OSCAR: Crew-Assisted Lunar Sample Return with Orion

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Orion Sample Capture and Return (OSCAR)

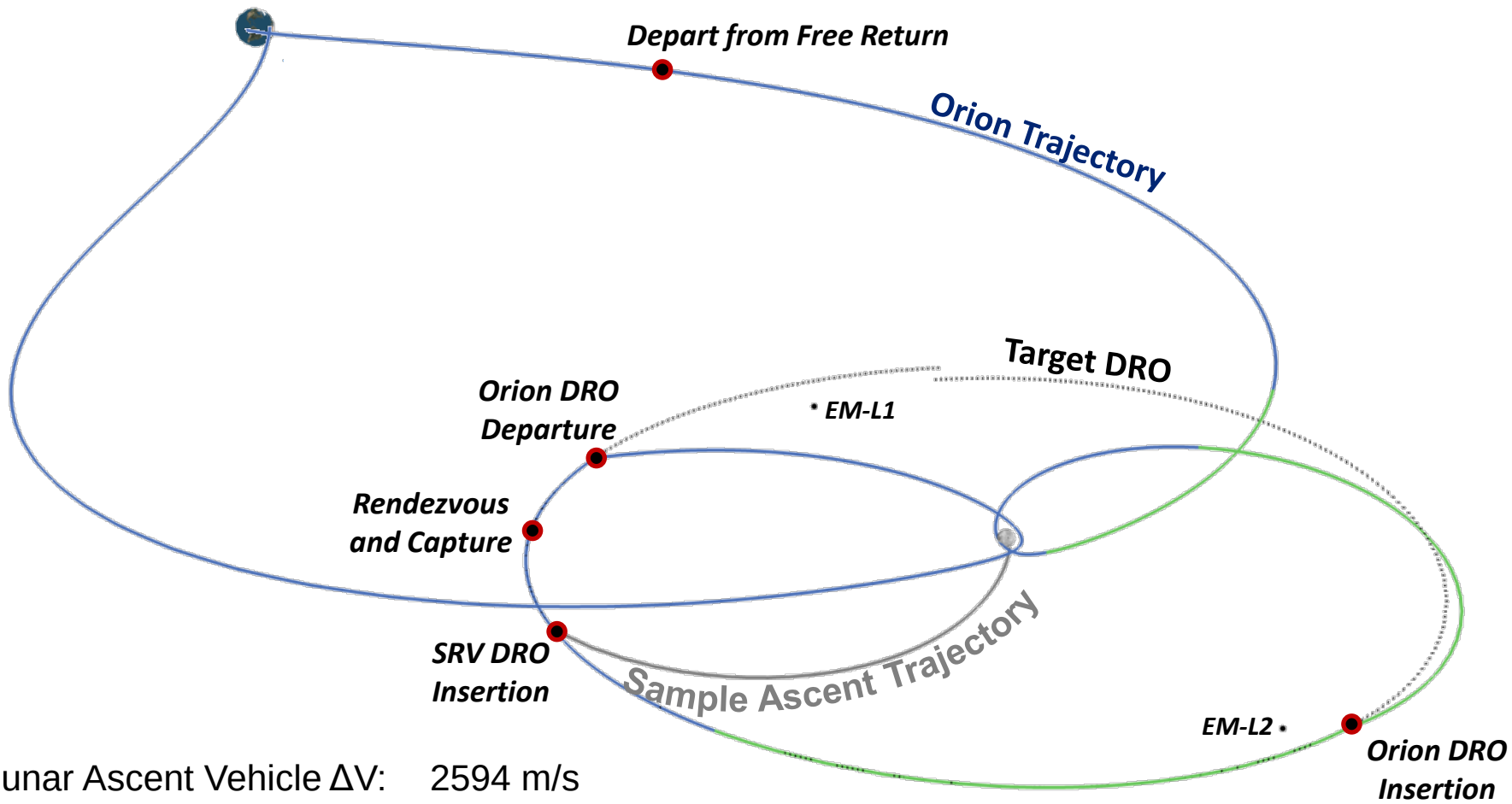
- **Several groups have considered using Orion for sample return from the Moon. For example, JPL estimated that an Orion/MoonRise hybrid could return 10X as much sample as the baseline robotic mission**

  (L. Alkalai et al. 2013, see reference page)

- **Working with JPL, Lockheed Martin has developed that mission concept in more detail**
- **The resulting "OSCAR" sample return capability could be used for lunar, asteroid, or Mars samples**
- **However, this is not currently part of the baseline Orion program**

