SMALL SPACECRAFT SAMPLE RETURN MISSION CONCEPT TO SUPPORT GATEWAY AND LUNAR SCIENCE

FLY
SUPPLY
EXPLORE

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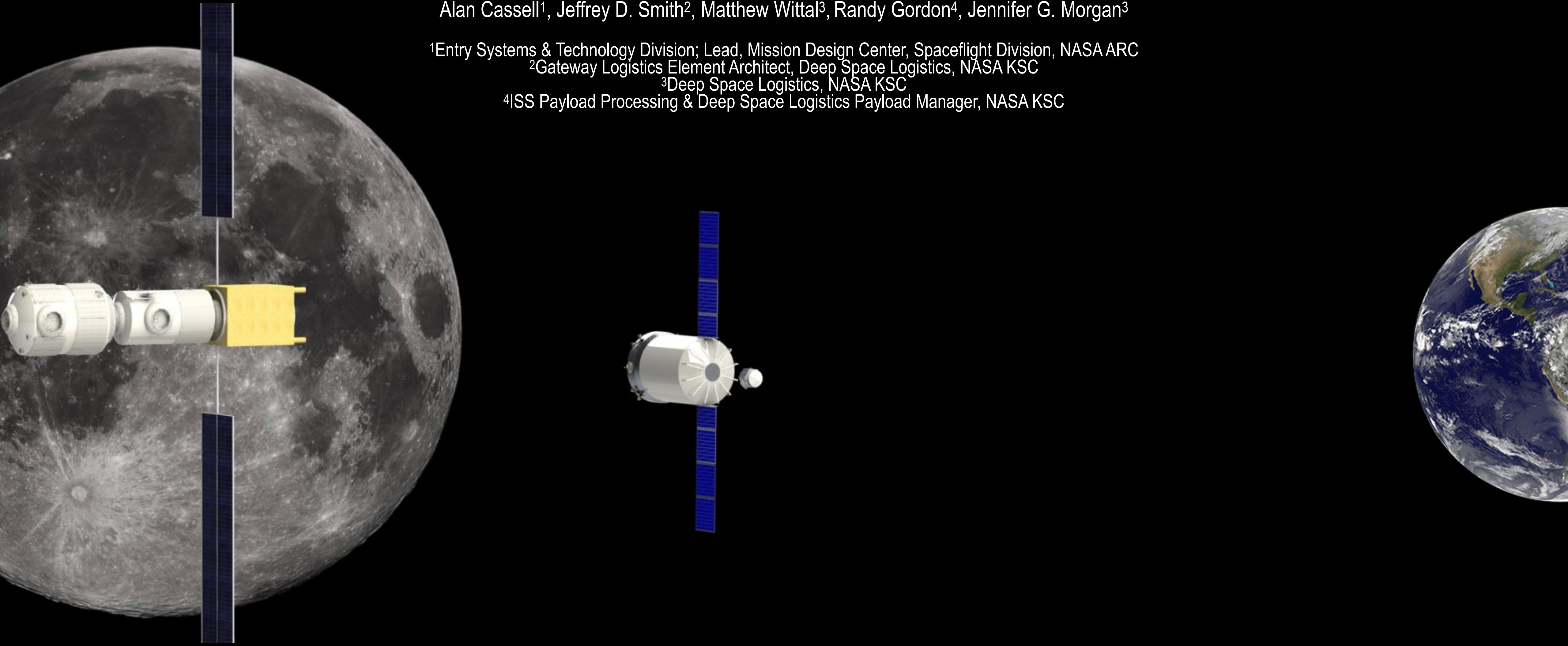

EXECUTIVE SUMMARY

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Opportunity:

- Gateway is seeking research and technology demonstration opportunities during the early development phase, which will pave the way for sustainable Human presence & Cislunar commerce development.
- SMD & STMD (and/or other partners) can team with Gateway to rapidly demonstrate small spacecraft sample return and pave the way for innovative science and technology demonstrations that enable the most-effective utilization.
- As Gateway infrastructure evolves and integrates with Lunar surface and CisLunar activities, small spacecraft sample return can significantly advance scientific research & technology development, bringing incredible value and catalyzing scientific discovery.

Approach:

- Study team drafted Goals and Objectives to assess feasibility for a technology demonstration mission concept (Demo-1).
- Stakeholder engagement was performed to status progress, consider alternatives, and understand key challenges for developing the opportunity.

Mission Design:

- Describes a mission concept that utilizes existing small spacecraft technologies to demonstrate a capability that can catalyze Cislunar Utilization and Sustainability that leverages the Deep Space Logistics outbound transportation segment.
- Emphasizes near-term use cases that can be examined to maximize scientific and technological progress that can evolve with science/technology needs and operational capabilities.

MOTIVATION/WHY NOW?

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Artemis Gap for Sample Return

- During early development, crews occupy Gateway for ~30 days/year (~8% each year). Gateway is operated robotically the rest of the year. Currently, there is no redundant payload return capability in the event of unplanned lapse in Orion operations.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						Crew Stay					

- Orion is capable of ~100 kg downmass. Early missions will return a minimum of 35 kg of surface samples (including containers) to Earth. Inclusion of other payload return needs is TBD.[1]
- Payloads using crewed return system via HLS/Gateway/Orion must meet stringent crew safety requirements, which may preclude certain payloads deemed hazardous for return on crewed vehicles.

Small Spacecraft Sample Return Value Proposition

- ISS downmass capability (>9,000 kg/yr) is primarily provided by SpaceX Dragon2 Cargo vehicle (up to 3000 kg/mission, 3 missions per year). The crewed vehicles have limited downmass (Soyuz & Crewed Dragon ~100 kg each mission).
- The NRC Decadal survey recommended development of a Sample Return Technology Program and outlined the benefits of using the Moon as a proving ground for developing sample return technologies.[2]
- Developing a small spacecraft-based sample return capability will pave the way for a variety of fully commercial, on-demand, cost-innovative (lower $/returned kg) sample return capabilities in the future.

