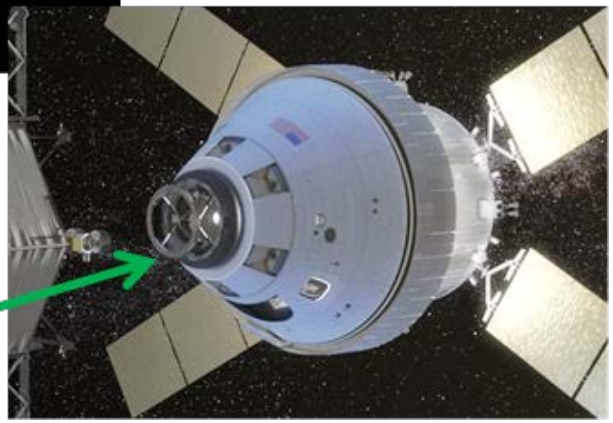
Orion Mission Kits Supporting Integrated Attitude Control (Cont.)

Docking Kit

- An International Docking System Standard Interface Definition Document (IDSS IDD)-compliant NASA Docking System (NDS) is used to mate Orion to ARRV
  - Passive half will be installed on the ARRV, active half on Orion

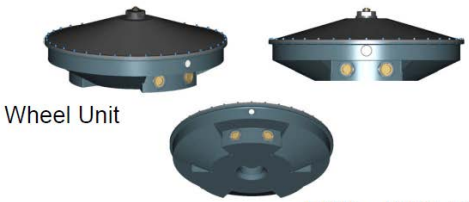


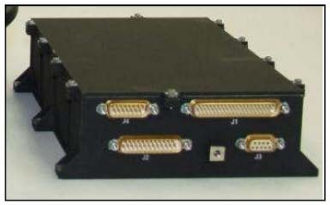
Passive Half of Docking Mechanism



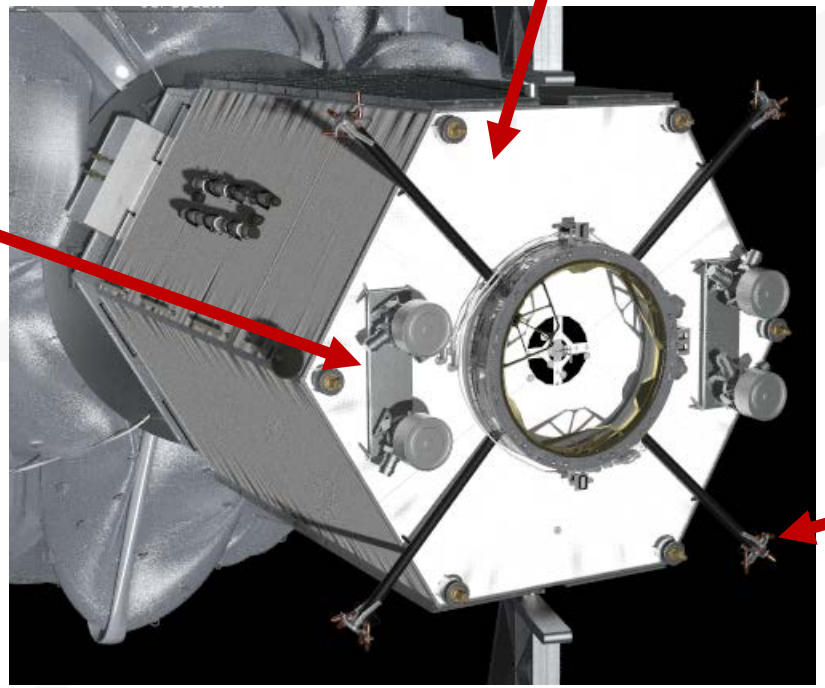
Active Half on Orion

ARV Characteristics (Attitude Control)




Wheel Drive Electronics

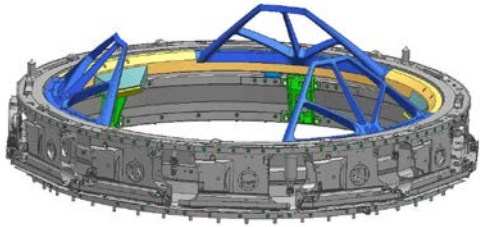
Reaction Wheel Assembly (RWA)
- SMAP Program heritage
- 0.2Nm torque @6k rpm, for attitude hold and slow maneuvers prior to asteroid capture