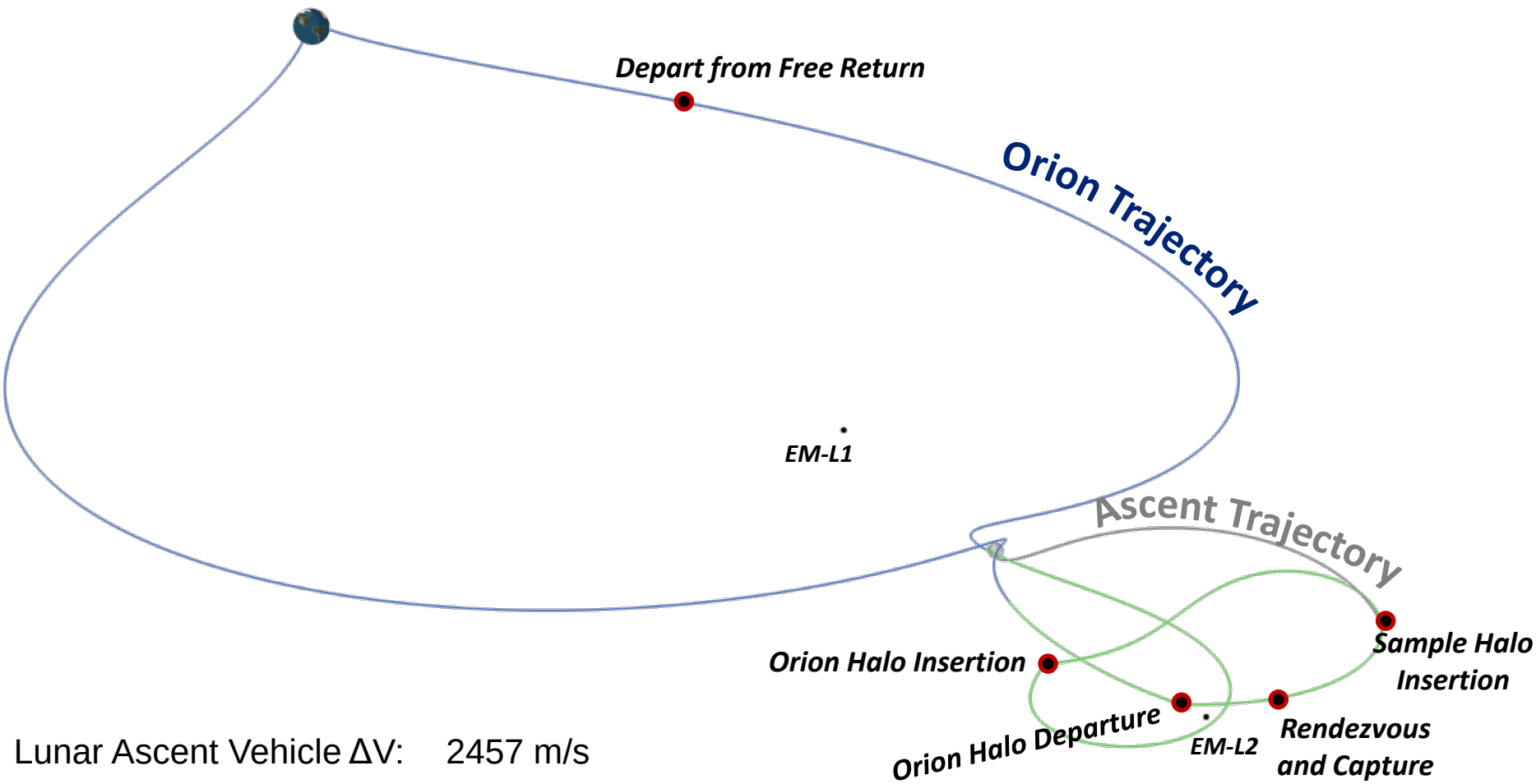
MoonRise Image courtesy JPL

Trajectory for Capture in DRO



Lunar Ascent Vehicle ΔV:	2594 m/s
Orion ΔV	1030 m/s

Trajectory for Capture in L2 Manifold

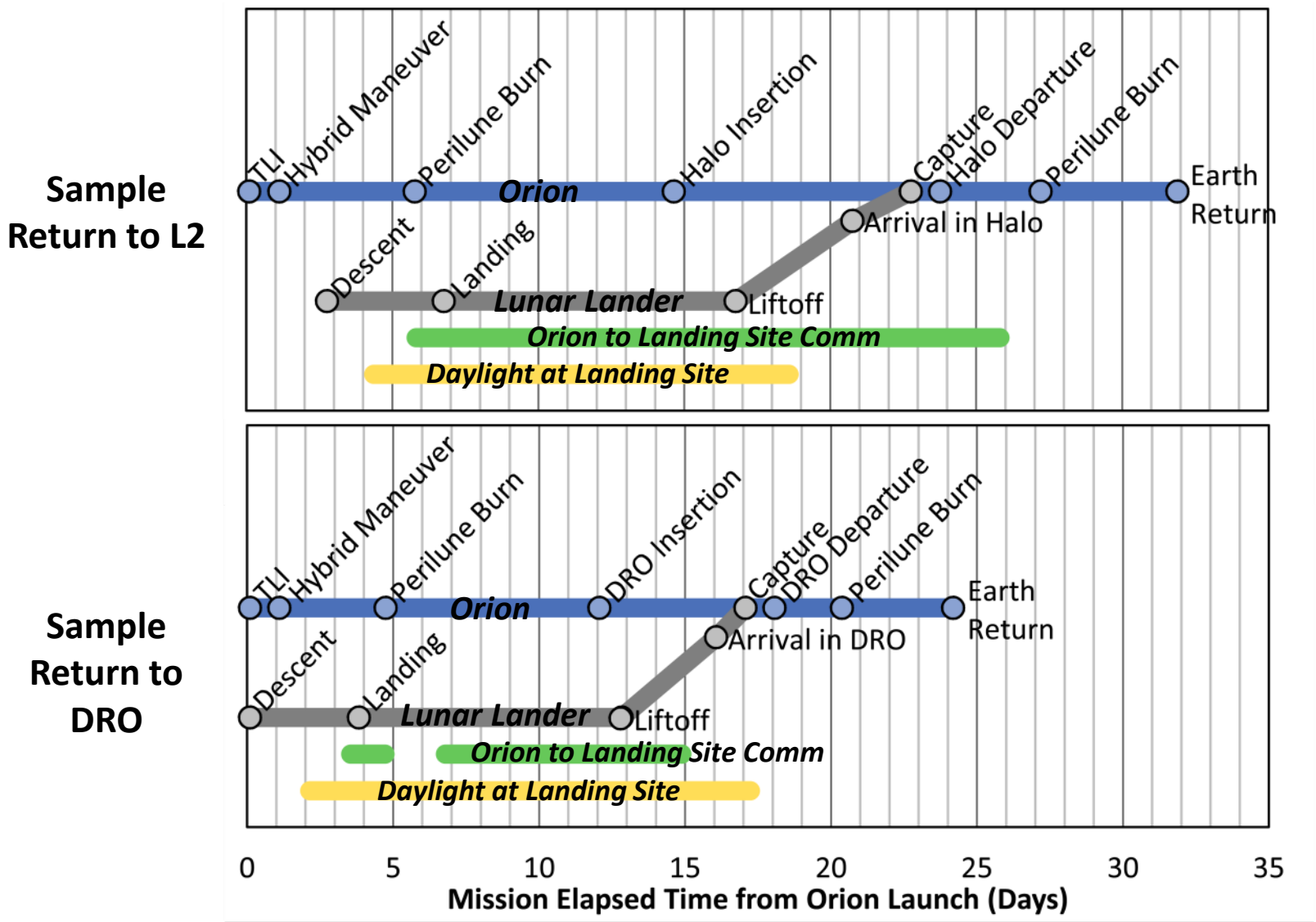


Lunar Ascent Vehicle ΔV: 2457 m/s

Orion ΔV 759 m/s

Combined Trajectory by JPL

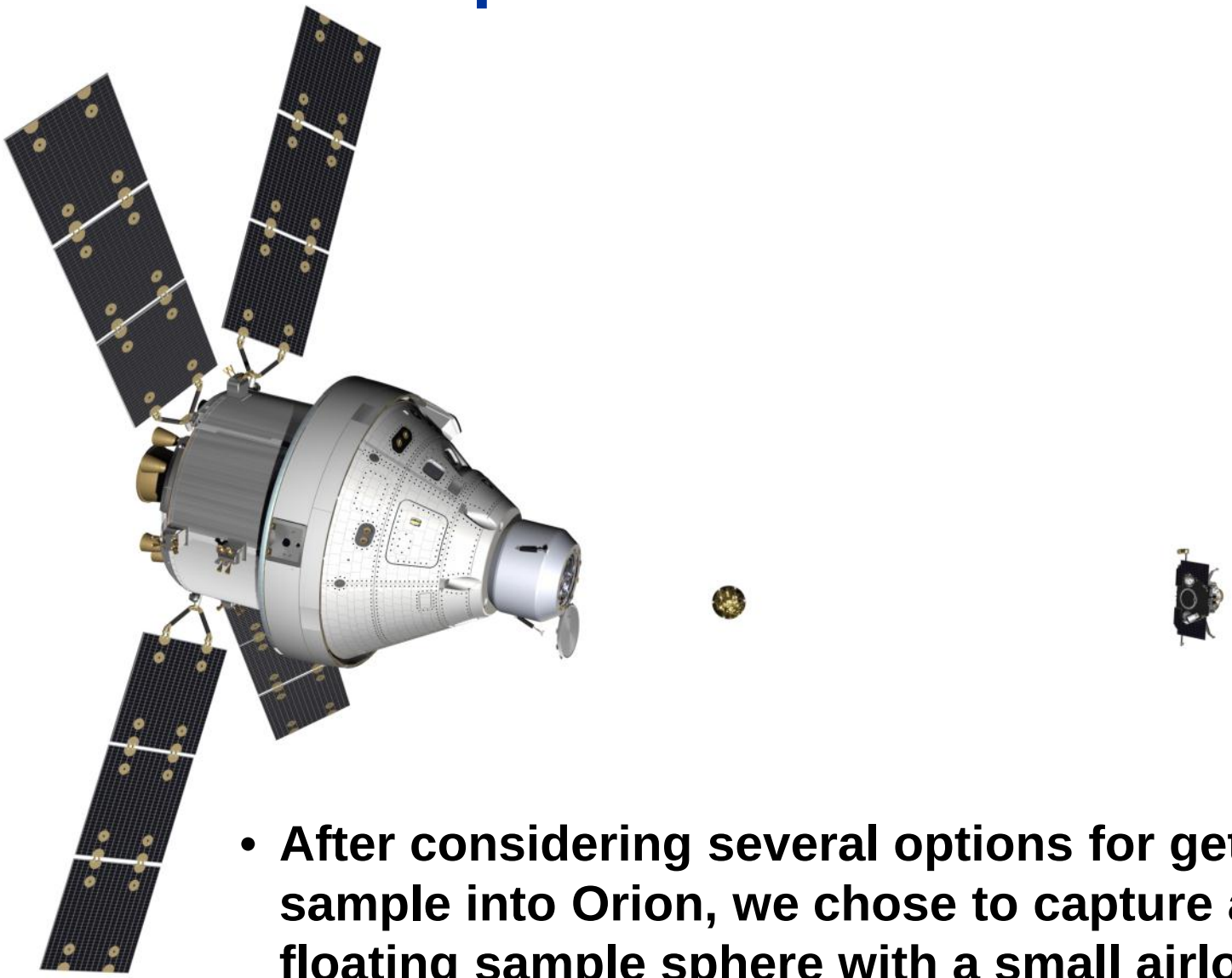
Mission Timeline Comparison



The Orbital Mechanics Details

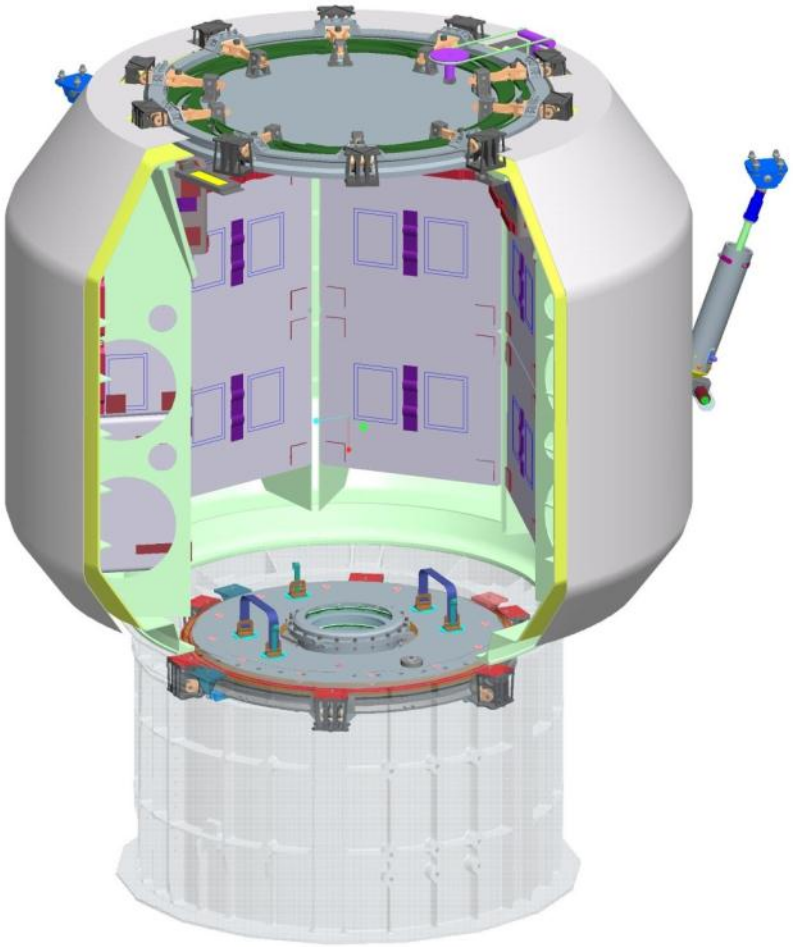
- Constructed a mission where Orion travels to either a DRO or L2 halo orbit to…
  - Act as a communications relay for a lunar farside science mission
  - Retrieve sample from robotic Lunar Ascent Vehicle
- Target L2 orbit is small amplitude manifold (not really a halo, but similar) about 65,000 km beyond the moon
- Target DRO has minimum ~70,000 km and max ~90,000 km distance from the Moon
- Both Orion and Lunar Ascent Vehicle trajectories were integrated into a mission timeline
  - Total mission duration for Orion must be less than ~32 days