1. Artemis-3 Science Definition Team Report, NASA/SP-20205009602.
2. C.R. Neal, et al "Developing Sample Return Technology using the Earth's Moon as a Testing Ground" Inner Planets Panel, NRC Decadal Survey, 2013

USE CASE EXAMPLES

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- LUNAR SURFACE: return lunar regolith samples for scientific analysis on Earth. Temperature control would allow for return of samples containing volatile compounds and preservation of sensitive cryopreserved cores. Synergy with robotic-based exploration at sites away from Artemis Base Camp (presumably the Lunar South Pole).

- PHYSICAL SCIENCES: return material samples that have been exposed to the deep space environment which advance exploration technology and future long-term missions into deep space (e.g- MISSE). In-space manufacturing, fluid physics, combustion, and dust mitigation could significantly benefit.

- HUMAN RESEARCH: return stabilized samples from crew or other model systems to understand and help mitigate the long-term effects of deep space exploration on the human body (synergistic effects of radiation, microgravity, loads, etc.). Temperature control will be necessary. Ability to maintain frozen samples would be exceptionally valuable.

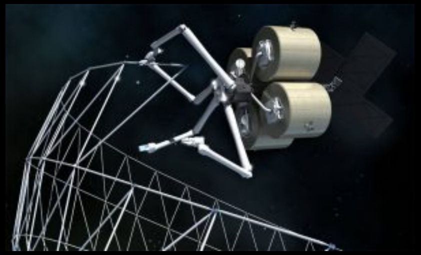
- SPACE BIOLOGY: return stabilized samples from microbiology, cell, plant or animal research for high-throughput “omics” analysis. Temperature control will be necessary and would allow live & stabilized samples to be returned. Ability to maintain frozen samples would be exceptionally valuable.

PREPARATION FOR BASE CAMP

ROBOTIC EXPLORATION

LONG TERM EXPOSURE

IN-SPACE MANUFACTURING



HUMAN RESEARCH- Develop best methods and technologies to support safe, productive human space travel using Gateway as a Mars Transit analogue.

BIOLOGICAL SCIENCE- crew health monitoring, detailed investigations of cosmic conditions on astronauts and other organisms. Detailed ‘OMICS’ research to develop therapies and mitigations to long-term human exploration of deep space.

GATEWAY SEGMENTS & NOTIONAL PARTNERS

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LEGEND

- ESDMD- GATEWAY PROGRAM
- ESDMD- DEEP SPACE LOGISTICS
- SMD- BPS
- STMD- GCD, SSTP, TDM
- MULTIPLE DIRECTORATES
- INTERNATIONAL PARTNERS

GATEWAY (ESDMD)
Power & Propulsion Element, Science Laboratory, Habitat, Transportation Hub, Comm

AUTONOMY & ROBOTICS
Robotic Arm (CSA), Intravehicular Activities

MISSION OPS
Mission Implementation, operations, returned payload processing

ENTRY, DESCENT & LANDING (STMD)
Develop/demonstrate sample return technology

DEEP SPACE LOGISTICS (ESDMD)
Logistics Module, Ground Processing, AI&T

INTERNATIONAL PARTNERS
ESA, JAXA, CSA, etc.

LUNAR SURFACE & GATEWAY UTILIZATION

- Science & Technology Demonstrations
- Gateway Science & Technology
- Biological & Physical Sciences
- Lunar Surface, CLPS, Artemis

SMALL SPACECRAFT TECHNOLOGY (STMD)
Cost-effective spacecraft systems

DEMO MISSION-1

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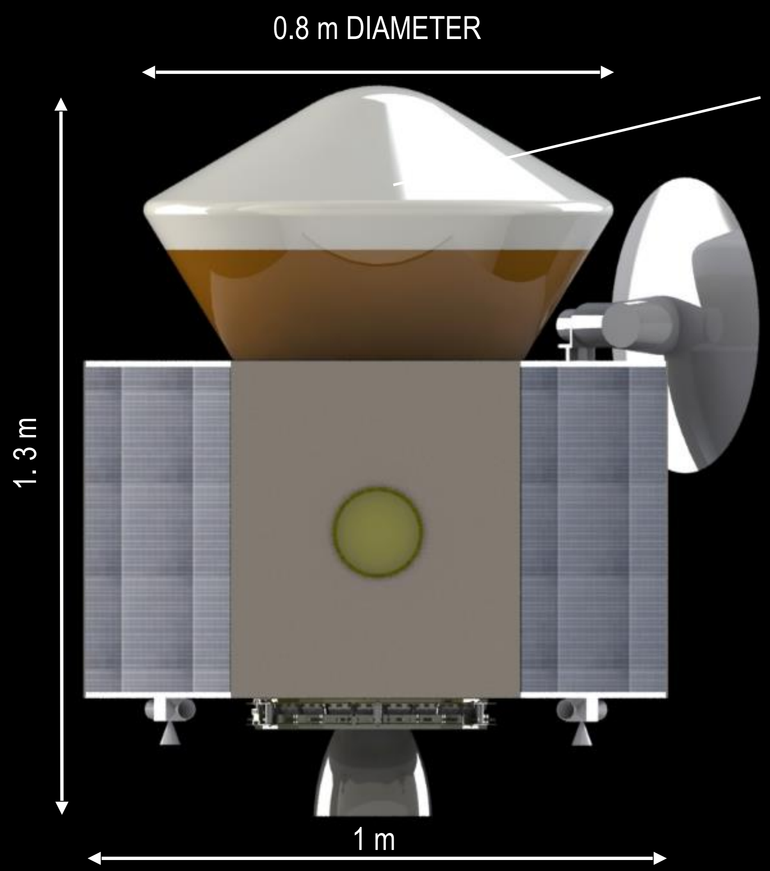
SMALL SPACECRAFT SAMPLE RETURN SYSTEM (NOTIONAL)

OBJECTIVE- DEMONSTRATE 10 kg RETURNED PAYLOAD



SAMPLE RETURN CAPSULE

- PAYLOAD-Sensor suite to monitor environments during mission. Thermocouples, IMU, etc
- RECOVERY SYSTEM- drogue chute and main.
- THERMAL PROTECTION SYSTEM- heat shield materials (PICA or HEEET), backshell can be various materials.

SPACECRAFT BUS

- BODY MOUNTED SOLAR PANELS
- S OR X-BAND COMM SYSTEM
- PROPULSION SYSTEM- ΔV ~ 500 m/s
- MOTORIZED LIGHTBAND x 2
- 3-AXIS CONTROL

CANDIDATE PAYLOADs FOR DEMO-1 MISSION

-Environmental Monitoring/Characterization
-Materials Exposure Demo?
-BioSentinel Return?

