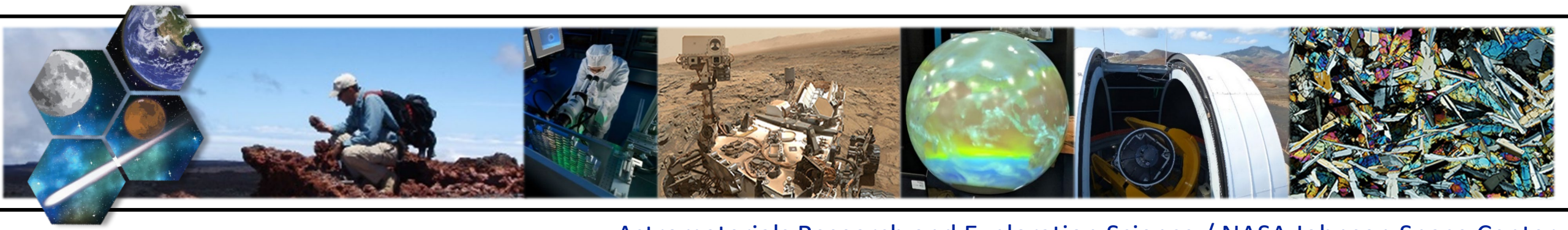


Astromaterials Research and Exploration Science / NASA Johnson Space Center

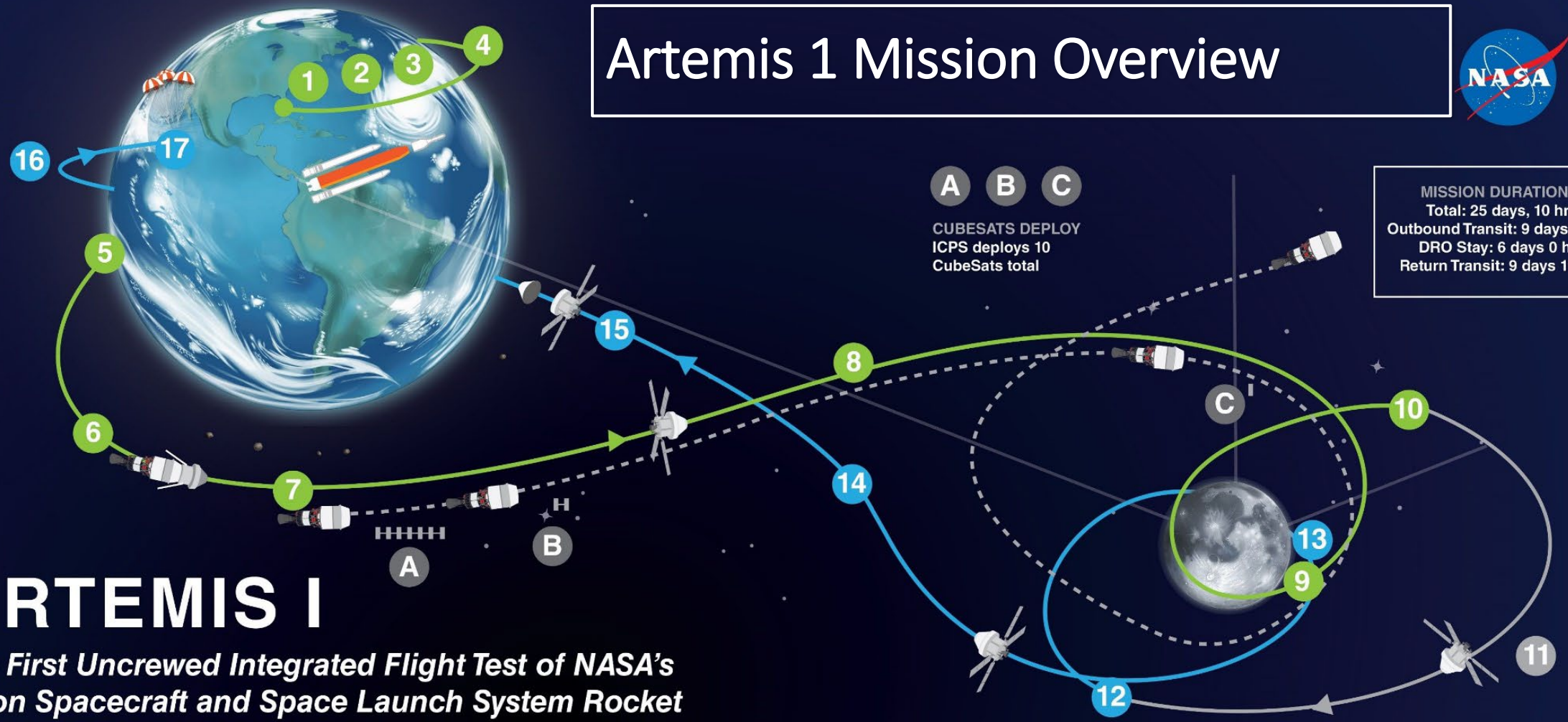
A Selection of Artemis-I Mission Support Lessons Learned Image Science and Analysis Group (ISAG) Perspective