  - Allowed for ~3.5 day descent of SRV from EM-L1 or EM-L2 halo orbit to center of South Pole-Aitken Basin
  - If line-of-sight from landing site to Orion is not continuous, Orion must at least be able to see the landing event for relay purposes
  - 9 to 10 days of science and sample collection
  - Sample ascent to L2 or DRO allowed to take as long as needed as long total mission duration not violated
  - Included 1-2 days for rendezvous, capture, and departure
- Mission synchronized with solar cycle such that science mission occurs during lunar day at site

Selected Sample Transfer Method



- **After considering several options for getting the sample into Orion, we chose to capture a free-floating sample sphere with a small airlock**

OSCAR Module



Orion Sample Capture and Return (OSCAR) module mounts to Orion front hatch

Three Functions:

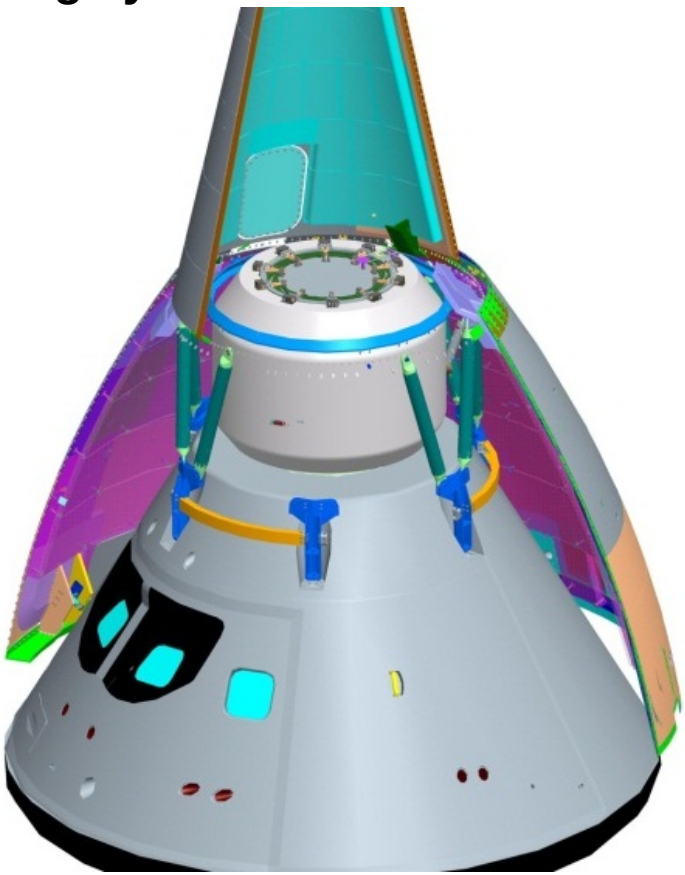
- **Added cargo storage**
- **Trash disposal airlock**
- **Sample capture airlock**