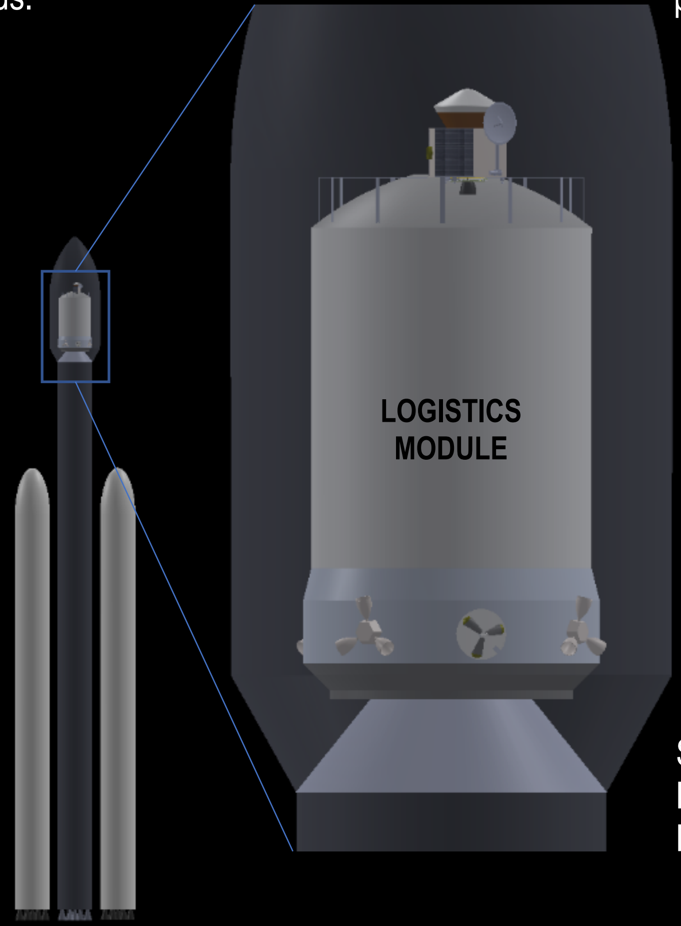
LAUNCH CONFIGURATION

FALCON HEAVY LAUNCH VEHICLE

- Will launch Logistics Module
- Ability to tailor Logistics Module to meet Gateway development needs.

SMALL SPACECRAFT RETURN SYSTEM

- Mounted as external unpressurized cargo
- Electrical & Physical interfaces per XORI standards.



SMALL S/C RETURN SYSTEM
DIMENSIONS: ~ 1 x 1 x 1 m
MASS: ~250 kg

DEMO-1 CONCEPT OF OPERATIONS

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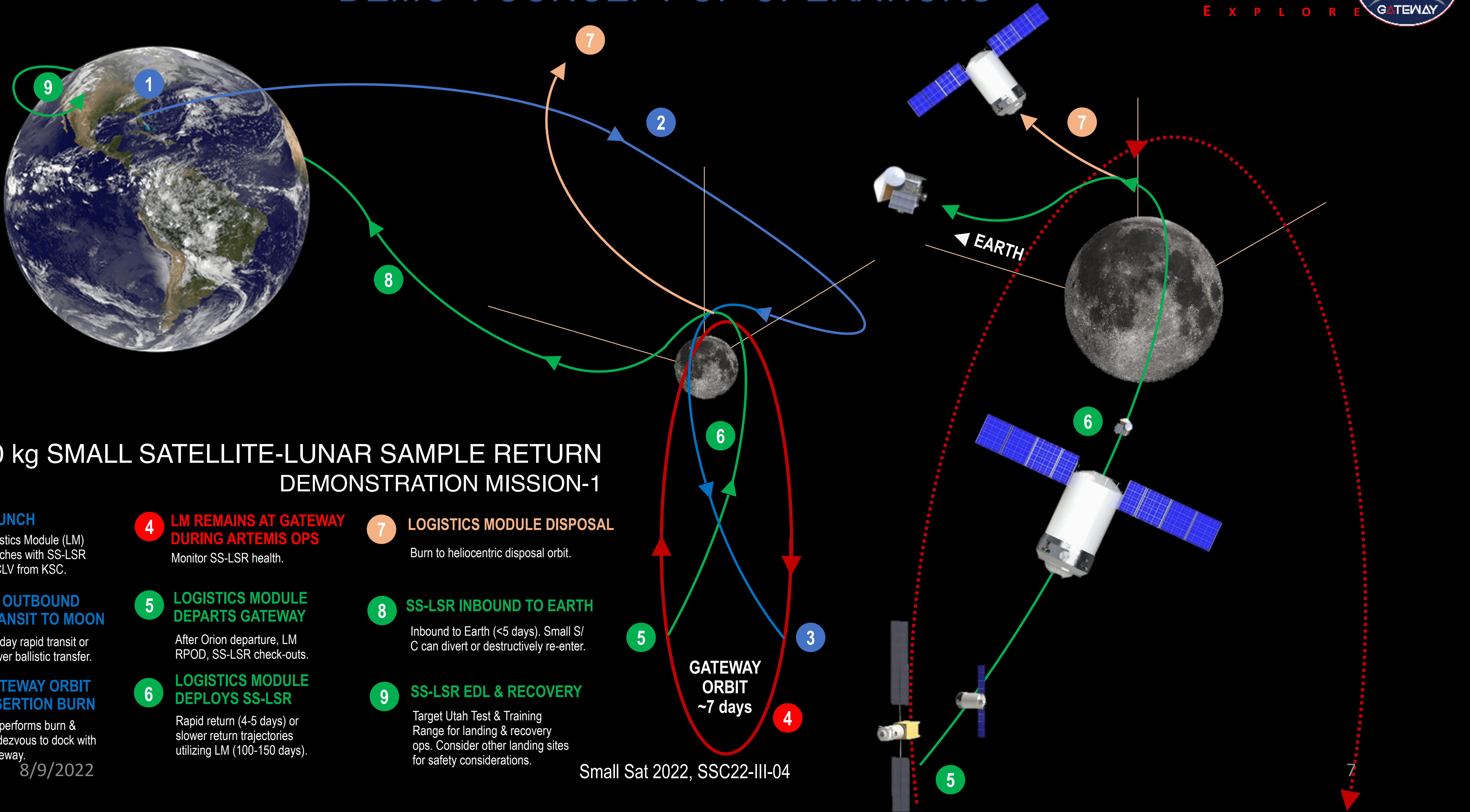


10 kg SMALL SATELLITE-LUNAR SAMPLE RETURN
DEMONSTRATION MISSION-1

1. **LAUNCH**
Logistics Module (LM) launches with SS-LSR on CLV from KSC.