Kenton Fisher

Lunar Surface Science Workshop

December 5, 2023

Artemis 1 Mission Overview



CUBESATS DEPLOY
ICPS deploys 10 CubeSats total

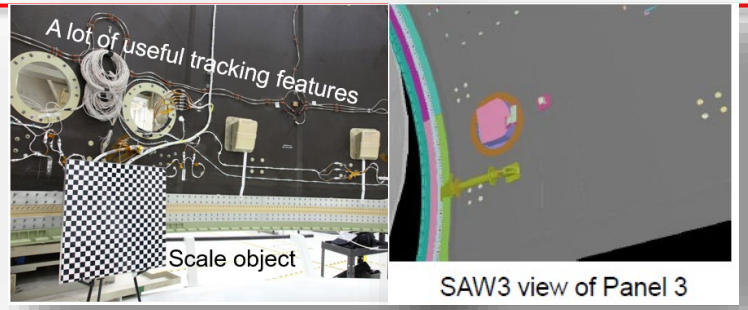
MISSION DURATIONS:
Total: 25 days, 10 hrs
Outbound Transit: 9 days 13 hrs
DRO Stay: 6 days 0 hrs
Return Transit: 9 days 19 hrs

ARTEMIS I

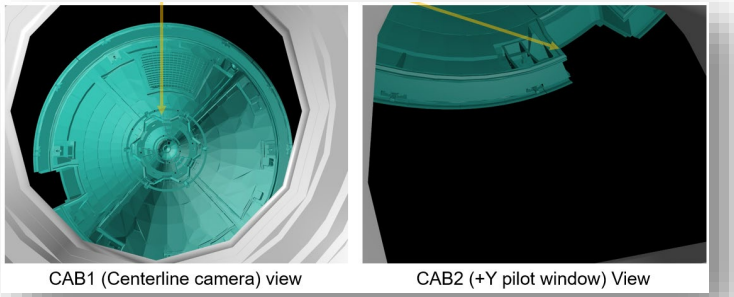
The First Uncrewed Integrated Flight Test of NASA's Orion Spacecraft and Space Launch System Rocket

1. **LAUNCH (11/16/22)**
   SLS and Orion lift off from pad 39B at Kennedy Space Center.
2. **JETTISON ROCKET BOOSTERS, FAIRINGS, AND LAUNCH ABORT SYSTEM**
3. **CORE STAGE MAIN ENGINE CUT OFF**
   With separation.
4. **PERIGEE RAISE MANEUVER**
5. **EARTH ORBIT**
   Systems check with solar panel adjustments.
6. **TRANS LUNAR INJECTION (TLI) BURN**
   Maneuver lasts for approximately 20 minutes.
7. **INTERIM CRYOGENIC PROPULSION STAGE (ICPS) SEPARATION AND DISPOSAL**
   ICPS commits Orion to moon at TLI.
8. **OUTBOUND TRAJECTORY CORRECTION BURNS**
   As necessary adjust trajectory for lunar flyby to Distant Retrograde Orbit (DRO).
9. **OUTBOUND POWERED FLYBY**
   105.5 miles from the Moon; targets DRO insertion.
10. **LUNAR ORBIT INSERTION**
    Enter Distant Retrograde Orbit.
11. **DISTANT RETROGRADE ORBIT**
    Perform a half revolution (6 day duration) in the orbit 43,730 miles from the surface of the Moon.
12. **DRO DEPARTURE**
    Leave DRO and start return to Earth.
13. **RETURN POWERED FLYBY**
    RPF burn prep and return coast to Earth initiated. Closest approach in middle of burn, 81 miles.
14. **RETURN TRANSIT**
    Return Trajectory Correction burns as necessary to aim for Earth's atmosphere.
15. **CREW MODULE SEPARATION FROM SERVICE MODULE**
16. **ENTRY INTERFACE**
    Enter Earth's atmosphere.
17. **SPLASHDOWN (12/11/22)**
    Pacific Ocean landing within view of the U.S. Navy recovery ship.

