

National Aeronautics and Space Administration



ARTEMIS II

LUNAR SCIENCE OPERATIONS REPORT



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About the Cover

Captured from the interior of the Orion spacecraft by the Artemis II crew, this image uniquely blends the crew's camera reflection with the half-illuminated Moon. The terminator shows the cratered geologic history of the Moon, and the massive Orientale basin stands out as a brighter, light-gray patch along the northwestern lunar limb. Crescent Earth hangs suspended in space in the far background.

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FOREWORD

Artemis II saw NASA's first integration of lunar science activities into human spaceflight operations in over 50 years. The Lunar Science Team (LST) activated the SCIENCE console with the Science Officer (SO) flight control position and stood up the Science Evaluation Room (SER) and the Science Mission Operations Room (SMOR) as dedicated lunar science support rooms. This established the operational architecture for future science teams to build upon. The LST, pulled from across NASA Centers, investigated all 10 planned lunar science themes, trained the crew to be mission scientists, and deployed planetary science strategies to capture images from handheld cameras, verbal observations, and annotations from cislunar space. The mission also validated the end-to-end lunar science data pipeline and the LST archived Artemis II lunar science data publicly in NASA's Planetary Data System (PDS), setting the baseline for future Artemis science data archiving. This document captures an overview of the operations structure, pre-mission planning, and mission execution underlying those achievements. Details of the LST's science objectives and how those objectives trace through mission operations are captured in this document's companion report, the Artemis II Preliminary Lunar Science Report.

The incorporation of a Mission Control front-room flight controller position into a human spaceflight mission represents not only years of tight integration between science and flight operations but stands on the shoulders of missions and simulations from Apollo, to low Earth orbit, to the deserts of Arizona, to the ocean floor off Florida, and especially to the halls of Mission Control in Houston, Texas. The trust built over years of learning the operations language and teaching operators the language of lunar science was ultimately on display when a Science Officer worked directly with the crew during Artemis II's lunar flyby scientific exploration.

Underpinning the Science Officer's integration with flight operations is the ability of mission science teams to mesh with flight operations through the SER and the SMOR. The development of a new flight control room in Mission Control (the SER) reflects the importance that science holds in Artemis and human exploration beyond low Earth orbit, and the scientists and data specialists staffing the SER and the SMOR carried forward the ultimate goal of crew safety, vehicle safety, and mission success while seizing every opportunity to maximize the science return of this historic mission.

By weaving science into the fabric of human spaceflight operations, we were able to accomplish science objectives in big moments like the lunar flyby, as well as small corners of the mission like crew study time in transit to the Moon. This report reflects this integration: the LST presents their structure, training, and, critically, lessons learned and recommendations for future science teams supporting endeavors such as the human exploration of our Solar System. This report serves as an outbrief of the Artemis II mission's lunar science integration, and we look forward to the community building upon the progress this summarizes to maximize science return from human spaceflight missions and expand our understanding of the Solar System and the Earth-Moon system.



1.0 MISSION CONTEXT AND LUNAR SCIENCE OPERATIONS OVERVIEW

1.1 Mission Context

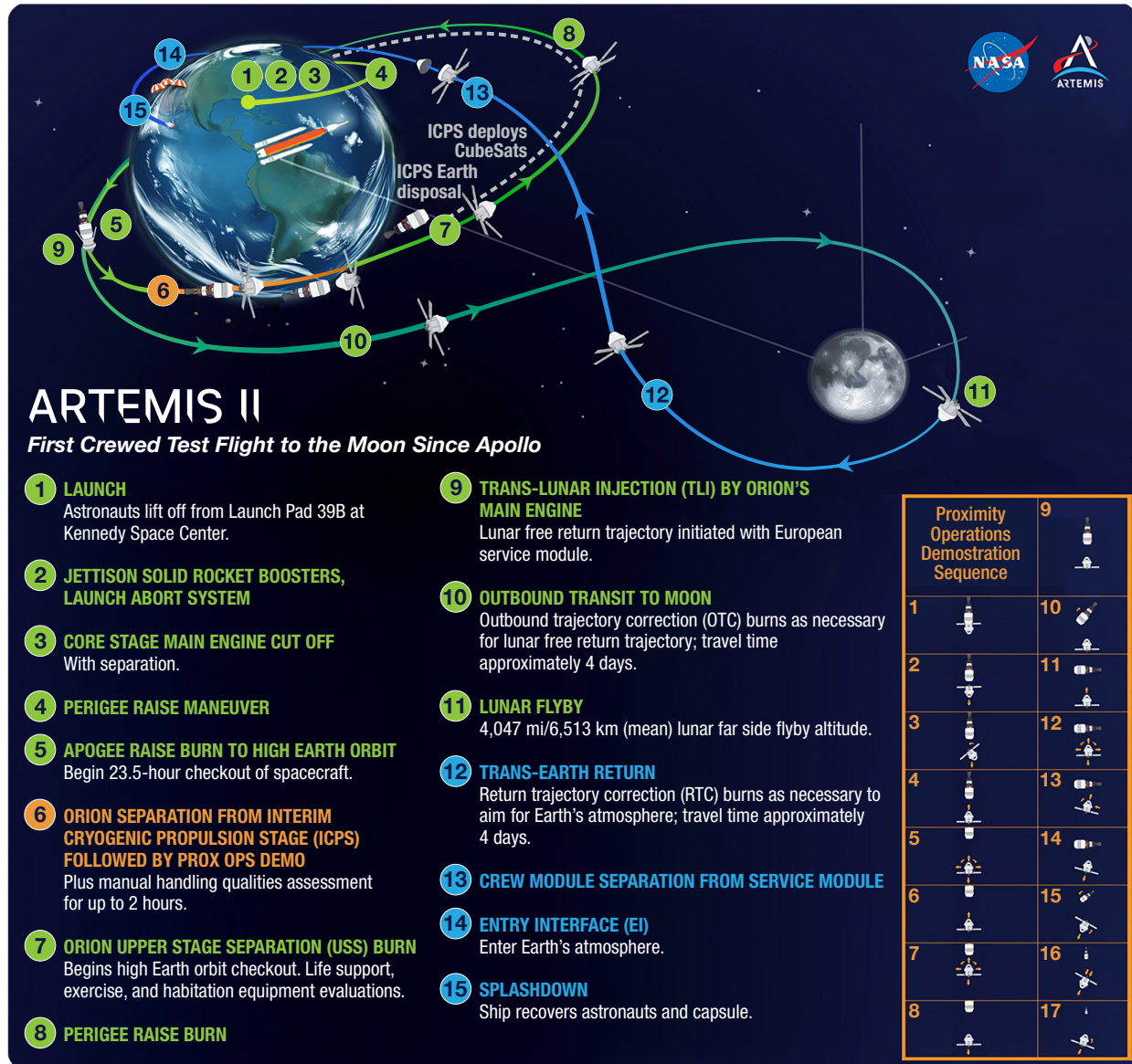


Figure 1.1: The Artemis II mission map outlines the primary mission stages during the approximately 10-day mission.

The Artemis II test flight was NASA's first crewed mission under the Artemis program. The mission launched four astronauts from NASA's Kennedy Space Center in Florida on a Block 1 configuration of the Space Launch System (SLS) rocket on April 1, 2026, at 6:35 p.m. EDT (22:34 UTC). The astronauts and their Orion vehicle, named *Integrity* by the crew, performed several vehicle checkouts and maneuvers around Earth before performing the trans-lunar injection (TLI) burn to send the crew to the Moon. Following the lunar flyby, the crew used its lunar free-return trajectory, in which Earth's gravity pulled Orion back home, ultimately ending in a successful splashdown in the Pacific Ocean (**Figure 1.1**).

The Artemis II crew included NASA's Reid Wiseman, Victor Glover, and Christina Koch, and Canadian Space Agency (CSA) astronaut Jeremy Hansen (**Figure 1.2**). Artemis II backup crew members were NASA astronaut Andre Douglas and CSA astronaut Jenni Gibbons. The mission lasted 10 days from launch to splashdown, which occurred on April 10, 2026, at 8:07 p.m. EDT (April 11, 2026, 00:07 UTC).

During the flight, NASA was able to evaluate the spacecraft's systems, assess the performance of the life-support systems, demonstrate proximity operations in low Earth orbit, conduct Earth departure and return operations, practice emergency procedures, and conduct science activities.

The Artemis II crew traveled 252,756 miles (406,771 kilometers) from Earth and 4,067 miles (6,545 kilometers) above the lunar surface. From Orion's windows, the crew viewed the Moon in the foreground and Earth, roughly a quarter-million miles away, in the background (**Figure 1.3**). The crew had a full-disk view of the Moon, including a portion of the lunar farside not seen by Apollo astronauts, providing them with the opportunity to observe some areas of the farside for the first time directly with human eyes. The LST worked with the crew in real time as the crew captured images with handheld cameras and recorded verbal descriptions and annotated scientifically interesting lunar areas on their crew tablets. Throughout the mission, Orion vehicle cameras also captured unique Moon and deep-space views useful for science analysis. Throughout this report, images taken by Artemis II crew and vehicle cameras are denoted by a blue outline.