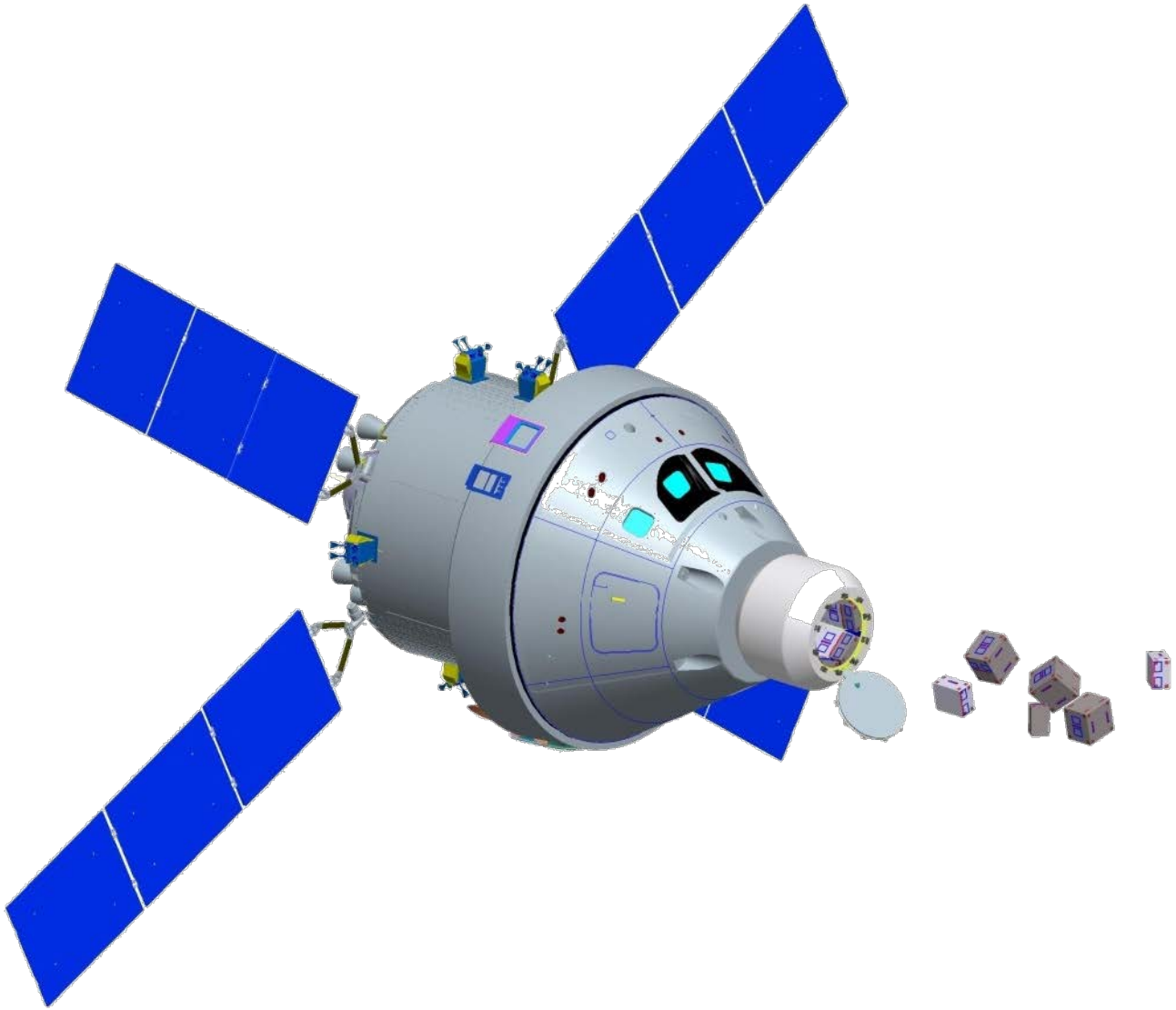
Roughly 300-350 kg empty mass

About 2 m^3 useful cargo space

OSCAR Module Launch Configuration

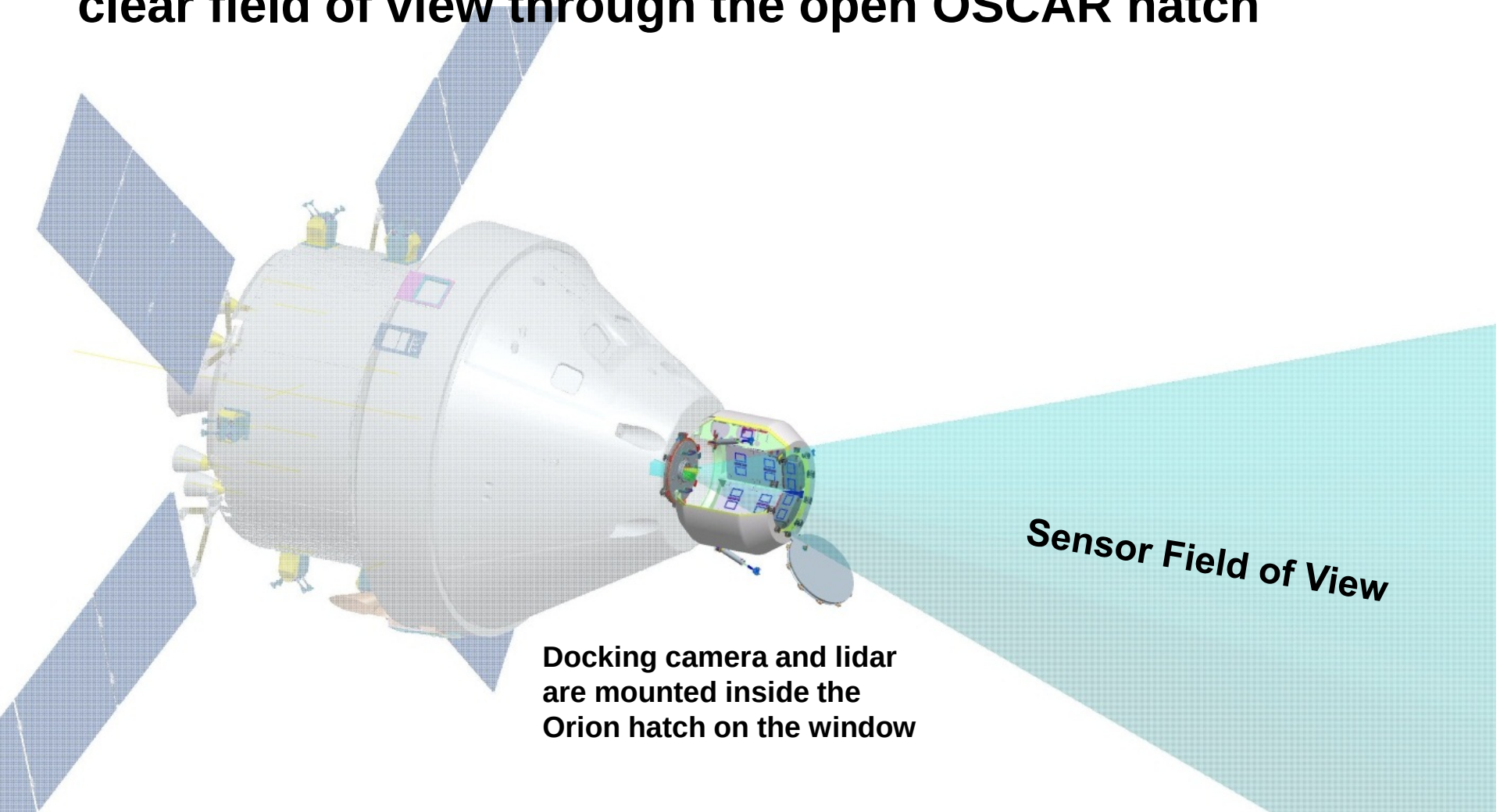
OSCAR module is carried inside the Boost Protective Cover underneath the Launch Abort System in place of a docking system