Hall thrusters
- 40-kW SEP
- 4 gimbaled thrusters
- Main propulsion asset
- Pitch, yaw, and roll control of the ARRV while in powered SEP flight

RCS thrusters
- Perform attitude control maneuvers while not in powered flight

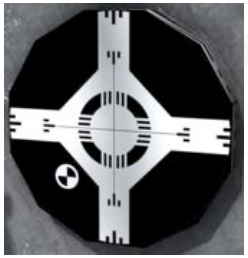
ARV Characteristics (Orion Integration)

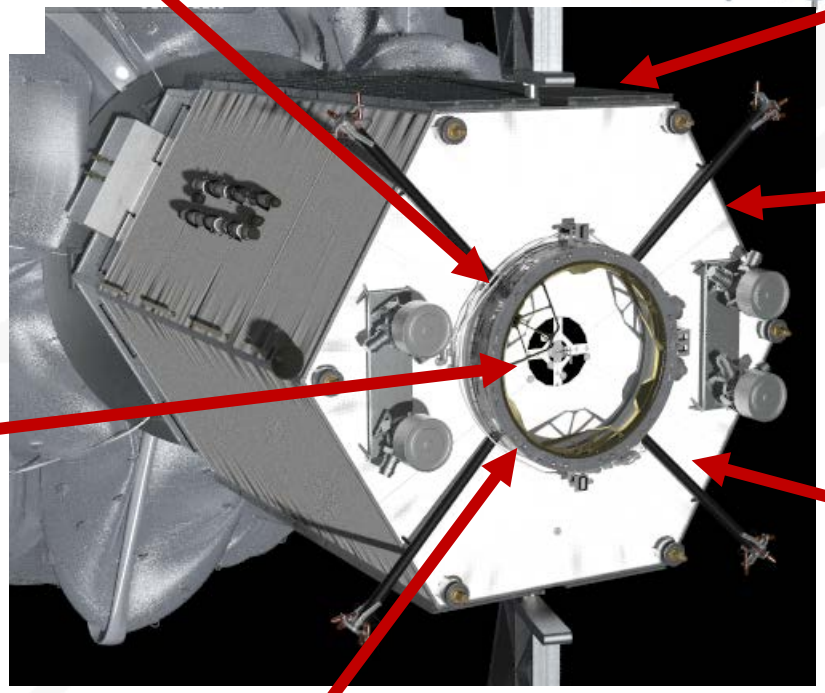


Docking Mechanism
- IDSS-compatible, passive side

Vehicle-to-Vehicle Comm
- Orion compatible low-rate S-band

Docking Target
- Augmented with features for relative navigation sensors
- Visual cues for crew monitoring