2. **LM OUTBOUND TRANSIT TO MOON**
4-5 day rapid transit or slower ballistic transfer.

3. **GATEWAY ORBIT INSERTION BURN**
LM performs burn & rendezvous to dock with Gateway.

4. **LM REMAINS AT GATEWAY DURING ARTEMIS OPS**
Monitor SS-LSR health.

5. **LOGISTICS MODULE DEPARTS GATEWAY**
After Orion departure, LM RPOD, SS-LSR check-outs.

6. **LOGISTICS MODULE DEPLOYS SS-LSR**
Rapid return (4-5 days) or slower return trajectories utilizing LM (100-150 days).

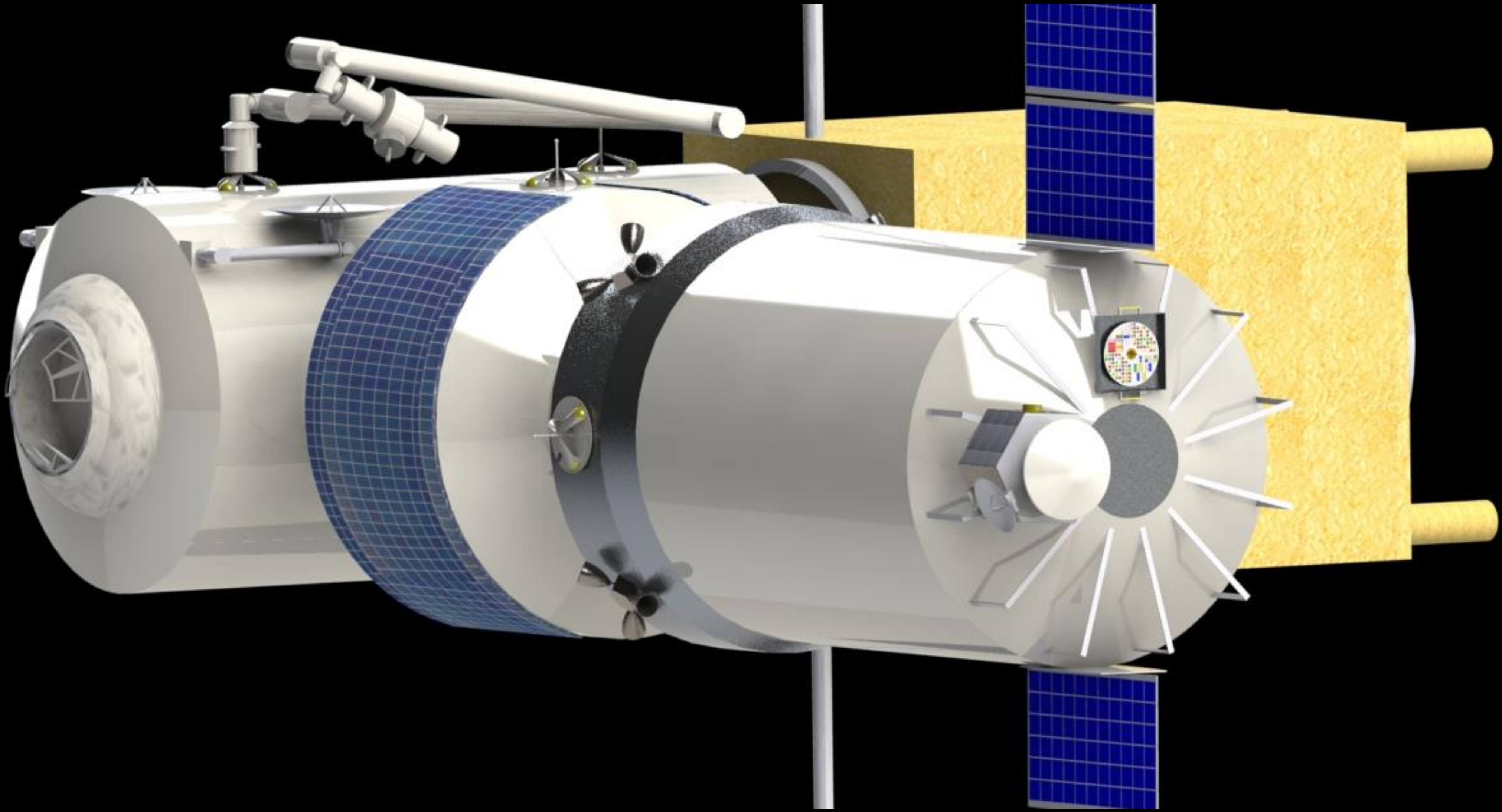
7. **LOGISTICS MODULE DISPOSAL**
Burn to heliocentric disposal orbit.

8. **SS-LSR INBOUND TO EARTH**
Inbound to Earth (<5 days). Small S/C can divert or destructively re-enter.

9. **SS-LSR EDL & RECOVERY**
Target Utah Test & Training Range for landing & recovery ops. Consider other landing sites for safety considerations.