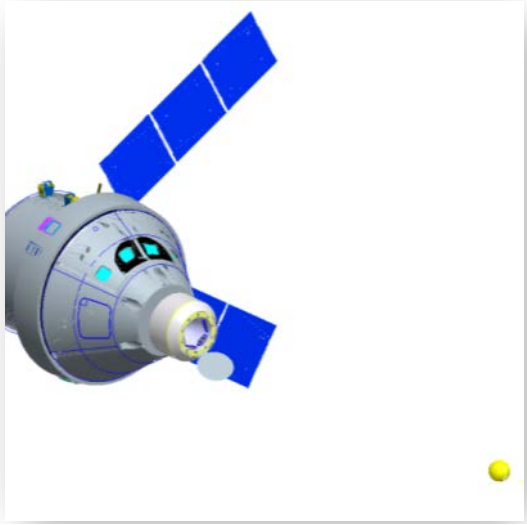
OSCAR module provides a way to store extra consumables and then dispose of trash

Orion relative navigation sensors are mounted on a window on the front of the Crew Module, and have a clear field of view through the open OSCAR hatch



Orion Sample Capture Process

1

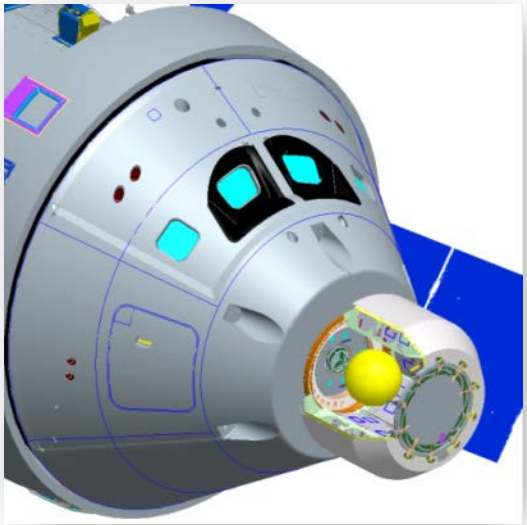


Hatch open, rendezvous with sample

2

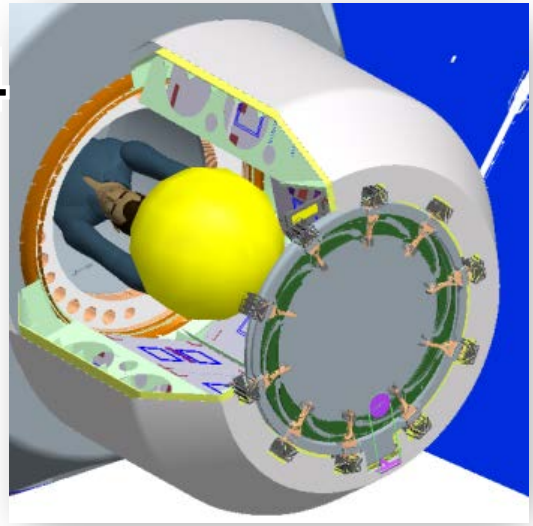
Capture sample

3



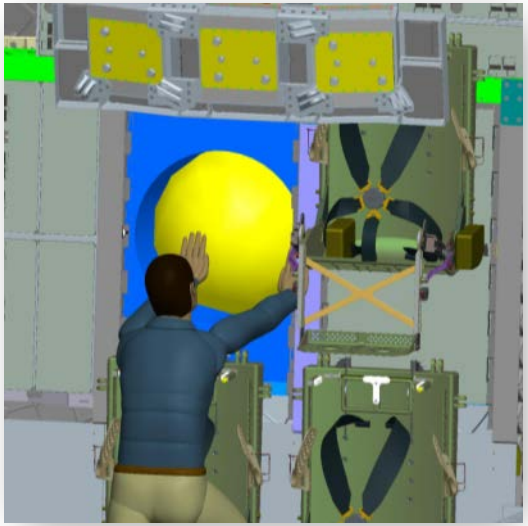
Close outer hatch, repressurize

4



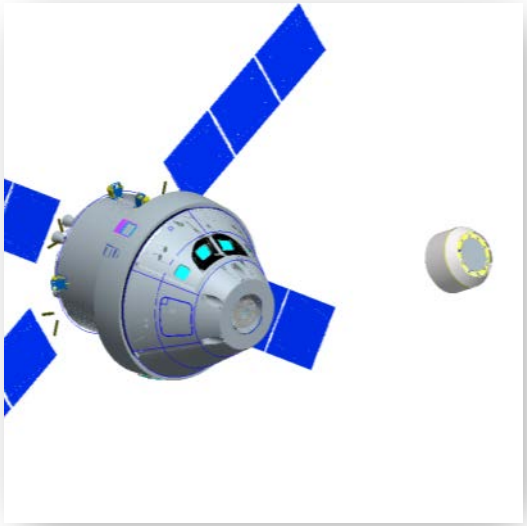
Open Orion forward hatch to access sample container