Artemis II also flew separate investigations led by the Human Spaceflight Mission Directorate (HSMD) Human Research Program (HRP) and Science Mission Directorate (SMD) Biological and Physical Sciences (BPS) division. Three HRP investigations examined Artemis II crews' physiology and behavioral responses to deep spaceflight; results will help NASA keep crews safe and healthy on future deep space missions. The BPS investigation leveraged Orion's microgravity and space radiation environment to study human biology and cellular responses in deep space through flying microfluidic devices containing living human cells. The Johnson Space Center Space Radiation Analysis Group (SRAG) flew a radiation monitor within the Orion vehicle. The radiation data will be used to address deep space environmental science objectives of SMD's Heliophysics Directorate (HPD). These investigations were managed independently of the LST's campaign and are outside the scope of this report.

1.2 Lunar Science Operations Overview

The LST operated throughout mission preparation, execution, and post-mission analysis under the lunar science lead, Dr. Kelsey Young, who was supported across all phases by two deputy lunar science leads, Drs. Marie Henderson and Jacob Richardson. The Artemis science flight operations lead, whose leadership ensured the integration of science within the broader flight control environment, directed mission operations. For Artemis II, Dr. Kelsey Young served both as the Artemis science flight



Figure 1.2: The Artemis II crew: Commander Reid Wiseman (bottom center), Pilot Victor Glover (top center), Mission Specialist Christina Koch (left), Mission Specialist Jeremy Hansen (right).



Figure 1.3: The unique perspective of the Earth-Moon system as observed by the Artemis II crew during the mission.

operations lead and the lunar science lead, which was an intentional choice based on expertise and the mission's developmental parameters. The LST was selected from across NASA to provide the science and science operational subject matter expertise to develop and implement the mission's lunar science objectives while simultaneously developing the concept of operations and underpinning processes and tools needed to support mission operations. During mission execution, the LST put this team structure into practice through science operations conducted from three areas at NASA's Johnson Space Center. Artemis II established a dedicated SCIENCE console in the flight control room (FCR), supported by two science support rooms—the SER in Johnson's Mission Control Center (MCC) (**Figure 1.4**) and the SMOR in Johnson's nearby Building 36 (**Figure 1.5**). The SCIENCE console was staffed across three shifts per day by three Science Officers (SO): Dr. Kelsey Young, Angela Garcia, and Trevor Graff. The SOs were certified flight controllers responsible for lunar science and geology objectives during the mission. The LST also coordinated with multiple consoles and support rooms throughout the broader flight control team (FCT) to sustain continuous science decision-making and mission support for the duration of the mission.

The LST's leadership and operational structure was built and tested through participation in a series of simulations and training events in the 2.5 years leading up to the Artemis II mission. These included LST-internal simulations and larger events integrating the LST with the broader Flight Operations Directorate (FOD) FCT, evaluation and testing of new flight control rooms and configurations, and development of roles and responsibilities needed for real-time operations. These simulations varied in scope, fidelity, and duration, ranging from shorter, multi-hour long LST-internal sessions to single-day, FCT-integrated scenarios to week-long, mission-style simulations intended to replicate operational tempo and decision-making demands. Participation in simulations varied accordingly, variously involving small, targeted groups, the full LST, or fully integrated activities with FOD, depending on each event's objectives and complexity.

The SOs and the LST integrated the 10 lunar science themes—outlined in the Artemis II Preliminary Lunar Science Report (<https://ntrs.nasa.gov/citations/20260009221>)—into the mission plan before and during Artemis II. The team coordinated with FOD and mission teams, including (but not limited to) various FCT disciplines, the Orion vehicle team, the Image Science and Analysis Group (ISAG), the Astronaut Office, the Crew Training Office, the Office of the Chief Information Officer, and the Orion Electronic Still Camera (OESC) team. Through these collaborations, the LST advanced lunar science awareness across the mission team while gaining operational and engineering fluency in return. This exchange allowed the team to establish methods that maximized lunar science yield, while maintaining crew and vehicle safety as the primary priority. The LST organizational structure, leadership team, and integration approach has set a strong foundation upon which the missions that follow Artemis II will build.



Figure 1.4: Members of the LST at work in the SER.



Figure 1.5: Members of the LST at work in the SMOR analyzing images of the eclipse taken during the lunar flyby.

2.0 EXPLORATION CAPABILITY OBJECTIVES

Artemis II, as the first crewed mission of the Artemis program, served as the initial opportunity to exercise and evaluate NASA's lunar science operations architecture in the Artemis flight environment. The mission also marked the return of dedicated lunar science activities in human exploration beyond Earth for the first time since the Apollo program, thus re-establishing crew-driven scientific observation as a core element of exploration. NASA designed this mission to test Orion's performance—not to land crew on the surface. As such, the lunar flyby profile provided a critical proving ground for demonstrating the foundational capabilities required for more complex future missions, described by SMD as exploration capability objectives. The LST's exploration capability objectives for Artemis II focused on developing, implementing, and improving the integration of lunar science into Artemis operations, both pre-mission and during mission execution, and refining processes, workflows, and tools, which will directly inform the design, readiness, and scientific return of future crewed Artemis missions.

These objectives were intentionally high level and discovery oriented. Rather than validating mature systems, Artemis II sought to expose gaps, stress test operations, and establish best practices for development of crew procedures, LST coordination, and the end-to-end flow of scientific data. The mission represented the first integrated use of the SER, SMOR, crew-facing product development pipelines, and lunar observation processes within the broader FOD environment. Findings from Artemis II, many of which are highlighted in **Section 7.0**, are directly shaping mission design, training, operations concepts, and data workflows for Artemis III and subsequent missions involving lunar surface activities.

Exploration Capability Objectives:

1. Exercise Crew Lunar Imagery and Observation Product Development and Execution Processes

This objective aimed to evaluate, for the first time in flight, how crew-facing science products, such as the Lunar Targeting Plan (LTP) and Lunar Geography Review (LGR), which are described in **Section 5.0**, support accurate and timely lunar observations. Artemis II provided an opportunity to test the full lifecycle of these products: their development by the LST, their integration into crew training, and their use during the lunar flyby. The mission allowed the LST to assess the clarity, usability, ideal timing for uplink and crew access, and operational relevance of these materials, and to determine how effectively the crew could apply training and reference materials in a dynamic environment.

The team accomplished this objective by developing multiple iterations of the LTP and LGR, producing targeted visual simulations to replicate expected in-flight viewpoints. Further, these materials were incorporated into a robust crew training flow that included classroom instruction, field geology exercises, and integrated simulations with the FCT. During the mission, the crew applied these products in real time, providing audio commentary and capturing images that demonstrated their ability to recognize surface features, follow observation timelines, and adapt to varying illumination and geometry conditions. Their successful execution validated the basic workflow, while also revealing refinements needed for more complex surface missions and increased crew time in lunar orbit.

2. Exercise Science Flight Team Support

Artemis II served as the first operational test of the integrated lunar science support structure that interfaces with the FCT during crewed lunar missions. This objective examined how the SO, SER, SMOR, and relevant FCT disciplines operate within real-time flight constraints. The mission allowed the LST to characterize the effectiveness of cross-discipline coordination, communication pathways, console tools, decision-support products, and team readiness under the time-critical conditions of the lunar flyby and other timed mission activities. By evaluating how science priorities were balanced with vehicle and crew operational constraints, the mission revealed procedural strengths and gaps, required role refinements, and verified communication best practices to strengthen science integration for Artemis III and later missions.

The team accomplished this objective by rehearsing SO, SER, and SMOR roles through FOD-integrated simulations before flight, staffing each role and room during all necessary mission phases, and coordinating with multiple FCT disciplines to ensure shared expectations for science priorities and operational constraints. During the lunar flyby, the SER provided rapid scientific interpretation, quick-look summaries, and decision support to the SO, who relayed key guidance to the crew during this dynamic science opportunity. These activities validated the general structure of the science operations model, while highlighting areas for improved cross-discipline integration and communication.

3. Exercise Science Data Capture Methods

This objective focused on assessing if the systems, tools, and processes designed to capture Artemis science data performed as expected during the flight. Artemis II provided the first opportunity to evaluate crew photography with handheld cameras, Orion vehicle camera images, crew audio documentation, crew portable computing device (PCD) annotations, and related metadata under actual mission conditions. The mission also tested coordination between the crew, the SOs, the SER, and relevant FCT consoles to request, receive, and validate downlinked data.