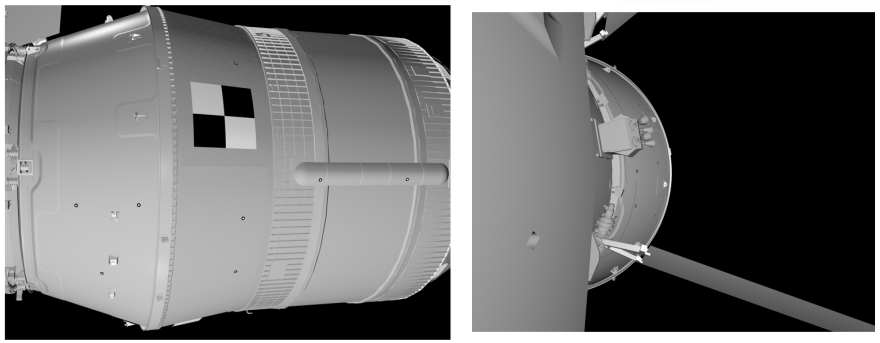
Mission Imagery Analyses



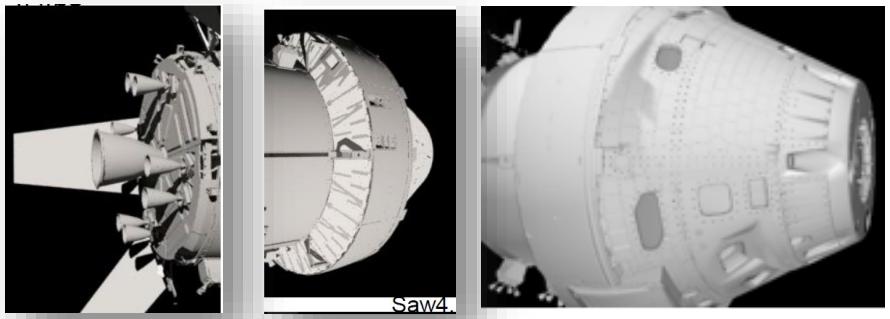
SAJ Fairing Jettison



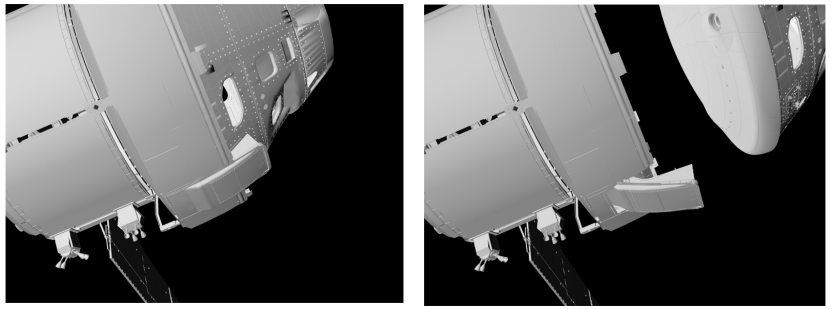
LAS Jettison



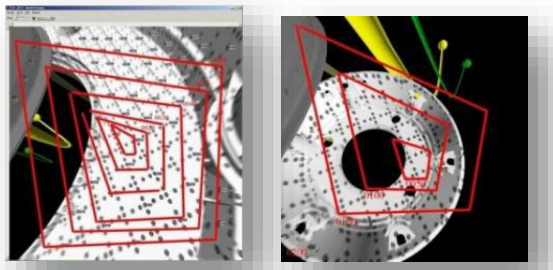
ICPS Separation



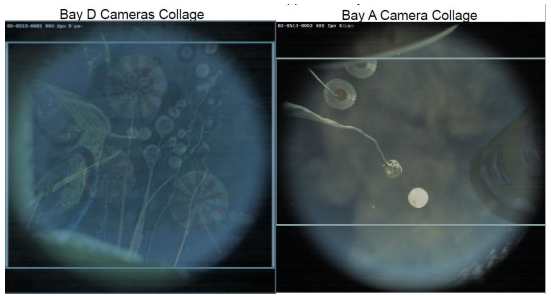
Service and Crew Module Inspection



CM Separation



FBC Separation



Chute Performance

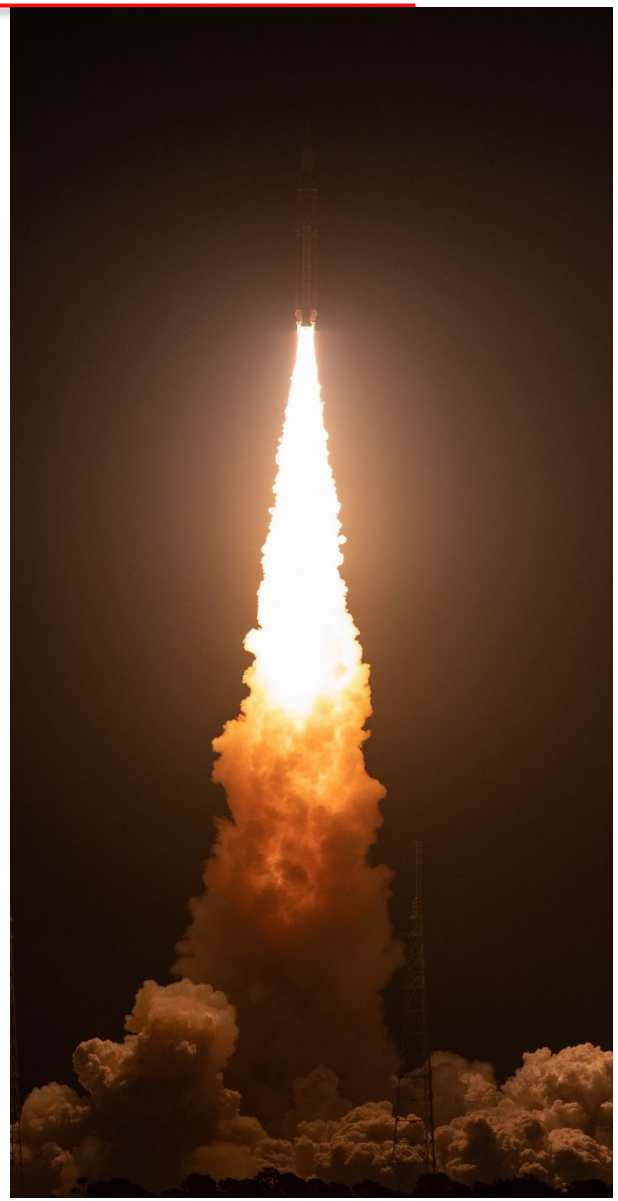
Mission Operations - IOT Support Overview