5



Astronauts bring sample sphere inside Orion and stow it behind seats

6

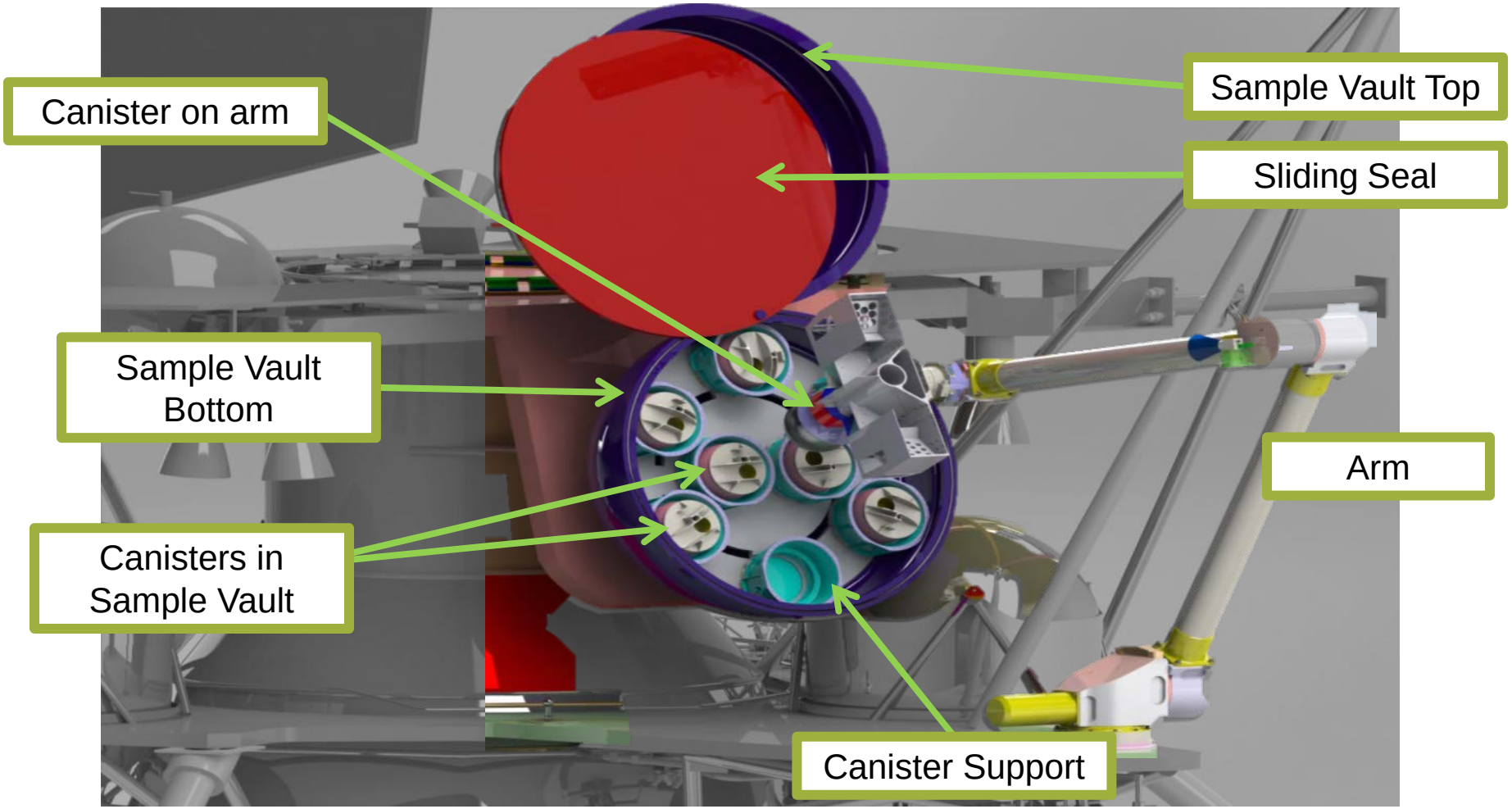


OSCAR is jettisoned before reentry

Sample Sphere Capture Requirements

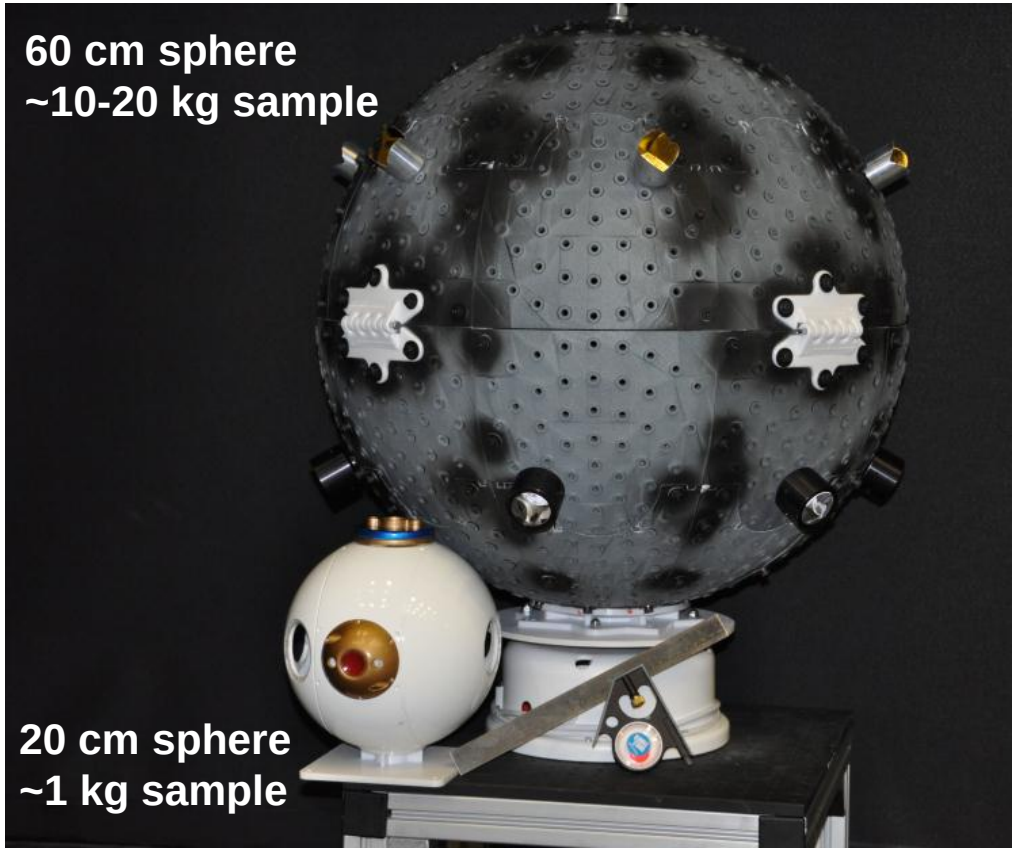
- Must be able to detect the sample sphere from a few km away and track it with sufficient precision to approach and capture it
- Sphere is passive: has optical retroreflectors for detection by Orion lidar but no avionics, power, or telemetry
  - Corner cubes are assumed to be flush-mounted in real sphere, but are external protrusions in the test articles.
- Maximum 60 cm (24 inch) diameter sphere
- 50 kg max total mass (empty + collected sample mass)
  - Max sample mass is determined in part by mass of container
- Center of mass may be offset from center of sphere
- Sphere may be spinning or tumbling up to a few RPM
- Astronauts will be able to move sample sphere to stow it, but will not open it
  - No manipulating samples or repackaging sample cans in other stowage, no exposure of astronauts to lunar dust