The team accomplished this objective through the downlink, management, and assessment of science data from lunar flyby and opportunistic imaging, and by having the crew acquire images and audio recordings of as part of a window quality developmental flight test objective (DFTO). Following crew and vehicle camera observation activities, the LST, through the SO, coordinated with the FCT console responsible for data downlink to request, track, and validate downlinked products. The LST and imagery specialists within FOD assessed image quality, exposure, field of view (FOV), and metadata accuracy, while monitoring the pace and performance of downlink operations. These efforts confirmed the basic viability of the capture pipeline and revealed opportunities to refine data collection configuration, data request protocols, downlink timing strategies, and overall pipeline robustness to ensure that science data is reliable and complete for future lunar surface and orbital investigations. For additional information on institutional partners, see **Section 4.2** of the Artemis II Open Science Data Management Plan (OSDMP).

4. Exercise Science Data Archiving Methods

Artemis II provided the first crewed test of the science data archival pipeline, which provides long-term data preservation and public release through the PDS. This objective evaluated foundational end-to-end data workflows, including data ingestion from mission assets, inventory generation, metadata validation, contextual event tagging, and rigorous quality assurance checks for completeness.

Central to this effort was the formulation and execution of the Artemis II OSDMP. Leveraging the updated SMD OSDMP template for missions (March 2025 revision), this initiative marked the inaugural application of this modernized framework to human spaceflight missions. As a core governing document, the OSDMP maps each mission data source and defines the technical workflows required for public archiving. The plan was engineered and matured across two formal NASA internal review sessions in collaboration with PDS personnel: an initial pre-mission review to establish baseline data schemas and a post-mission review to refine and calibrate pipeline parameters based on the empirical data successfully captured during flight operations. Guided by this framework, the team maintained structured inventories, verified timestamps, and preserved critical mission context necessary for scientific interpretation in concert with this mission report, the Artemis II Preliminary Lunar Science Report, and the accompanying Data User Guide. Consequently, the Artemis II lunar science data

products are fully archived and publicly accessible on the PDS website. This inaugural operational deployment establishes a scalable, high-fidelity baseline to support the increasingly complex data architectures of future Artemis missions.

3.0 LUNAR SCIENCE TEAM IN OPERATIONS – STRUCTURE AND PREPARATION

During operations, the LST implemented the activities required to address the mission's lunar science objectives. LST members served in a variety of roles described below; each role was developed throughout pre-mission simulations. Substantial evolution was needed as clarity about mission deliverables and milestones, as well as LST operations processes, evolved. The LST, responsible for executing the primary lunar science objectives of the mission, received support from members of the image analysis team, staffing and logistics coordinators, asset managers, the communications team, SMD representatives, and SMD project support leads. LST members were selected from multiple NASA centers to meet both the lunar science and exploration capability objectives. Accordingly, a diversity of skills was required, from lunar science expertise, field geology background to provide context for scientifically valuable observations, Geographic Information System (GIS) specialists, visualization experts, image analysts, and more, to develop and staff the operations roles described in this report. Though future Artemis missions will incorporate science team members solicited from the broader science community, Artemis II necessitated a short turn-around time on mission planning and execution, as well as adapting to rapidly evolving mission parameters made easier by uniform access to NASA resources, resulting in an LST selected only from within NASA (civil servant and contractor workforce).

3.1 Flight Operations Directorate Integration

Artemis II brought lunar science into the core of human spaceflight operations, requiring close coordination across the broad mission team to embed scientific priorities into planning, training, and real-time execution. The LST and FOD's FCT worked together to develop operational products from a science perspective, ensuring the crew had clear, actionable tools to carry out high-value observations during the mission. Through sustained collaboration and proactive, iterative practices, the NASA Geology Training Team trained the crew in lunar geology and in the operations of science data acquisition. This integration of science objectives into mission processes strengthened communications across disciplines, enabled timely decision making during the flyby, and established an operational model that will support increasingly complex scientific exploration in future Artemis missions.

NASA's FOD maintains responsibility for directing human spaceflight missions. FOD integrated lunar science into flight operations for the first time during the Artemis program through the Artemis science flight operations lead and the SCIENCE console. The science flight operations lead aligned lunar science and geology with mission preparation and execution through an operational framework; certified LST members serving operational roles and the lunar science workspaces (the SER and SMOR) through established FOD processes; represented science in FOD forums through designated leadership roles; and directly supervised the SO team, as well as training and certifying the LST for operations.

The SCIENCE console was staffed by an SO. The SOs, as part of the FCT, led lunar science and geology objectives, represented the LST during flight operations, and enabled observations through direct, real-time coordination with FCT disciplines. Communication with other disciplines pre-mission secured timeline activities and clarified decisions that impacted science outcomes. Integrated simulations and pre-mission sessions built operational understanding of SO responsibilities and lunar science mission objectives across the FCT and within the LST. FOD integration began years before the mission, established a framework to align lunar science and geology with Artemis operations, developed the SCIENCE console and certification requirements, trained SOs and LST personnel, and built cross-console communication paths. Artemis II saw lunar science accomplished due in part to how integrated the SO team was within the FCT. Critical to this success was the trust and relationship-building forged over years of work on building a common language, demonstrating deep commitment to the principle of

crew and vehicle safety prioritized above all else, and showing in practice that science enables exploration and exploration enables science. Through analog mission simulations, such as the Desert Research and Technology Studies (DRATS) and the NASA Extreme Environments Mission Operations (NEEMO) tests, this trust and relationship-building flourished and ultimately contributed to the foundation of what would become the SCIENCE console and its supporting operations team.

The LST completed nine integrated simulations with FOD, as well as numerous internal LST simulations (see **Appendix 9.2**). The broader Artemis II FCT simulated all critical phases of the flight, from launch through splashdown, while the LST focused on simulations of the lunar flyby and the shifts planned between the TLI burn and arrival at the Moon. During these integrated simulations, LST members served as ‘crew surrogates,’ providing scientifically realistic observations over voice loops to the FCT whenever crew members were not available. This supported training the FCT and the broader science team by supplying more realistic science data than the FCT could otherwise have provided, further deepening integration of the LST with FOD.

3.2 Science Officer and Instructors

3.2.1 Role Overview

3.2.1.1 Science Officer

The SO (call sign SCIENCE), was the senior flight controller responsible for lunar science and geology objectives during Artemis missions. SCIENCE is a flight control room (FCR, or MCC front room) console position and was responsible for reporting quickly and efficiently to the Flight Director, coordinating with other FCR disciplines, and ensuring lunar science objectives and activities were accomplished during the mission.

Staffed by: Dr. Kelsey Young, Trevor Graff, and Angela Garcia (**Figure 3.1**)



Figure 3.1: Science Officers (left-to-right) Angela Garcia, Dr. Kelsey Young, and Trevor Graff seated at the SCIENCE console in the Artemis FCR.

3.2.1.2 Science Officer Instructor

The Science Officer Instructor was responsible for the planning and execution of lunar science objectives during FOD-integrated simulations and evaluation of the on-console SO during the simulations. This role ensured simulation science objectives were accurately represented, operationally feasible, and effectively communicated to support teams. Furthermore, Science Officer Instructors served as a bridge between lunar science teams, training officers, and other discipline instructors to maintain high-fidelity simulation environments.

Staffed by: Kiarre Dumes and Angela Garcia

3.2.2 Path to Certification

Beyond their nominal Artemis science-related job duties, each SO had spent years developing deep expertise in Artemis mission parameters and lunar science operations. Despite their depth of subject matter expertise, each SO also underwent a 6–12 month (dependent on individual and simulation schedules) mission-specific training and certification process to gain proficiency in flight control console operations, the associated tools and processes, and integration with in-room flight controllers for Artemis. This process was structured to align with established FOD standards and mirrored the certification pathways used by other Mission Control disciplines, ensuring SOs met discipline-specific technical requirements and foundational FOD expectations, including effective communication, the ability to operate within the flight control environment, and a clear understanding of FOD operations and culture. This discipline does not draw from an International Space Station operations background; accordingly,

Chief Training Officers (CTOs) worked closely with all SOs to provide operational context, expectations, and guidance necessary to function effectively within FOD. Final certification authority rested with the Artemis Flight Directors, who reviewed each SO's readiness and granted console certification upon successful completion of all requirements, including the final certification simulation for each SO.

The Science Officer Instructor followed a similar certification path and was evaluated and certified by the CTO cadre. Training process details are provided in **Sections 3.2.2.1 – 3.2.2.3**.

3.2.2.1 Classroom Content

SOs began with a two-week FOD boot camp—an intensive introduction to MCC operations, critical systems, console responsibilities, and facility safety procedures. Boot camp included instructor-led lessons, system demonstrations, and guided walk-throughs supported by reference materials, video modules, and foundational reading. This training established the baseline operational knowledge required for any front-room flight controller.