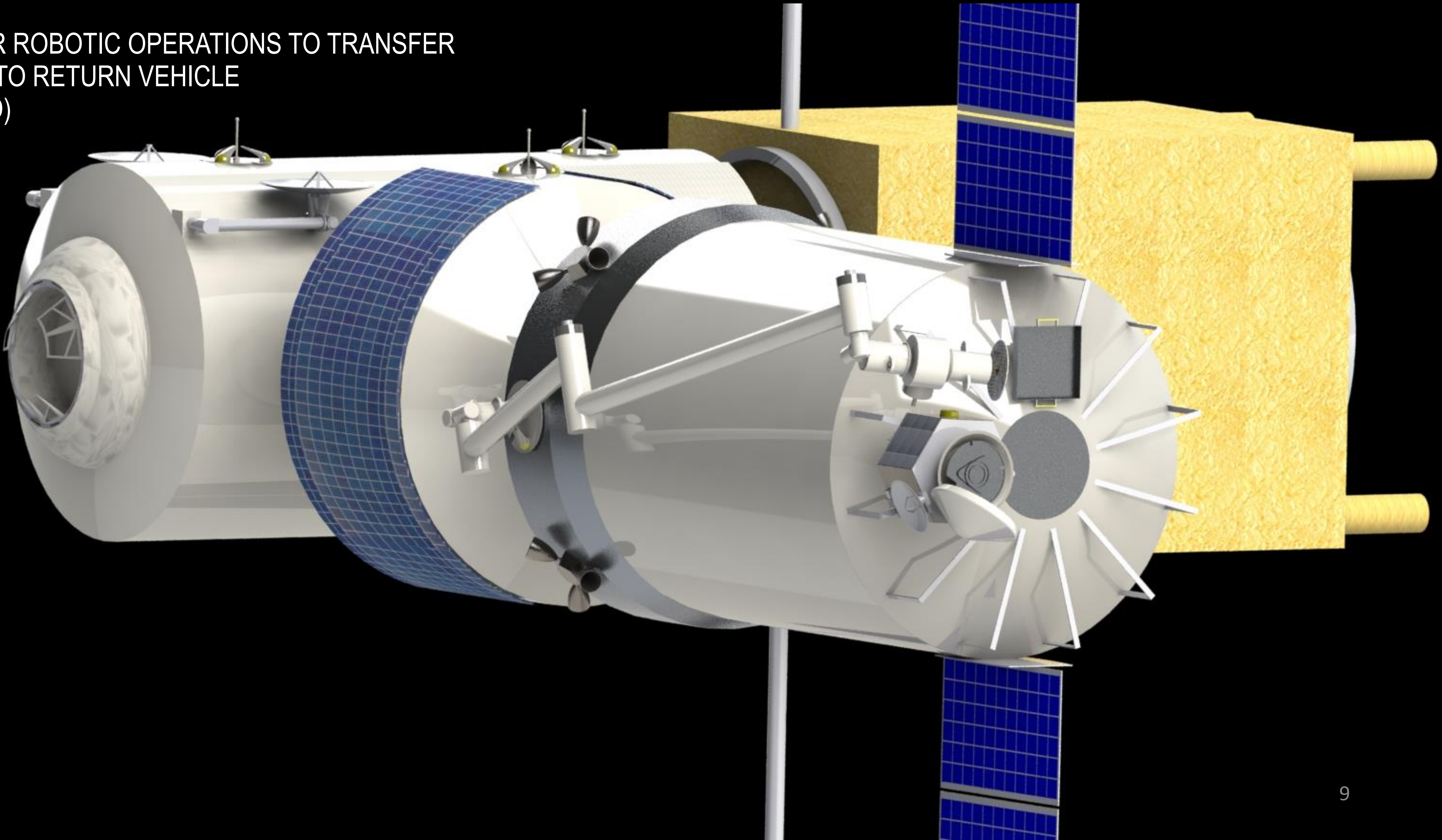
DEMO MISSION- MISSE LIKE SAMPLE RETURN

MATERIALS **I**NTERNATIONAL **S**PACE **S**TATION **E**XPERIMENT- LIKE PAYLOAD



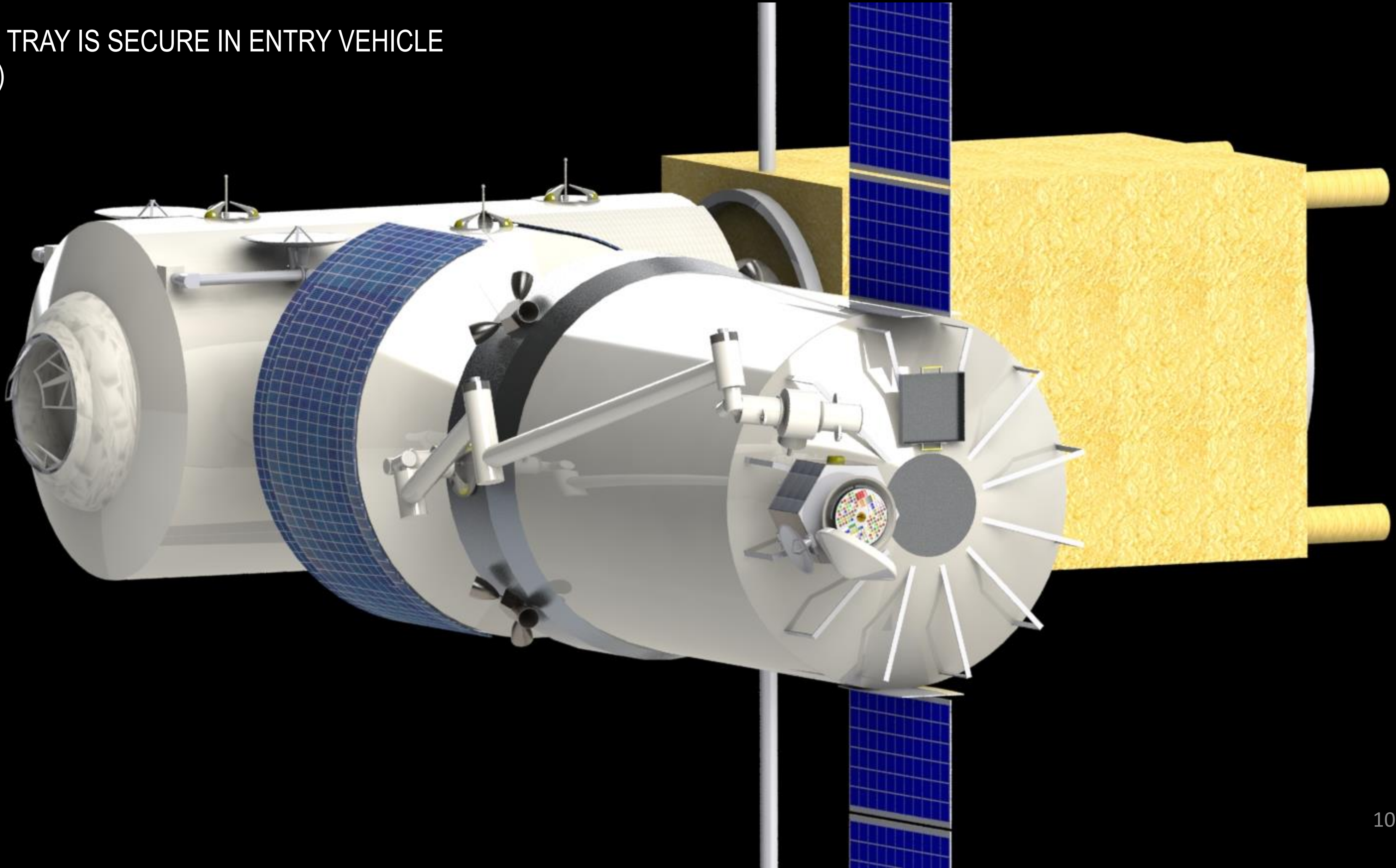
DEMO MISSION- MISSE LIKE SAMPLE RETURN