Imagery Ops Team (IOT) fulfilled two functional Artemis mission needs:

1) **Imagery operations and data management**
   - Three console positions staffed in B36 Imagery Ops Center (IOC)
     - Imagery Coordinator, Imagery Data, Asset Manager
2) **Imagery acquisition planning, screening and analysis**
   - Analysts staffed in B36 Imagery Science and Analysis Lab (ISAL)

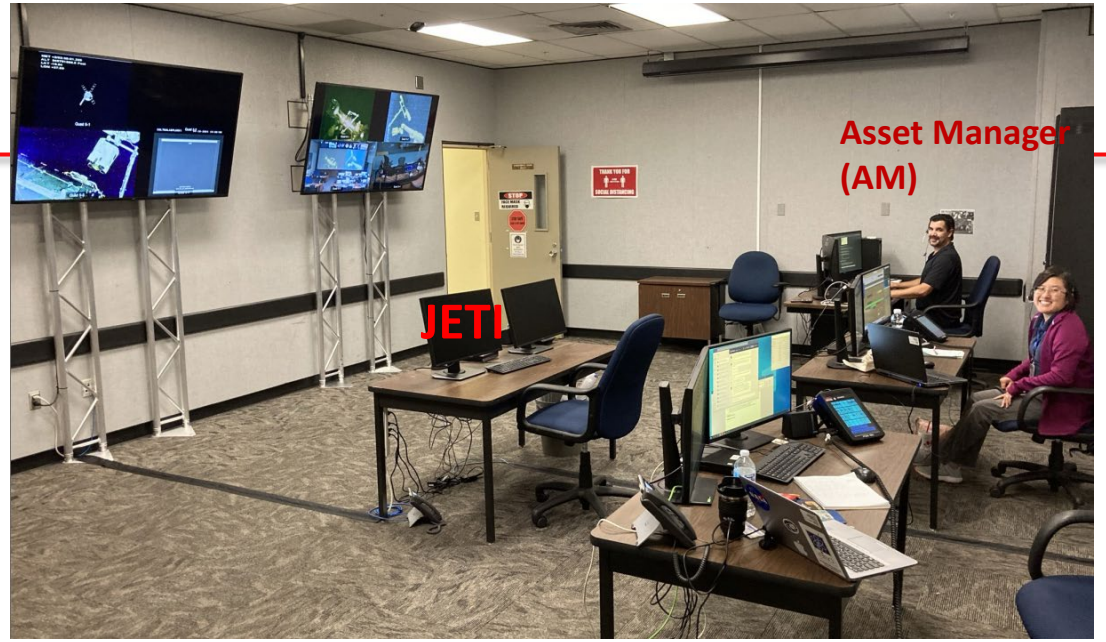
Responsibilities of the IOT include:

- Orion engineering imagery (EI) data management: managing the transfer of imagery files from camera memory to onboard memory and prioritizing/initiating the downlink of critical EI files to ground servers.
- Mission operations focal point for elements supporting Orion EI acquisition
- Imagery screening, enhancement and photogrammetric analysis in support of flight-test & mission objectives, vehicle performance, and problem solving



Imagery Science Analysis Lab

- Imagery Operations Center (IOC)
  - Staffed 24/7
- B36 / 2028 “Front Room” lab
  - Staffed during events



Video Processing

Imagery Screening

Imagery Enhancement
Video Editing
Ops Communication

Lessons Applicable to the Science Operations Community

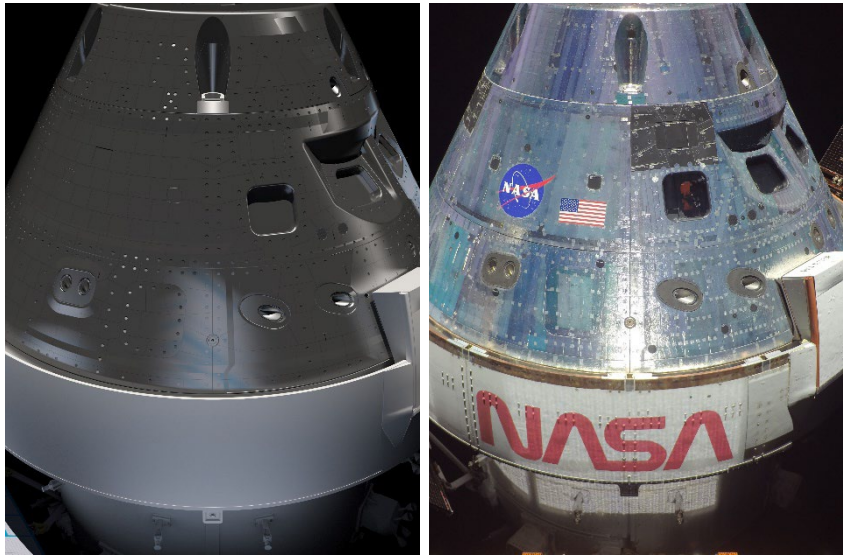
Artemis-I Pre-Flight Prep & Training for Imagery Operations