3.2.2.2 Online Content

SOs completed a series of self-paced online lessons through the FOD training library and Artemis-specific learning platforms. These modules introduced core console operations, flight control principles, Orion system fundamentals, and general MCC tools and procedures. SOs also completed required self-studies and computer-based training events, all designed to build foundational operational knowledge.

3.2.2.3 Simulations

Simulation training formed the core of SO preparation. Mentor-led MCC workstation sessions introduced the SOs to essential console functions and mission displays, culminating in a practical assessment. SOs also participated in integrated simulations with Flight Directors, other front room consoles, and both science backrooms during which lunar flyby timelines, voice loop communication, and real-time decision-making were rehearsed. Performance was formally evaluated during each simulation, with certified Science Officer Instructors documenting strengths and identifying areas for growth to guide each SO's focus on subsequent events. Final certification as a SO was granted by the Flight Director office and the Science Officer Instructors based on demonstrated performance across these simulation events, ensuring SOs were prepared for real-time lunar science operations.

3.3 Lunar Science Team

The LST was comprised of NASA scientists, engineers, software developers, geographic information systems experts, crew lunar observations (CLO) team members, imaging experts, data scientists, and more (**Figure 3.2**). Pre-mission, the LST worked to define lunar science objectives; develop the required software and crew products; train the crew and as an operations team; develop the crew activities and associated procedures; integrate science into FCT-integrated simulations; and advocate for expanded lunar flyby time to support lunar science objectives. During real-time operations, the LST staffed operational roles to support SCIENCE deliverables, crewed activities, and evaluate science data received. Post-mission, the LST was responsible for delivering all lunar science data to the PDS, writing and making available to the public a Data User Guide, a Preliminary Lunar Science Report, and this Operations Report. The following roles and responsibilities were staffed by the LST to accomplish science needs and deliverables.

3.3.1 Operational Roles

3.3.1.1 SER/SMOR Lead

The SER and SMOR leads developed the LST mission shift structure and staffing plan and managed the operations during mission execution. Pre-mission, the leads defined the roles required to meet the LST's needs during the 10-day mission and ensured each role was prepared and trained. During



Figure 3.2: The Artemis II LST in the SER during the mission.

the mission, the SER and SMOR Leads coordinated LST activities, directed resources to respond to SO needs, and ensured timely data evaluation by the LST. The leads also maintained LST situational awareness by producing shift summaries and notes and by synchronizing meetings when rooms were staffed at the same time.

Staffed by: Dr. Jacob Richardson and Dr. Marie Henderson (SER); Dr. Cherie Achilles and Dr. David Hollibaugh Baker (SMOR)

3.3.1.2 SER/SMOR Deputy Lead

The SER deputy lead role was staffed during high-activity shifts when staffing volumes did not conflict with competing mission priorities. In the SER during these busy shifts, the SER deputy lead supported SO requests through the in-room communicator (SERCOM), while the SER lead managed the LST activities and deliverables. In the SMOR, a deputy lead role was not part of the staffing plan but a deputy function was delegated to an available staff member during high-volume post-flyby data analysis in the SMOR to support the SMOR lead in maintaining data tracking deliverables and assisting with shift summaries and handovers.

Staffed by: Dr. Jacob Richardson and Dr. Marie Henderson (SER)

3.3.1.3 SER/SMOR Communicator

The SER communicator (SERCOM) and SMOR communicator (SMORCOM) were responsible for maintaining mission situational awareness between the SO and the science operations support rooms. Pre-mission, SERCOMs crafted templates for written, in-mission operational messages to the SO preparing for known, in-mission communications that would occur between the LST, SO, and other consoles. During the mission, SERCOM and SMORCOM supported the SO and room leads by passing of information in a timely and accurate manner to enable decision making. They also provided mission

situational awareness to the SER and SMOR teams by monitoring and communicating on select voice loops. Except during dynamic handover phases, the SERCOM served as the sole voice communicator from the SER to the SO. The SERCOM received additional voice-loop and Orion-vehicle training to monitor several voice loops simultaneously to maintain team awareness of any issues or activities that could impact science data collection.

Staffed by: Dr. José Hurtado and Kiarre Dumes (SER); Dr. Aaron Regberg (SMOR)

3.3.1.4 Science Theme Leads (Scrum)

The science theme leads were responsible for representing the 10 Artemis II lunar science themes, documented in the science traceability matrix (STM), throughout mission planning and execution. Pre-mission, science theme leads supported the development of LTPs for several possible launch dates and lunar flyby scenarios in support of FCT-integrated mission simulations. During the mission, science theme leads, clustered in a group of tables in the SER called the ‘Scrum’, used the Orion trajectory and scheduled crew observation time to optimize the potential science objective coverage in the LTP. For each LTP developed, the science theme leads analyzed trajectory-specific viewing parameters, identified potential scientific targets, and prioritized the most optimal targets, crew choice periods, and guided discussions to address each objective. After the lunar flyby, each science theme lead evaluated verbal descriptions and images to assess the extent to which the science objectives were achieved.

Staffed by: Dr. Ariel Deutsch (Lead), Dr. Juliane Gross, Dr. Debra Needham, Dr. Jennifer Heldmann, and Dr. Anthony Colaprete

3.3.1.5 Science Traceability Matrix Documentarian

The STM documentarian was responsible for maintaining a working knowledge of the STM and tracking STM coverage (or how the LTP targets address each of the 10 lunar science themes) at each mission stage to understand the impact of evolving mission constraints. During LTP development, the STM documentarian worked with the science theme leads to evaluate the impact of target-selection decisions on STM coverage. In-mission, the STM documentarian worked with the LST to help track how downlinked data mapped to STM objectives and documented planned versus achieved STM coverage.

Staffed by: Dr. Ryan Ewing

3.3.1.6 Science Documentarian

The science documentarian recorded LST activities by documenting data-based interpretations and the subsequent decisions made throughout the planning and execution phases of the mission. During operations, the science documentarian created a record for each shift to ensure the team could reference specific details, trades, and contexts for key decisions. This record was used operationally on future flight days for LST reference, for up-and-out in-mission reporting, and for LST reference throughout the data downlink and archiving process. The science documentarian kept the LST organized by keeping real-time notes, linking critical documents, and collecting LST questions and requests. The science documentarian served as a bridge between real-time mission execution and long-term scientific discovery by capturing real-time hypotheses, debates, surprises, and cognitive leaps made by the crew and the LST.

Staffed by: Dr. Barbara Cohen

3.3.1.7 Observation Planners

The observation planners were responsible for developing actionable instructions to enable the crew to accomplish the science objectives of each LTP target during the lunar flyby. The observation planners translated science observation tasks for each respective LTP target into operational cues for the crew, working in collaboration with the science theme leads to ensure actions were consistent with science intent and training knowledge. They also supported LTP development for pre-mission simulations and the as-flown lunar flyby LTP.

Staffed by: Amber Turner, Dr. Megan Borel, Dr. Ryan Watkins, and Dr. Cynthia Evans

3.3.1.8 Visualization Specialist

The visualization specialist was responsible for creating photorealistic visualizations of the lunar surface under a variety of illumination conditions; these were used for crew training, simulations, observation planning, in-mission tracking, and public engagement. This entailed writing code to translate lunar terrain datasets and solar system and spacecraft ephemerides into data and scripts used to drive high-end, commercial, three-dimensional animation and rendering software (Autodesk's Maya and Pixar's RenderMan). The visualization specialist generated synthetic spacecraft trajectories to support simulations of different launch dates and created tables of event times, flight statistics, and observation phenomena. On Flight Day 02, using a post-TLI trajectory provided by the flight dynamics officer (FDO), they created a lunar flyby visualization that informed observation target selection by the LST.

Staffed by: Ernest Wright

3.3.1.9 Crew Lunar Observations Team

The CLO team served two distinct operational roles: CLO operators and CLO data and tools. As operators, the CLO team was responsible for supporting the LST in the SER by developing, creating, and delivering two products: (1) the Live Encounters Guide (LEG), used by the Scrum/SER to generate the Outgoing Targeting Request (OTR) database; and (2) the LTP for the Artemis II crew. All members of the CLO team were required to complete simulation-based proficiency training, demonstrate operational readiness with all CLO software and scripts, and maintain competency in Analytical Graphics, Inc.'s (AGI) Systems Tool Kit (STK).

Developers on the CLO team were responsible for writing, testing, and documenting all mission support software. Operationally, the CLO team generated data-rich encounter visualizations for SER use, including generation of the portal used to receive the OTR database from the Scrum/SER team. This required supporting multiple rounds of review and building the final crew-facing LTP with the OTR data. In addition, the team produced clear, user-friendly, flight-tested LEG and LTP data packages containing observation specifics and supporting imagery.