EXTRAVEHICULAR ROBOTIC OPERATIONS TO TRANSFER EXPERIMENTS INTO RETURN VEHICLE (INTERFACES TBD)



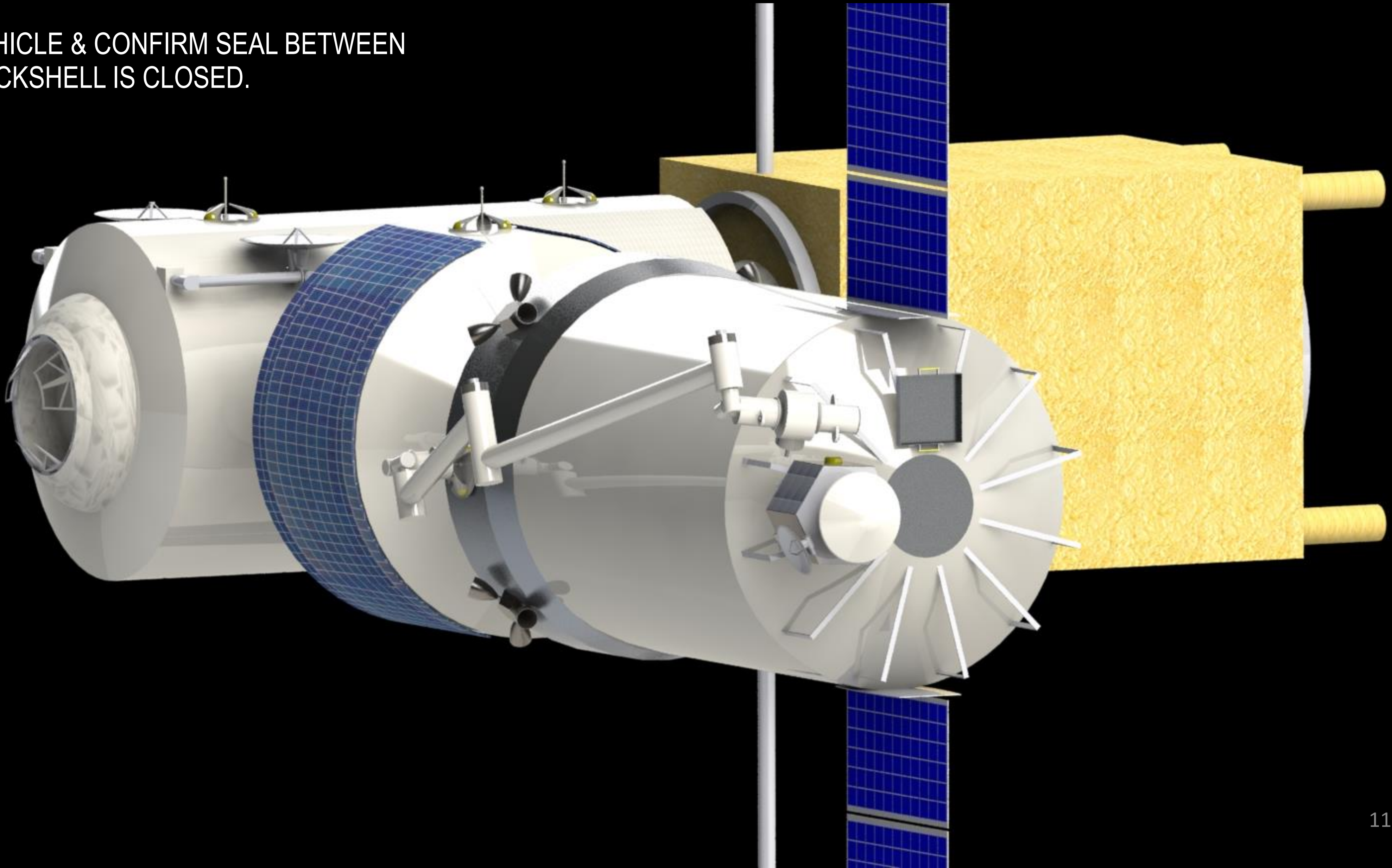
DEMO MISSION- MISSE LIKE SAMPLE RETURN

CONFIRM SAMPLE TRAY IS SECURE IN ENTRY VEHICLE
(INTERFACES TBD)