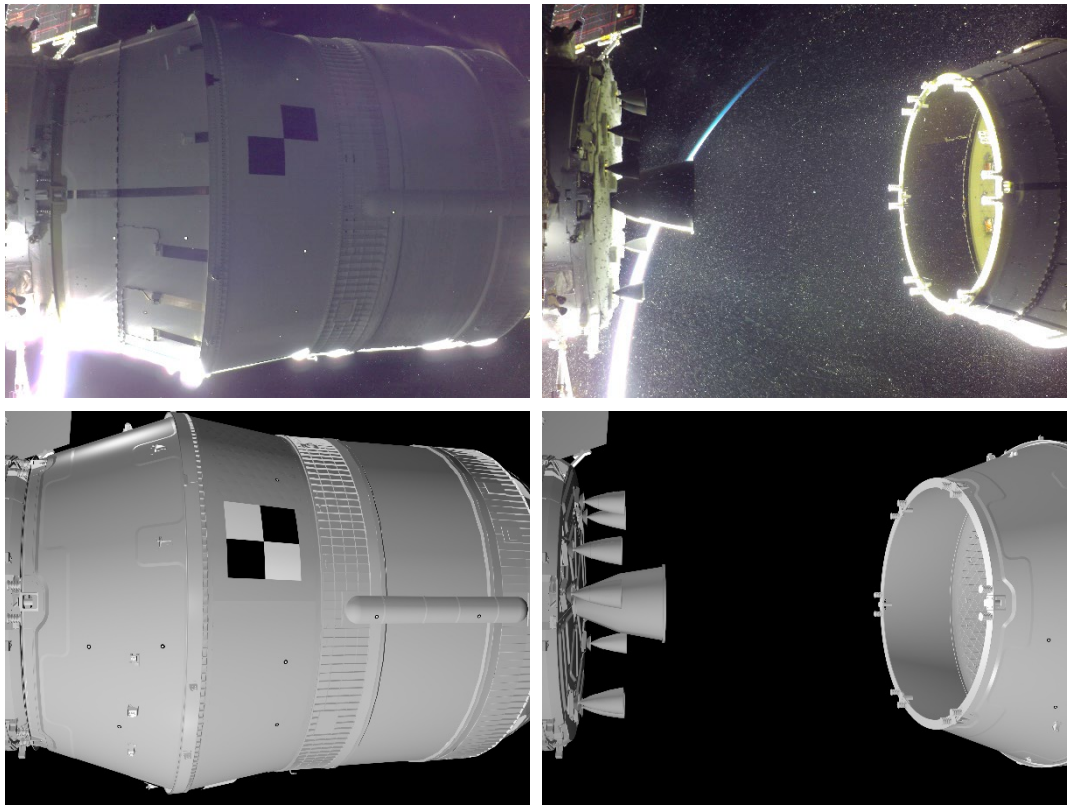
- Thorough preflight planning was a key to successfully acquiring and retrieving engineering imagery with quality adequate to support Flight Test Objective closures.
  - ISAG created an online imagery accounting and reporting database, worked with JETI on cross program planning documents, wrote Operations Interface Procedures and gave input to many FOD flight procedures.
  - ISAG hosted various paper simulations with IRD/FOD disciplines to practice interactions for imagery file handling and data management.

- Due to lack of high-fidelity simulators, our team (along with INCO and CDH) had to adjust many aspects of imagery operations on-the-fly during the mission.
  - Regular sims did not provide capability to practice Orion imagery operations so we could only realistically train if a sim utilized Lockheed Martin test facilities (rare).
  - The first end-to-end operation of acquiring imagery, retrieving and transferring through onboard and ground network systems occurred during the mission.

Artemis-I Imagery Analysis Pre-Flight Planning

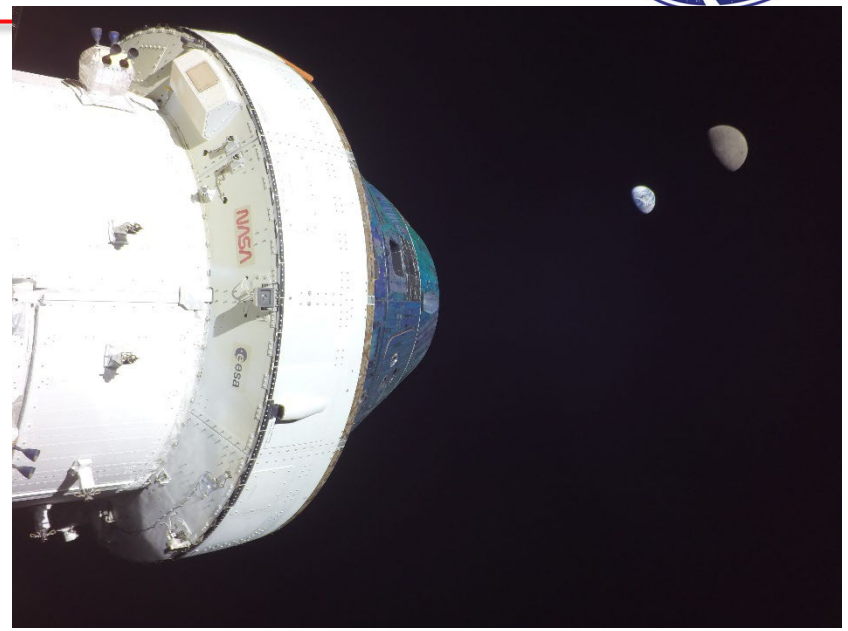
- Pre-flight coordination with all stakeholders (engineering, PAO, operators, ground systems, science team) is critical.
- Based on the compilation of engineering imagery analysis needs, optimal camera pointing and settings were defined.
- CAD-based simulation of imagery (previsualization) was implemented as a tool to aid in definition of camera pointing and event camera settings.
- Environment properties and imagery system effects - including lighting, exposure, blur and material reflectivity – are highly variable and pre-flight modeling can currently only provide marginal insight on resulting impacts.