As data and tools subject matter experts, the CLO team aided other personnel in the SMOR with organizing and transferring data, tools, and ad hoc data and file-sharing requests. The team was responsible for organizing and transferring data to the LST via file sharing platforms and custom web interfaces; monitoring the current status of data delivery and retrieval; processing audio to generate precise transcripts with synchronized timestamps; and capturing all relevant crew data analyst input to compile data bundles that were transferred into individualized file share locations.

Staffed by: Sara Schmidt (Lead), Alex Stoken, Wilfredo García López, Jared Ralleta, David Charney, and Cody Boyer

3.3.1.10 Vehicle Image Science Lead

The vehicle image science lead was responsible for collecting science data from the Orion vehicle camera system. They developed procedures to ensure the plans were uplinked and science data were downloaded. This lead coordinated closely with the Scrum to identify vehicle camera imaging strategies and opportunities to complement crew activities and to prioritize key observations. They worked with ISAG to develop the lunar flyby vehicle imaging plan and to request and track the downlink of high-priority images.

Staffed by: Dr. Maria Banks

3.3.1.11 Timeline Manager

The timeline manager was responsible for scheduling targets and activities during pre-mission and in-mission LTP development. They tracked timeline constraints, target dependencies, and scheduling priorities; drafted the order and duration of LTP observations; and then worked with the science theme

leads to finalize the plan. After the lunar flyby, the timeline manager was responsible for building the as-executed timeline of science observations based on the downlinked audio files and crew images.

Staffed by: Dr. Cherie Achilles

3.3.1.12 Crew Data Analyst

Crew data analysts were responsible for analyzing and organizing crew-generated science data (i.e., audio recordings, annotations, and images) in preparation for science evaluation. They combined observations and analysis into summary reports to facilitate LST data access and deliver a preliminary understanding of the received data. They contributed to the generation of scientific metadata to assist in the search and discovery of data based on scientific target and theme. Crew data analysts also aided in locating or distilling data products by scientific theme and time.

Staffed by: Alexandra Constantinou, Dr. Andrew Needham, Dr. Megan Borel, Amber Turner, and Dr. Cynthia Evans

3.3.1.13 Window Quality DFTO Data Analysis Team

The window quality DFTO data analysis team was responsible for analyzing images from the from the Flight Day (FD) 03 window quality DFTO and reporting the results to the LST and FCT. The team worked alongside David Bretz from ISAG to compare the images acquired from different positions within the forward windows and the docking hatch window to look for image distortions at specific focal lengths. The analysis resulted in decisions on imaging position and no limitation on imaging focal length. The team combined observations and analysis into a preliminary report (included in the Data User Guide), to inform the LST, SO, and FCT.

Staffed by: Dr. Marie Henderson, Dr. David Hollibaugh Baker, Dr. Maria Banks, Alexandra Constantinou, Dr. Andrew Needham, and Alex Stoken

3.3.1.14 Asset Manager

The asset managers were responsible for managing SER/SMOR room access, projection/TV screens, and console setup. They responded in real time to room needs during the mission (i.e., to resolve screen display issues or troubleshoot SER/SMOR tasks).

Staffed by: Ryan Bieber (Co-Lead), Marco Lozano (Co-Lead), Michael McLehany, Luke McSherry, Pedro Sanchez, and Daniel Thomas

3.3.1.15 Staffing Coordinator

The staffing coordinators ensured that the LST maintained continuous operational support throughout mission execution. Pre-mission, the coordinators developed and maintained the LST staffing schedule, updated the scheduling tool used to inform the LST about shift changes, and distributed static copies of the schedule via email and Teams chats. During mission execution, the coordinators provided near-24/7 support by monitoring attendance, managing last-minute adjustments due to call outs or timeline changes, and ensuring adequate coverage for all operational roles. They remained available in or near the SER and/or SMOR, enabling quick response to needs related to logistics, equipment, and operational resources. In addition, they maintained inventory of information technology (IT) and room materials and supported VIP room visitor management when heavy traffic risked disrupting team performance. Coordinators also communicated time-critical schedule changes, operational alerts, and staffing concerns directly to SOs, SER/SMOR leads, and the NASA Public Affairs Office (PAO).

Staffed by: Andrea Wenzel, Madeline Walker, and Abigail Cantoni

3.3.1.16 Communications Team

The Artemis II Lunar Science Communications Team was responsible for ensuring that lunar science activities and goals were shared publicly by working directly with external and social media as well as integrating lunar science into NASA's overall communications plans—such as live broadcasts, public

engagement exhibits, and news briefings. Working closely with appropriate subject matter experts from the science team, communications team members wrote messaging, talking points, and web articles, reserved Johnson photographers, scheduled and supported media interviews, drafted captions and uploaded imagery to the website, and created and shared social media content.

Staffed by: Molly Wasser (Lead), Rachel Barry, Lonnie Shekhtman, Victoria Segovia, and Caela Barry

3.4 Lunar Science Team Training

The LST participated in a comprehensive, evolving training program to prepare for real-time science operations support during critical timeline activities. The training ensured the entire LST—including SER and SMOR personnel, discipline-specific specialists, and operations support personnel—were fully prepared to support mission operations, analyze downlinked data, and support completion of scientific objectives during the Artemis II timeline. Preparation was overseen by LST leadership, Science Officer Instructors, and asset managers, who ensured that rooms, tools, and support personnel were scheduled and ready for each event. The LST members were certified for participation in real-time operations by the Artemis science flight operations lead, in consultation with other members of the LST leadership team.

Training for science support during Artemis II covered two major areas:

1. Team-Readiness Simulation Events

A series of LST-only training events focused on phase-based preparation for mission-relevant science activities. These events supported, or directly led up to, mission-timed tasks, such as LTP generation. Training included week-long, in-person sessions designed for short, phased reviews of science activities, as well as slow simulations (sims) that allowed the team to work through workflows, processes, and decision pathways at a deliberate, non-operational pace to focus on key phases of flight. The development of major science workflow processes, such as target planning and downlink management, served as both operational preparation and structured training for the entire team.

2. FOD-Integrated Simulations

The LST participated to support SOs, develop skills for more operational roles (e.g., SER Leads, SERCOMs), training additional SER and SMOR personnel for mission-timed activities, and develop team operational processes and products needed to support relevant shifts. These events served as essential opportunities for the broader LST to gain experience operating within a mission support environment, including the use of console management tools, adherence to voice-loop protocols, and coordination with flight controllers. Through this participation, the team was able to rehearse workflows, build proficiency in operational tools, and validate processes required for lunar science support during Artemis II.

Beyond the structured training, LST membership itself reflected relevant prior operational experiences. Many team members had previously participated in field tests, analogs, SMD mission operations (e.g., Mars rovers, Lunar Reconnaissance Orbiter), and simulations related to Artemis lunar surface missions. These experiences were a deliberate factor in their selection for LST roles, providing a foundation of operational judgment that complemented the structured training resulting in a highly experienced and capable Artemis II science operations team.

4.0 SCIENCE OPERATIONS FACILITIES

The LST operated primarily out of two rooms: the SER and the SMOR. The exceptions were the SOs (**Sections 3.1–3.2**), who staffed the SCIENCE console in Johnson MCC's primary flight control room. This section describes the SER and SMOR design, functionality, and layouts used throughout mission execution.

4.1 Science Evaluation Room

4.1.1 Room Overview

The SER, located in Johnson's MCC (Building 30), served as the primary lunar science operations room for Artemis II. LST personnel occupied the SER during designated science operations shifts and/or when SCIENCE required support from SERCOM and/or other subject matter experts.

The Artemis science flight operations lead, with support from the LST, was able to work with the MCC facilities team to provide input on the design and development of this new operations room. This collaboration on SER design ensured that the unique nature of supporting science operations could be accommodated by the facility. Where traditional flight control rooms include rows of consoles with operators linked to each other primarily through communications over voice loops (with occasional air-wave communications within the room), the SER design evolved to ensure open science dialogue could occur within the room, while maintaining access to additional loops and connectivity to the broader mission. The team made two aesthetic decisions to add a science spirit to the physical room design. A stripe painted around the top of the SER was chosen to be as similar to Earth blue as possible. Additionally, the hexagonal carpet tiles were organized in a two-dimensional representation of the three-dimensional crystal structure of anorthite, encapsulating one of the most dominant Moon-forming minerals. In this way, a walk in the SER represented walking on the Moon while looking back at Earth (**Figure 4.1**).



Figure 4.1: Photograph of the SER in use during the Artemis II mission, taken from the corner console (asset manager position). In the far corner in this view is a video camera that provides a real-time view of the SER to the SCIENCE console in the FCR. This layout corresponds to **Figure 4.4**.