Multiple Canister Sample Sphere Concept

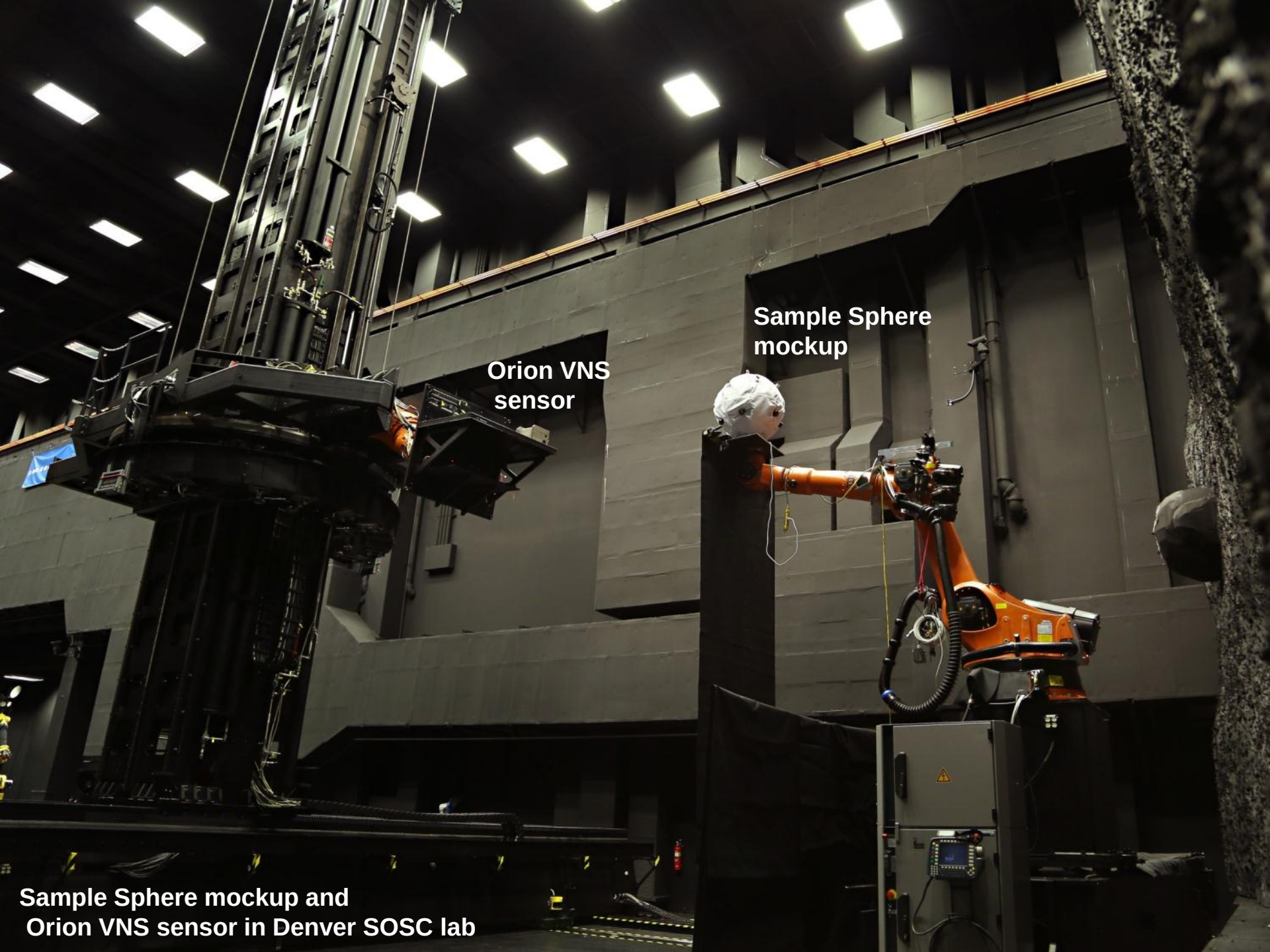


Design and artwork by JPL

Testing Tracking of the Sample Sphere

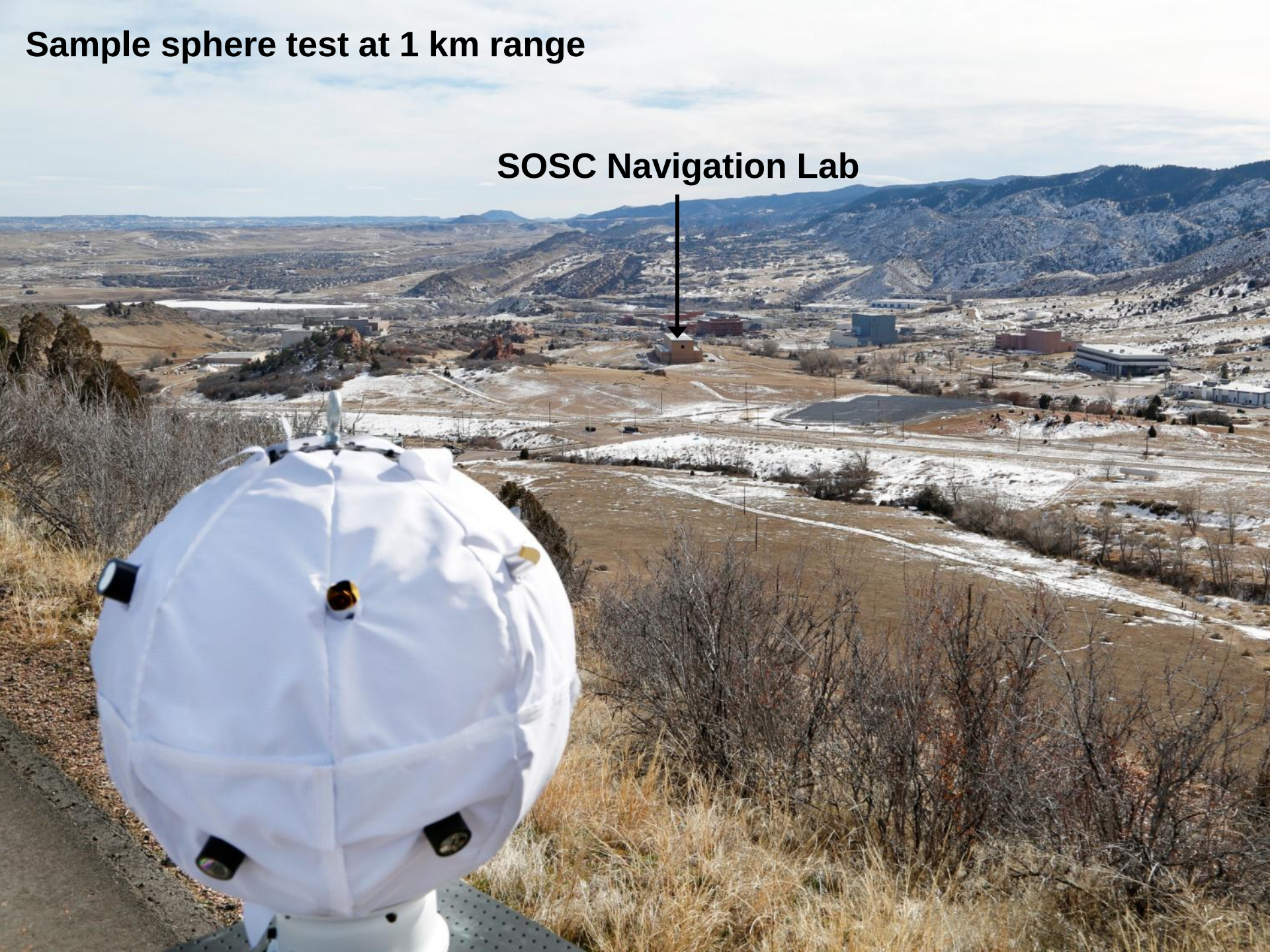


- **LM is doing relative navigation testing with mockup sample spheres in our Space Operations Simulation Center (SOSC) to demonstrate Orion's ability to detect and track the sample container**



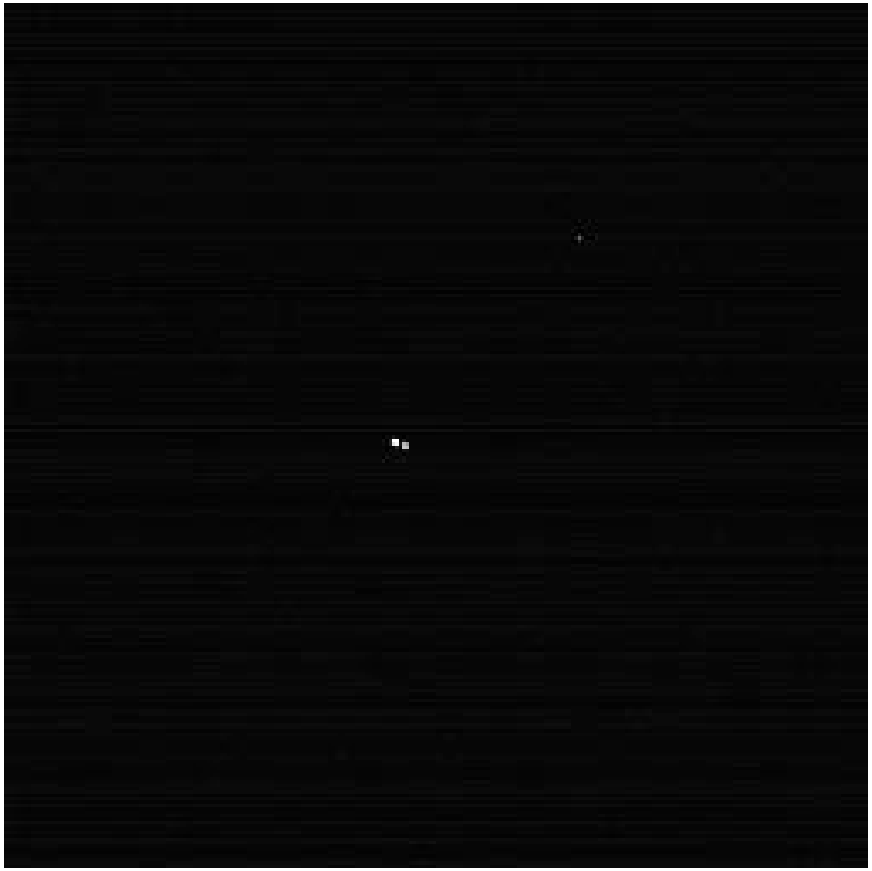
Sample Sphere mockup and
Orion VNS sensor in Denver SOSC lab