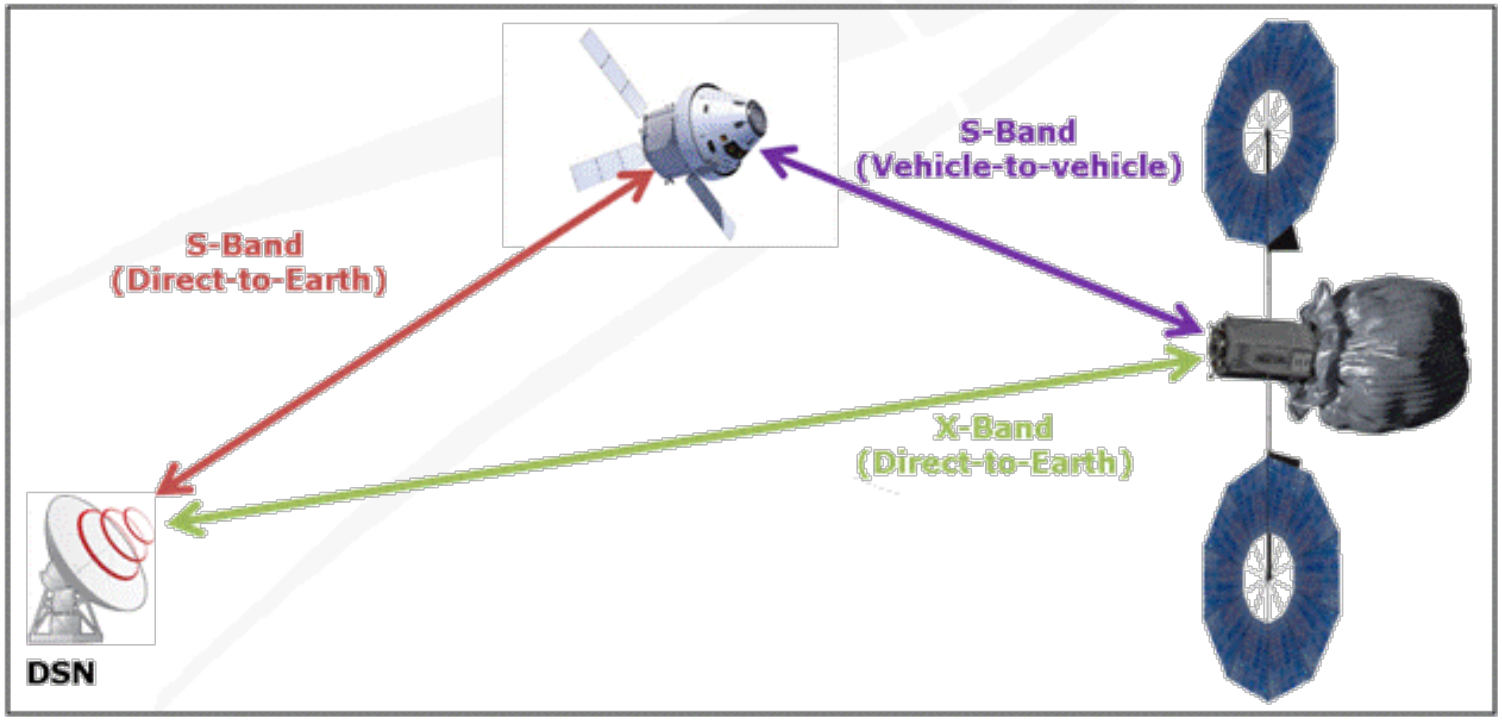
Reflectors
- Tracked by the LIDAR during rendezvous and docking

LED Status Lights
- Indicate the state of the ARV systems, inhibits and control mode

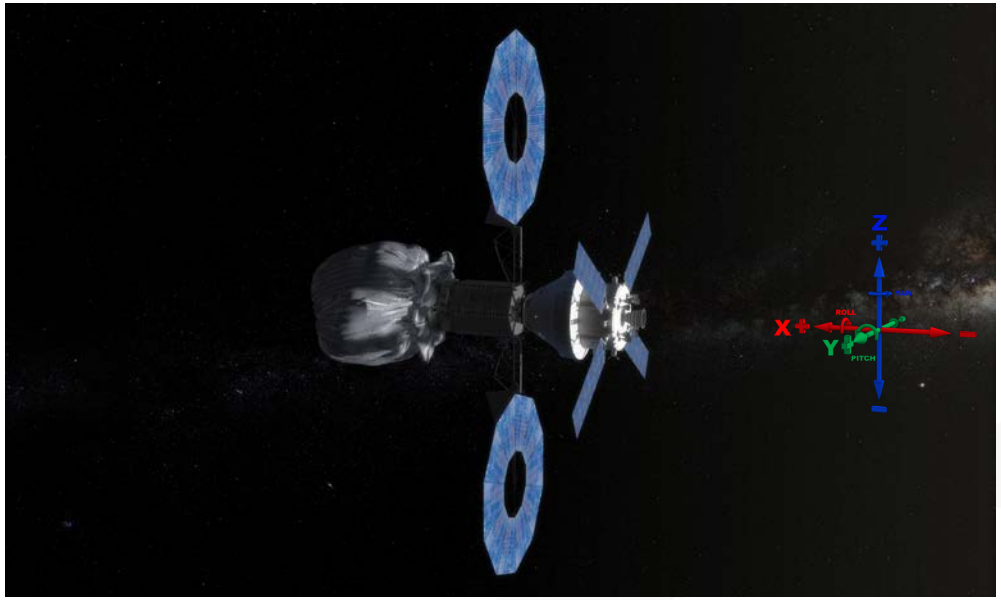
Power and Data Transfer
- Supports extensibility
- Transfer through FRAM-like connectors already part of the docking mechanism design

Vehicle to Ground Communications

- Orion will use the same S-Band system used in EM1 and EM2 for vehicle to ground communications as well as Spacecraft to Spacecraft comm
- ARRV will use an X-Band system to communicate with the ground and Orion-compatible S-band system for vehicle-to-vehicle
- Preliminary assessment shows ARRV and Orion Space to ground communication systems provide adequate communication coverage during reference mission.