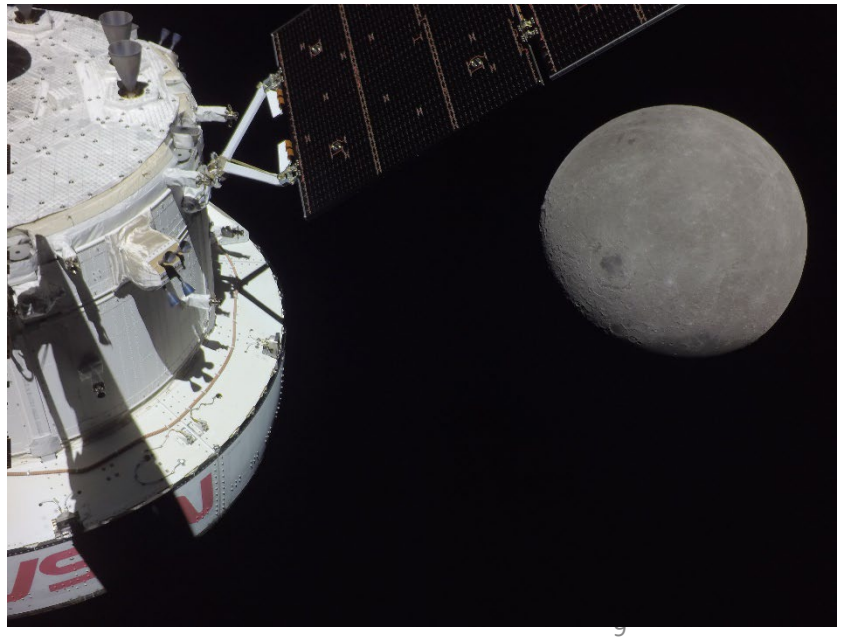




Artemis-I Imagery Analysis Task Documentation

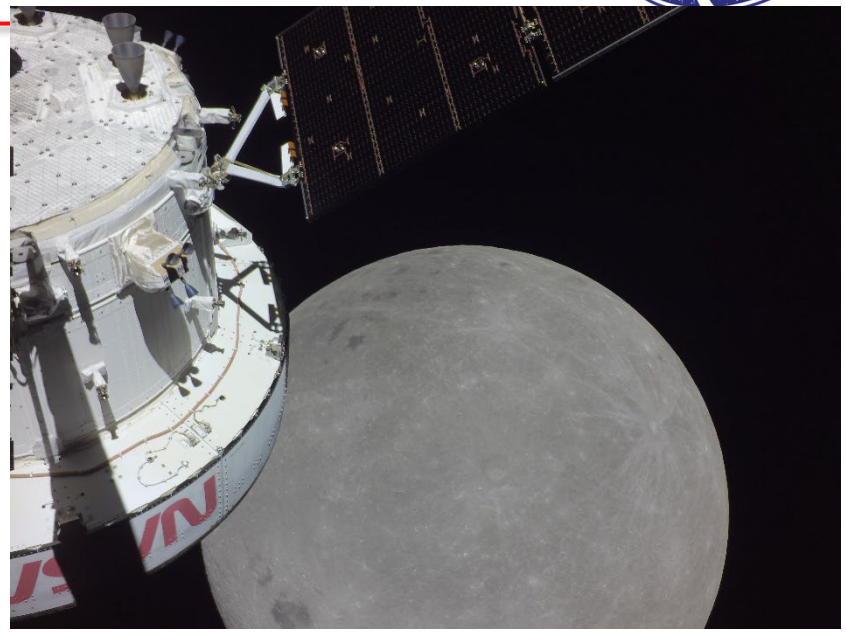
- Artemis-I flight test objectives are defined in Orion Multi-Purpose Crew Vehicle Program EM-1 and EM-2 Flight Test Objectives.’
  - The onboard camera architecture and settings were defined specific to the imagery analysis needs. Science specific settings need to be defined and included in procedures prior to mission.
- Data Analysis Plan defines schedules for post-flight analysis and reporting activities, preflight activities to support the timely completion of the post-flight activities, and identification of data needed to satisfy the Flight Test Objectives.
  - Science team should prepare their own list of flight objectives and timeline for post-flight analysis.