DEMO MISSION- MISSE LIKE SAMPLE RETURN

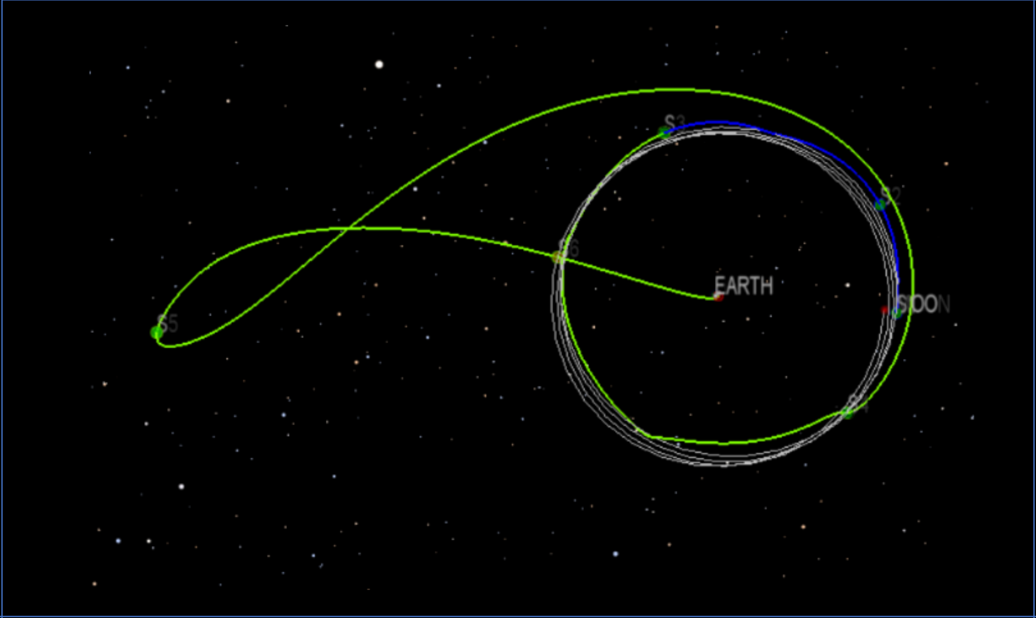
CLOSE ENTRY VEHICLE & CONFIRM SEAL BETWEEN
HEATSHIELD & BACKSHELL IS CLOSED.



INBOUND TRAJECTORY TRADES

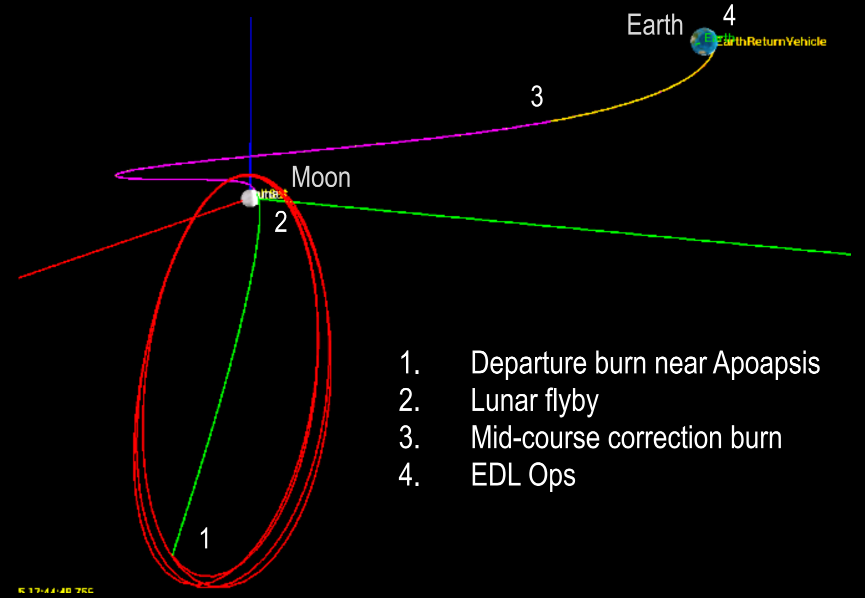
LOW THRUST

Consider utilizing Logistics Module as return spacecraft element. Low thrust trajectory can add an additional 4-5 months of deep space operations time with LM destructive re-entry or heliocentric disposal.



HIGH THRUST

Consider utilizing dedicated small spacecraft element with high thrust capability for quick return times (3-5 days).



	LOW THRUST	HIGH THRUST
Departures/month	4	4-?
ΔV required (m/s)	10-100 m/s	300-500 m/s
Transit time (d)	100-180	3-5
S/C Disposal Options	Destructive Reentry or Heliocentric Orbit*	Destructive Reentry or Heliocentric Orbit

*Current Logistics Module (LM) Ops has LM disposed in heliocentric orbit, Dragon XL has limited ΔV capability