4.1.2 Room Layouts

The SER (**Figure 4.1**) includes three fully equipped console workstations that support solo or dual operations, each with two 42-inch monitors, two console computers, and two digital voice inter-communications equipment (DVICE) voice loop terminals. Eight TV monitors and one full-wall screen are configurable to host MCC feeds or in-room ClickShare feeds. Two digital whiteboards and a display

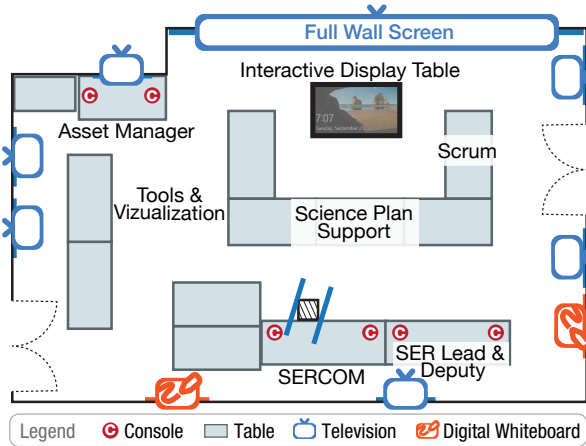


Figure 4.2: The SER layout used for initial science operations during the mission. Each table supported two occupants (except for one small printer table). This setup enabled all-hands LST meetings and early LTP preparation.

table at the room's center enable group activities requiring interactive visual collaboration.

The modular seating arrangement for SER personnel was developed through an iterative, trial-and-error process during integrated simulation activities conducted before the mission, with each run providing feedback that refined where individuals and teams were positioned for each critical science phase. This approach allowed the layout to evolve naturally as workflows, communication paths, and real-time coordination needs became clearer. During mission execution, the team largely adhered to the established plan, where different activities led to different seat configurations. The initial configuration (**Figure 4.2**) included a row of tables surrounding an interactive display table, which enabled room-wide discussions led at the front of the room. During the first two days of the mission, science theme leads typically sat on the far right in this room layout; CLO and tools support were on the far left; and observation, timeline, and visualization planners were in the room center. Science plan reviews were performed in small groups, which led to tables being organized as islands (**Figure 4.3**). Later mission phases required the Scrum to support the SCIENCE and SER lead more directly and more often, with a smaller support team. Tables were then organized to focus the Scrum near the SER lead (**Figure 4.4**).

TV screens were configured to provide room-wide situational awareness. The large video wall often included computer visualizations of the Moon, schedules, mission elapsed time and milestone count-down clocks, and a FCR live feed. Wall-mounted televisions showed other mission status feeds and duplicate clock and schedule feeds.

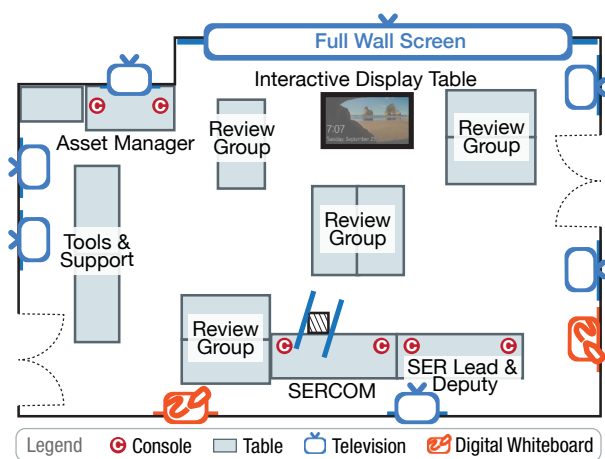


Figure 4.3: SER layout used during final LTP planning and review.

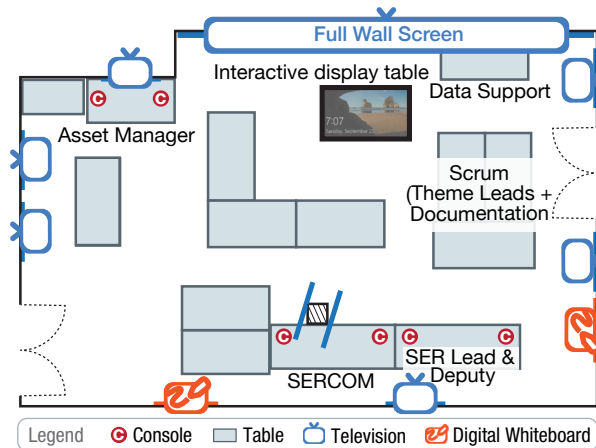


Figure 4.4: SER layout used during “execute” shifts from the flyby through splashdown. The Scrum area was occupied by decision makers who were positioned as close as possible to the SER lead desk. The Scrum area was surrounded by data support personnel.

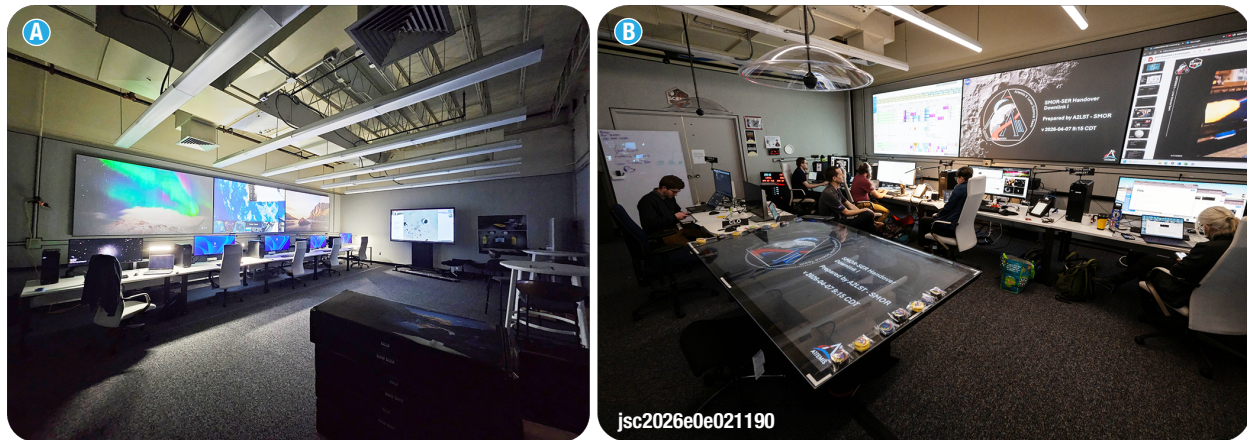


Figure 4.5: (A) Photograph of the SMOR located in Johnson's Building 36 (image credit: K. Young). (B) In-mission use of the SMOR by the LST.

4.2 Science Mission Operations Room

4.2.1 Room Overview

The SMOR, located in Johnson's Building 36 (a ~5-minute walk from MCC), served as a secondary science operations room throughout Artemis II. The SMOR has similar capabilities to the SER, specifically DVICE and video-feed access, to support the SCIENCE console if the SER is not staffed or operational. The SMOR function shifted throughout the mission to accommodate evolving mission science needs, including primary science data analysis and window quality DFTO analysis (Figure 4.5).

4.2.2 Room Layouts

The SMOR was laid out to optimize quick, efficient data analysis. The SMOR lead, while given a seat far from the SMORCOM (Figure 4.6), was highly mobile throughout shifts. Data analysts sat on the right side of the room facing the main video wall, while data and tools support staff sat on the left, near SMORCOM. While all five front tables had DVICE units, the two left DVICE units (asset manager and SMORCOM seats) were used almost exclusively in-mission. The other DVICE units were used more sparingly—to project important voice loop audio to the room, and, in infrequent cases, facilitate direct communication between the SMOR lead and the SER. All DVICE units in the SMOR were used in lunar surface mission simulations, demonstrating another potential use case for the SMOR based on mission parameters.

The SMOR's audiovisual infrastructure was built around a central video wall serving as the room's primary shared display. The main video wall includes three Epson 4K projectors on three 120-inch screens. Five workstation consoles line the video wall; these workstations are equipped with 39.7-inch monitors with one workstation including a 27-inch pen-enabled Wacom Cintiq Pro tablet. Additional movable monitors are available to create more workstations at tables that line the back and right of the room. A moveable 86-inch, 4K ViewSonic touchscreen display is stationed along the right-side wall. An 86-inch, touch-enabled display table (smart table) with the capability to project to the video wall is in the center of the room. During the mission, the video wall was used to display LST visualizations, the LTP, timeline and shift schedules, science data for room discussion, live feeds to the SER and FCR,

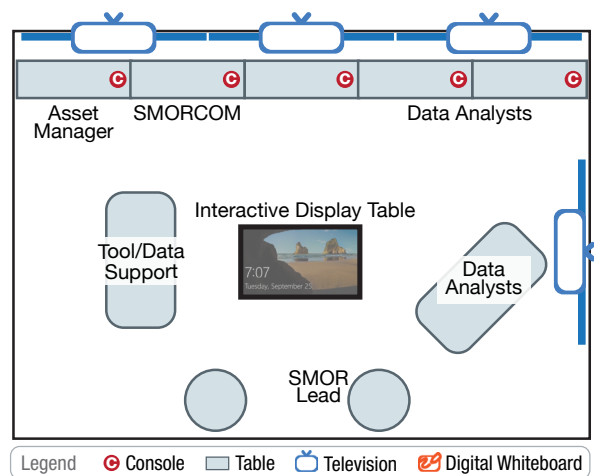


Figure 4.6: SMOR layout showing screen and DVICE locations.

and other mission context feeds. Additionally, a screen from the SMOR could be shared on the video wall in the SER to enable consistent communication during joint meetings.