ARCM Mated Attitude Reference Frame



- X-axis along the length of the mated stack
- Z-axis along the ARV solar array support structure
- Y-axis through the Orion EVA hatch

- Nominal mated attitude assumed to be solar inertial with sun in the -X axis direction
  - Minimizes impact on Orion thermal control system
  - ARRV at nominal attitude prior to rendezvous

Flight Attitude Constraints

Orion and ARV are designed to fly Solar Inertial flight attitude with sun oriented along the minus X-Axis.

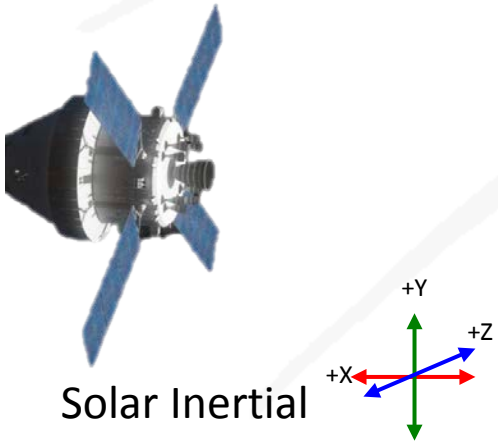
Thermal: Preliminary analysis indicates Orion Thermal system can accommodate up to 20˚ of off pointing

Power: Preliminary analysis indicates Orion Power Generation can accommodate up to 30˚ of off pointing

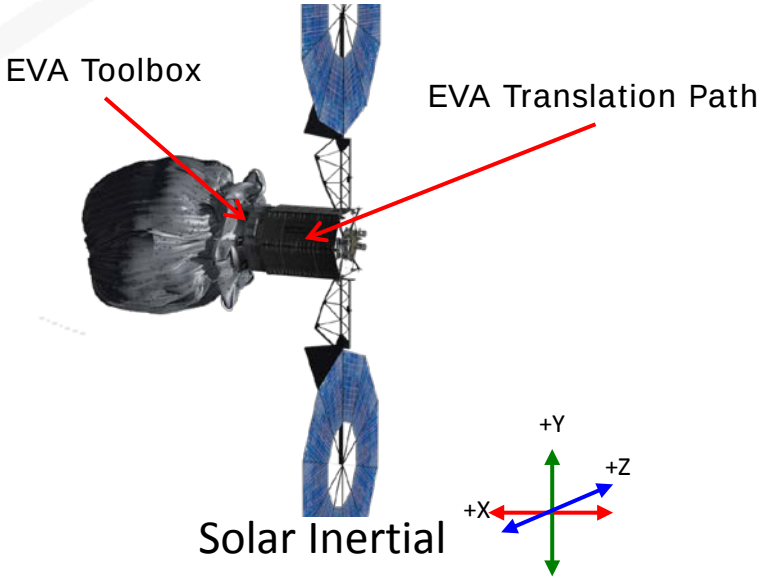
Communications: Coverage Analysis shows sufficient Orion Space to Ground communications for 0˚, 15˚ and 30˚ of off pointing.

Lighting: EVA suits can accommodate short durations in shade, but require solar coverage for extended work.

ARRV attitude control assets: SEP and RCS thrusters cannot be used as they could damage Orion TPS