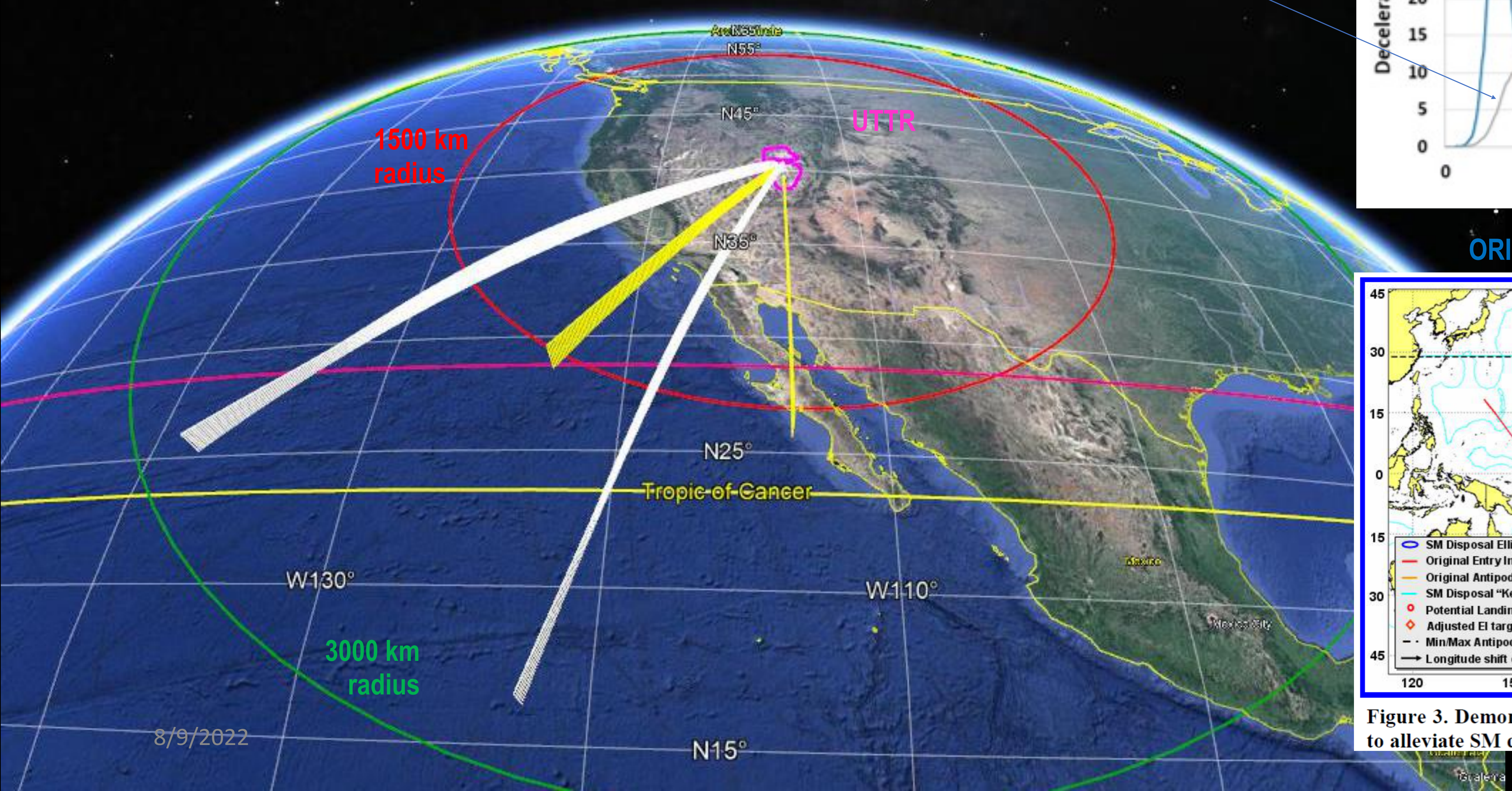
EDL DESIGN & RECOVERY OPERATIONS TRADES

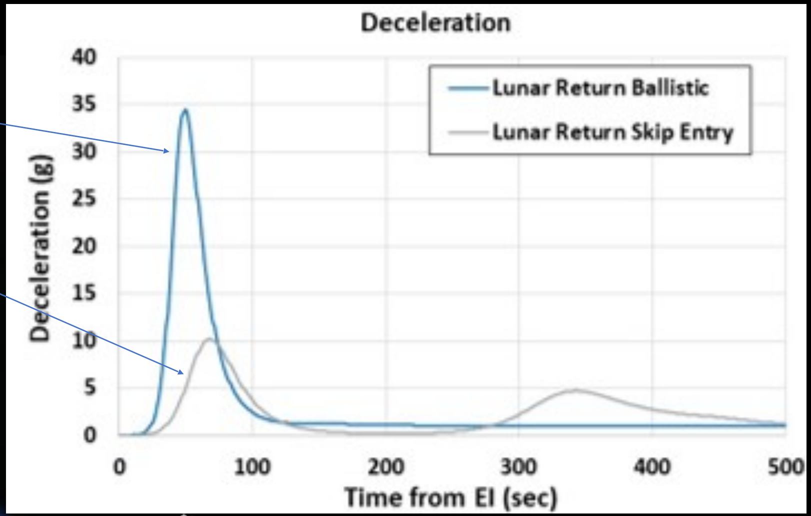
BALLISTIC ENTRY TRAJECTORIES- *increased deceleration loads*

Stardust geometry @ – 6 deg EFPA, ~1500 km max down range

GUIDED ENTRY TRAJECTORIES- *capability to manage deceleration loads*

Lifting vehicle configurations provide increased down & cross range & greater operational flexibility





ORION LUNAR RETURN STRATEGY

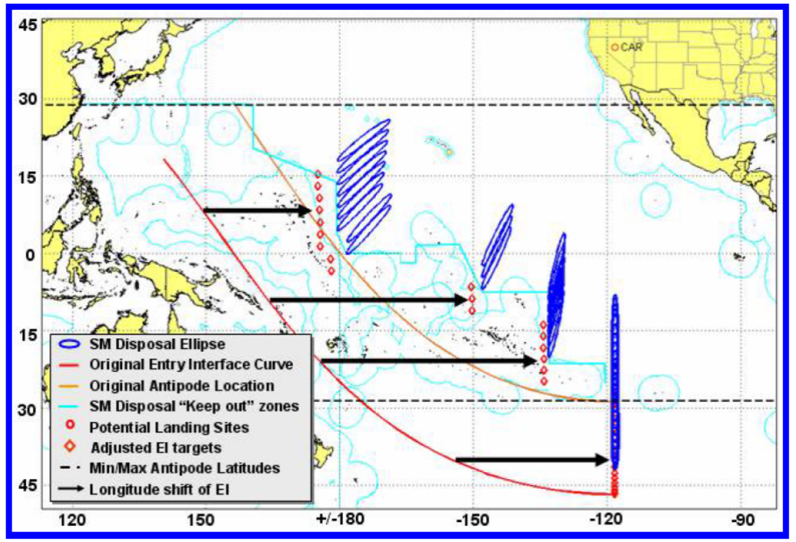


Figure 3. Demonstration of longitude and azimuth control concept to alleviate SM disposal issues.

SUMMARY

FLY SUPPLY EXPLORE

<u>Opportunity:</u>

- Feasibility of a small spacecraft-based return capability utilizing the Deep Space Logistics module as the outbound transportation host to facilitate rendezvous and proximity operations at Gateway established.
- Identified key interfaces and operational segments to study in further detail.

<u>Approach:</u>

- Assessed near-term demonstration mission options such as utilizing external robotic arm to demonstrate return ~10 kg of materials exposed to Gateway orbit or similar operational scenario.
- Emphasized near-term use cases that can be examined to maximize scientific and technological progress that can evolve with science/technology needs and operational capabilities.

<u>Mission Design:</u>

- Utilized ESPA Grande class small spacecraft with power, communication, propulsive, and navigation performance noted.
- Examined other payload options and opportunities to expand the architecture trade space for deceleration and temperature sensitive mission concepts.

<u>Future Work:</u>

- Examine how an on-demand payload return capability could be leveraged by Gateway community and commercial partners.
- Understand how cost/returned kg scales with anticipated needs.