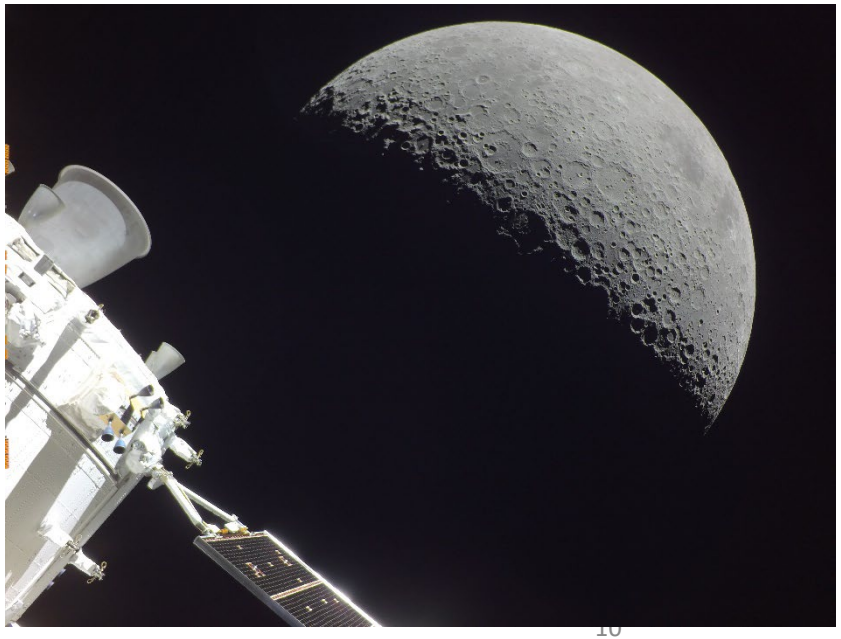




Artemis-I In-flight Imagery Ops and Data Management

- Having dedicated personnel with IT expertise to help manage files and to route/process imagery is crucial.
- The process to identify the onboard imagery files, transfer them to camera controller, downlink to the ground, and post them to the JSC Imagery repository required the coordinated efforts of the ISAG Imagery Ops Team, MCC INCO & CDH flight controllers and IRD personnel.
- Retrieval of science imagery will be time consuming, and bandwidth limited so requests for downlinks must be realistic. Must perform preflight and live planning for every image and video file requested.
  - Very small subset of science will be downlinked during mission.





Artemis-I In-flight Imagery Ops and Data Management

- The PAO imagery plan was not fully developed and communicated prior to the mission. PAO didn't grasp how low PAO imagery was in downlink priority.
  - In addition to our duties tracking and managing Engineering Imagery, we spent a ton of time planning, executing, and downlinking PAO imagery. There were several ad hoc PAO-type events that required addition effort for the Imagery (camera settings, position), INCO (camera command scripts), GNC (attitude), and MPO (solar arrays) personnel to plan/coordinate on short notice.
  - Science imagery requests are not as simple as "take photos of the Moon". Most requests will require vehicle maneuvers and must be approved by Orion/FOD due to thermal and prop constraints, assuming they are coordinated with the imagery team/INCO/CDH.
- Export Control: Mission specific guidelines should be documented early and communicated widely prior to flight. Distribution plans for science imagery should be fully reviewed and approved prior to mission to prevent issues.

Summary of Recommendations for Science Operations

1. Clearly define science plan prior to mission, identify contact points with engineering and operations teams. Develop plan for distribution (even internal) of science imagery and get it approved by export control.
2. Frequently participate in integrated simulations to test interactions with engineering and operations teams.
3. Develop ‘certification’ process for Science Evaluation Room roles and include full team in sims.
4. Have dedicated personnel with IT expertise to help manage files and to route/process imagery.
5. Proper planning prevented issues with network connectivity or communication with JSC MCC, KSC, and MFSC personnel. Have a backup plan.