Solar Inertial

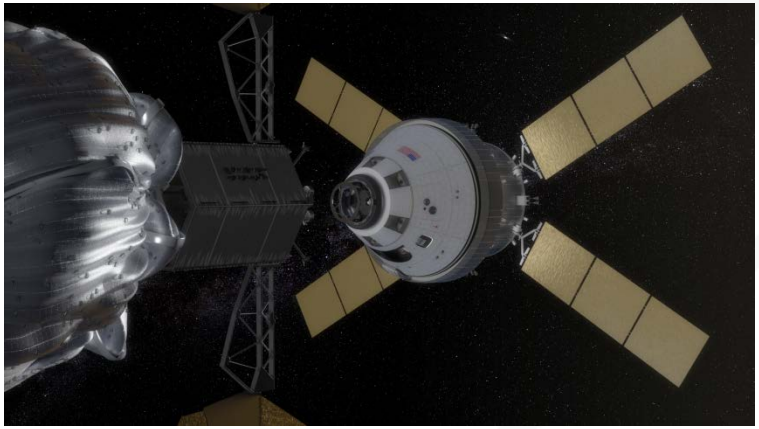


Solar Inertial

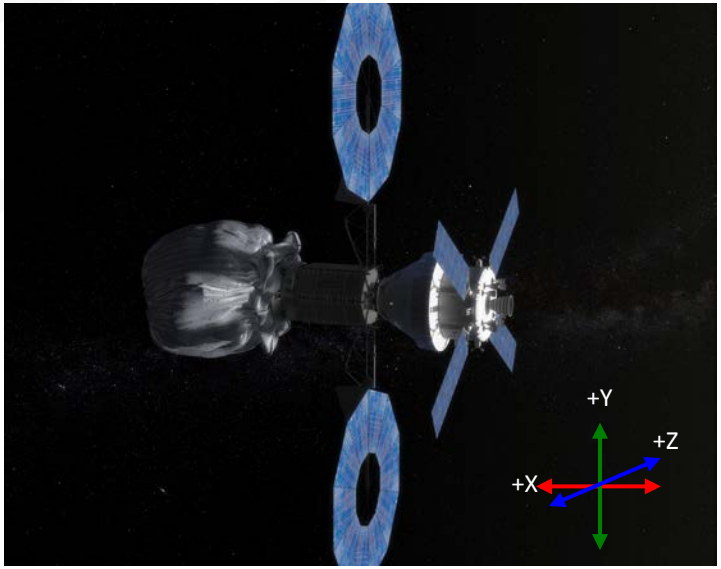
Integrated Attitude Control Strategy

Docking

- ARRV prepositioned to planned mated attitude and perform reaction wheel desaturation prior to rendezvous
- ARRV commanded to free drift
- Orion RCS used to dock Orion to ARRV, arrest rates, and restore stack to solar inertial attitude
- The ARRV will then maintain the integrated stack in solar inertial attitude using reaction wheels and solar pressure on the arrays



Orion approaching ARRV prior to docking



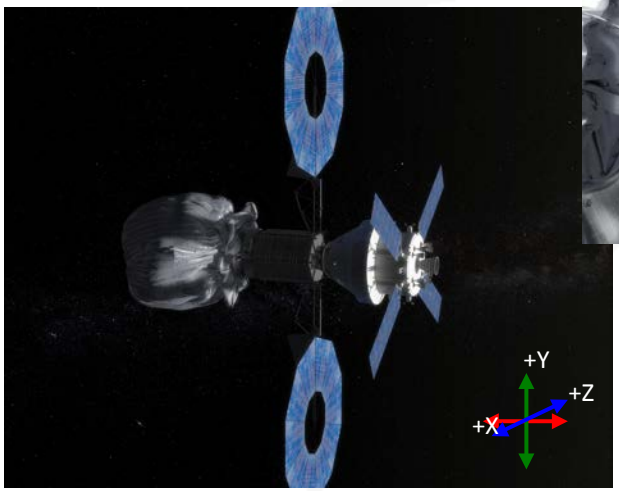
Nominal Solar Inertial Attitude

Integrated Attitude Control Strategy (Cont.)