5.0 CREW SCIENCE SUPPORT SOLUTIONS

5.1 Crew Flight Products Overview

The LST developed the LTP and LGR flight products for the crew. These tools were designed to enable successful completion of timed science activities during the lunar flyby and other mission segments. The LTP, created by the CLO team with input from the broader LST and the Artemis II crew, is a stand-alone, interactive browser-based tool hosted on the crew's PCDs. The LTP, which was iterated on and implemented in pre-mission simulations, training events, and execution of the mission, serves as a tangible representation of the mission's lunar science plan.

5.1.1 Lunar Geography Review

The LGR (**Figure 5.1**) serves as a lunar atlas and science review product. The crew used the LGR to reference and study lunar geography, mission lunar science themes, and geologic and scientific background information. The LGR included labeled maps of the nearside, farside, and eastern and western limbs of the Moon, with variable lighting scenarios and lunar phases that could be selected for each view of the Moon. The team loaded the first LGR onto crew PCDs prior to the crew's first mission-specific lunar science training session in Spring 2025. The team reloaded updated LGR versions onto PCD training units after each subsequent release, enabling the crew and the FCT to work with, and provide feedback on, the evolving product. The final LGR was loaded onto the crew-assigned PCDs prior to launch, enabling the crew to review geography, mission science objectives, and lunar science fundamentals in the days before launch and in-mission prior to the lunar flyby.

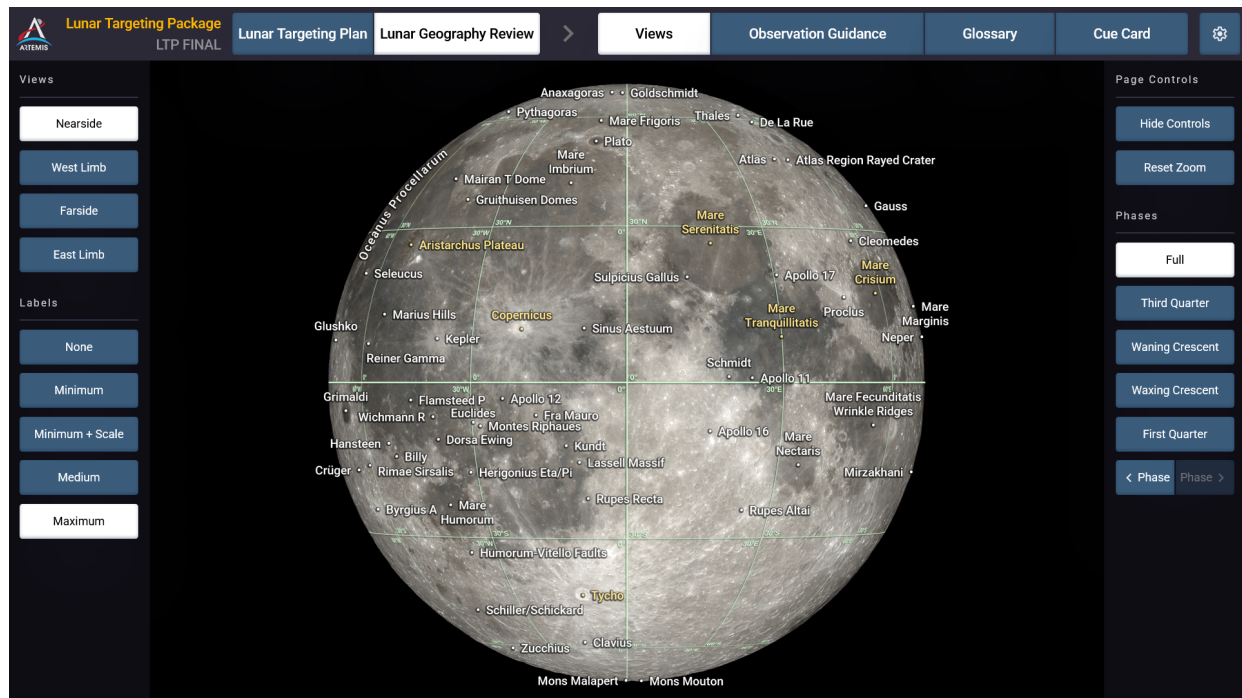


Figure 5.1: LGR view showing a labeled map of the nearside of the Moon and multiple review tabs for Scientific Observations Guidance, Glossary, the Cue Card, and other lunar views.

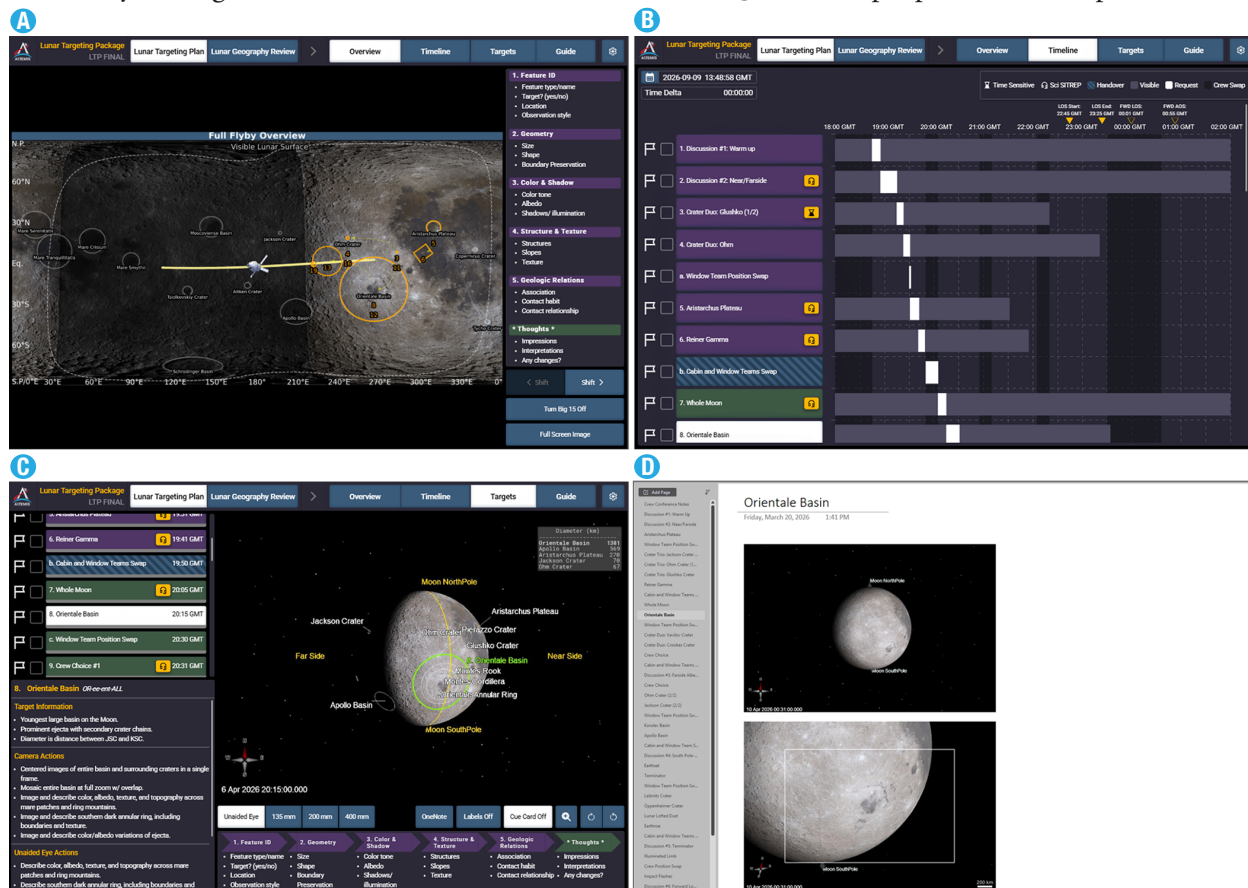
5.1.2 Lunar Targeting Plan

The LTP (**Figure 5.2**) is the primary product created by the LST for crew use during lunar flyby science operations. It contains summary information about the flyby, a user's guide, and a full timeline of targeting activities, giving the crew a spatial and temporal outline of when and where observations will occur. Each target has its own detailed page with observation objectives and visualizations showing the target at the LST-requested time, including expected viewing geometry and illumination. Each target page also links to a OneNote notebook, which the LST populated with unlabeled rendered images to facilitate crew annotations. Information about LTP development is provided in **Section 6.3**.