Sample sphere test at 1 km range

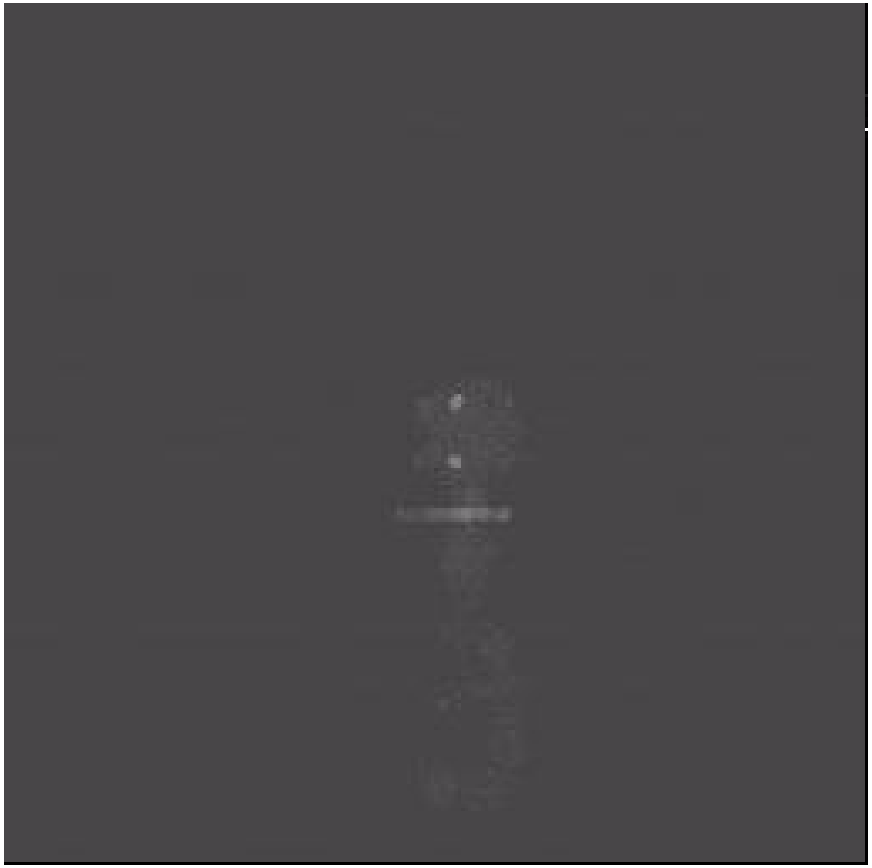


Orion VNS Lidar Views

Orion VNS view of sample container separating from Lunar Ascent Vehicle at 1 km range

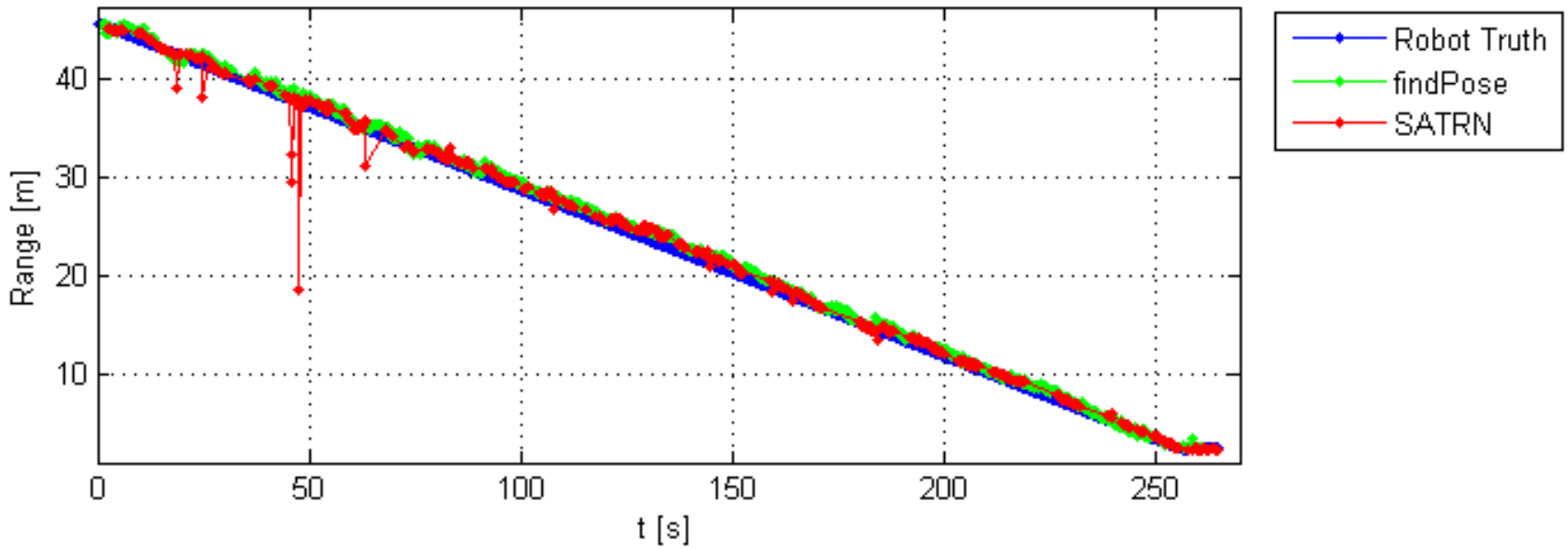


Orion Lidar view of Sample Vault at close range (click to play video)



Relative Navigation Capability

- **Orion's standard sensor suite can detect a passive sample sphere from at least 2 km away**
- **Using two different algorithms (findPose and SATRN) the sensors can determine the position of the sample sphere with enough accuracy and precision for capture**



Conclusion

- **EM-L2 is a good location to telerobotically explore the lunar farside**
- **A 31-day mission to a small halo orbit at EM-L2 can be performed by the Orion vehicle using a mission extension kit or a reduction in crew size**
- **A lunar farside sample return mission provides opportunity for international cooperation**
- **The use of the Orion spacecraft achieves science and human spaceflight objectives and may allow for greatly increased sample mass**
- **Good feed forward to Mars orbit sample capture for Mars Sample Return**
- **Lockheed Martin is actively partnering with industry participants and studying concepts that demonstrate Orion's ability to detect, track, capture, and return a sample canister returned from the lunar surface**

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Washington University, St Louis: Brad Jolliff

University of Colorado: Jeff Parker, Chelsea Welch, Kate Davis

Additional References

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