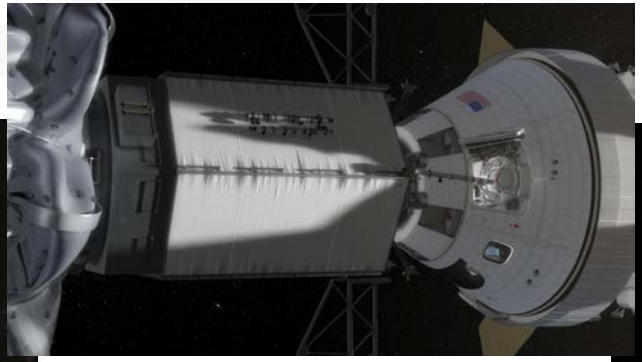
Attitude Maneuvers

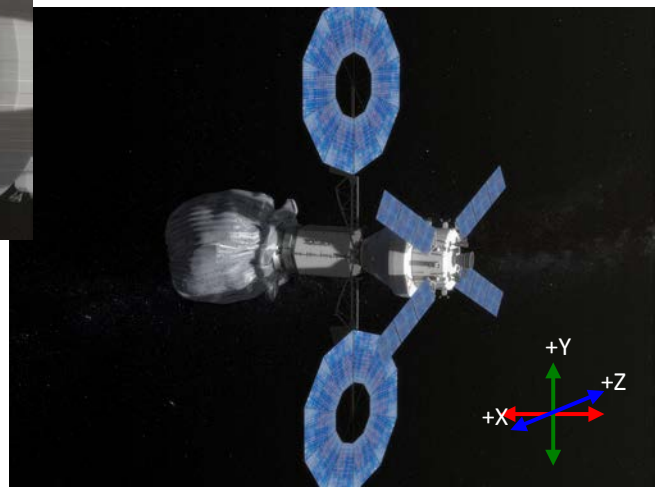
- Prior to each EVA, the Orion SM RCS jets will slew the stack to the EVA flight attitude (+15˚ yaw) and arrest rates*
- Stack is then moded to free drift for the duration of EVA operations
  - ARRV reaction wheels may be used to maintain biased stack attitude (analysis in work)
- Orion RCS thrusters will be used to return stack to nominal solar inertial attitude and arrest any residual rates*
- ARRV reaction wheels will resume stack attitude maintenance

**Preliminary analysis shows the Orion SM has sufficient control and propellant for all stack attitude maneuvers and to arrest residual rates*



Nominal Solar Inertial Attitude


EVA Translation Path

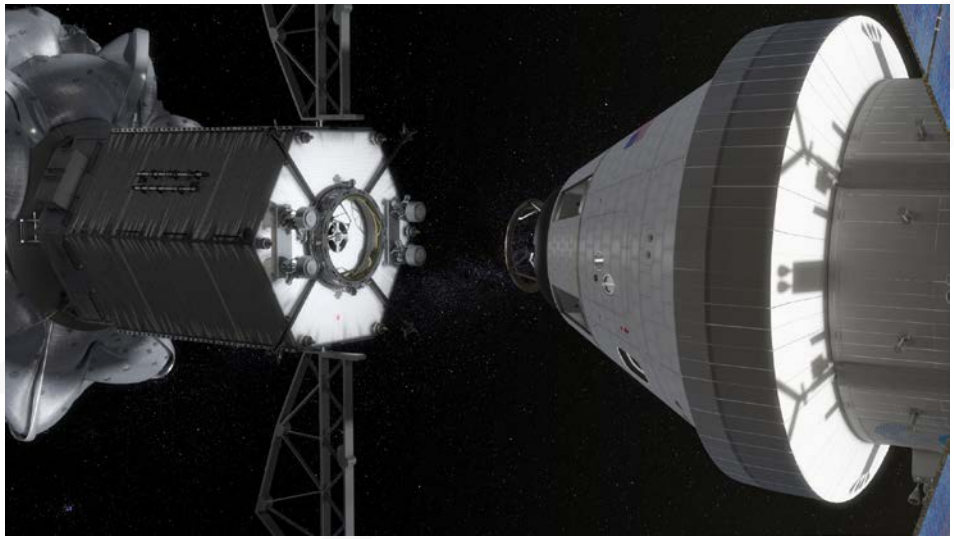


EVA Biased Attitude

Integrated Attitude Control Strategy (Cont.)

Undocking

- ARRV commanded to free drift, will remain in free drift until Orion is a sufficient distance away
- Orion RCS used to undock Orion
- The ARRV reaction wheels will then resume control of the ARRV and return vehicle to nominal solar inertial attitude



Orion moving away from ARRV after undocking

Summary

- Integrated attitude control strategy for the ARCM has been assessed
- Use of Orion RCS thrusters to maneuver stack to nominal (solar inertial) and biased EVA attitudes (+15 yaw), and to arrest any residual rates
  - Use of ARRV SEP and RCS thrusters not possible due to docking of Orion to aft of ARRV
  - Attitudes selected based on Orion thermal and power constraints, as well as EVA thermal and lighting conditions
- Use of ARRV reaction wheel assembly to hold stack at each attitude
- Initial review shows current attitude control strategy can be used to successfully complete all ARCM objectives

Acknowledgments

- This work could not have been possible without the support of the Asteroid Redirect Mission teams from JPL, LaRC, GRC, MSFC, JSC, and KSC

BACKUP CHARTS