The first LTP was loaded onto crew PCDs in June 2025 for a crew training event. Throughout development, the LTP was repeatedly tested on flight-like PCDs to ensure compatibility. Updated versions were provided for each crew training event and simulation, allowing continuous feedback between the developers, crew, LST, and FCT. A total of fifteen LTP instances were submitted for simulations, trainings, and pre-launch loading, each reflecting launch-date and trajectory-dependent targets and their changing viewing conditions.

The LTP includes an overview page showing a two-dimensional map of the lunar surface with illumination conditions for the flyby date, requested targets, distinct features, and the Orion ground track for each targeting shift and for the full flyby. This basemap was custom generated by the LST for the date- and time-specific lighting conditions expected during the crew's observations.

The LTP timeline page displayed the complete flyby period, including all requested targets and activities, as well as planned crew breaks and crewmember role swaps. Targeting activities were color-coded to visually distinguish the observation shifts. As shown in **Figure 5.2B**, purple activities represented the



crew pair in the first lunar observation shift (**Section 6.2.6**), with hatched markings indicating a crew break in observations, followed by green activities marking the start of the next shift. Symbols were included to highlight specific operational constraints: an hourglass icon denoted time-sensitive targets, a headset icon indicated targets requiring a science situation report (SitRep; see **Section 6.2.6**), and upside-down triangles marked the start and end of loss-of-signal (LOS) periods.

Each target page (**Figure 5.2C**) provides general information about the target, the science impact of crew observations, and specific prompts for the camera-holding crew member (camera actions) and the crew member observing with the unaided eye (unaided-eye actions). All prompts were developed by the LST to guide the crew in making scientifically useful observations. Each target also had pre-loaded images on OneNote where crew could draw annotations directly onto their view of the Moon (**Figure 5.2D**). Most targets include about 56 simulated images of the expected view of the target from Orion generated via the AGI STK program to enable the crew to locate the target and understand the target-specific prompts (**Figure 5.3**). These images encompass various:

- **FOVs:** Unaided eye (~50mm), 135mm, 200mm, and 400mm to cover the range of possible views through the camera viewfinders when using the range of available lens focal lengths;
- **Rotations:** Eight 45° rotations for each generated FOV to be used as a visual aid, accounting for multiple possible observation orientations relative to the Moon that the crew might prefer when operating in microgravity; and
- **Labels:** Labeled and non-labeled images at each rotation for each FOV, with the labels highlighting nearby feature names to aid in identification and descriptions.

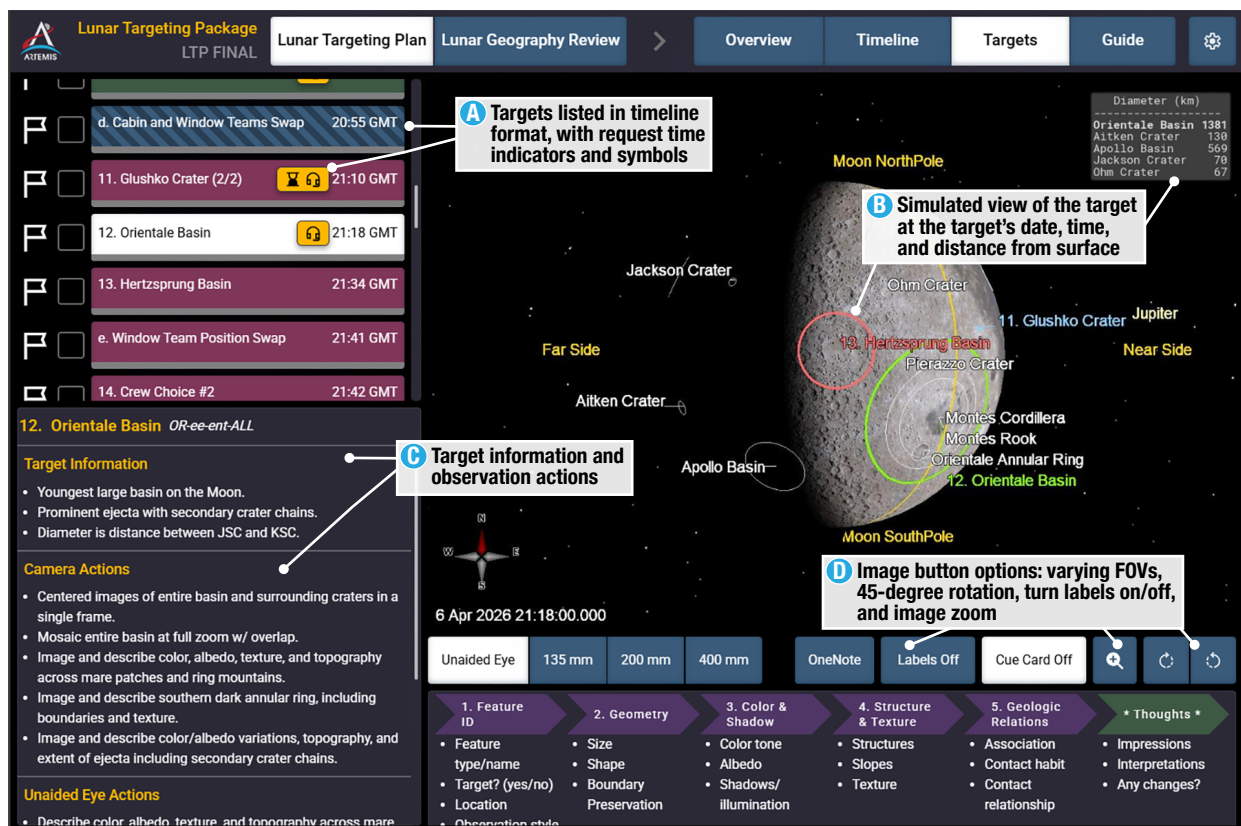


Figure 5.3: Example of the Targets page of the flight-used LTP with annotations explaining page features.

5.1.3 Procedures

Crew procedures were developed to aid the crew as they completed their timed lunar science activities, including use of the LTP and LGR. These six procedures were developed by the SOs in

conjunction with the crew and other relevant FCT consoles (e.g., the Photo/TV team responsible for the crew-operated cameras). These procedures were referenced by the crew and the FCT in simulations and mission execution.

5.2 Crew Training

The LST delivered a comprehensive lunar science and science operations training program that prepared the Artemis II crew to operate as mission scientists and conduct orbital lunar observations (**Figure 5.4**). **Appendix 9.3** lists full details and training events. The crew completed a structured series of science and operations events designed to build foundational knowledge, strengthen observational skills, and establish proficiency in the tools and processes required for effective lunar science data acquisition during the mission.

Training, which used hands-on time with the LTP to guide instruction, included: an introduction to lunar geology and exploration, lunar geography with a focus on the farside of the Moon, specific lunar targets common to multiple possible trajectories and the science questions that could be addressed by observing these targets, and the operations required for collecting scientific data. Referred to as orbital observations training, field work in relevant terrestrial analogs such as Kamestastin Impact Crater, Labrador, Canada, and the Icelandic highlands augmented this training curriculum.

Additionally, the training included practice identifying, describing, and imaging features of interest based on the mission's science objectives, the STM, and feature illumination and viewing parameters. Training also included hands-on practice in a variety of settings (classroom, Johnson's Building 9 Orion mockup, and in integrated FCT simulations) and in the operational mechanics of lunar observations and the tools (camera systems, headsets, PCDs, procedures, LTP, LGR) used to document the lunar surface from orbit. Biweekly homework, individualized crew feedback, and one-on-one observation tutorials allowed the crew to gain proficiency in their knowledge about the Moon and use of the tools, as well as building confidence in their scientific observations and descriptions. As mission target launch windows evolved, additional training focused on updates of illuminated surfaces on the Moon during the lunar flyby and changes in the targeting plan, including just-in-time training on eclipse observations.

The NASA geology and lunar science crew training team developed the crew training plan from deep experience training crew, flight controllers, and engineers for science operations. The geology and lunar science crew training team designed curriculum to provide fundamental science instruction in a hands-on way that resonates with operators as students, developed in close coordination with academic instructors and aligned with NASA and FOD crew instruction standards. **Sections 5.2.1–5.2.3** provide additional detail on significant segments. The training and the collaborations between the LST and the flight operations teams—specifically the support provided by the mission's CTO to integrate science into the training flow and simulations—contributed to the success of the mission.

Members of the Artemis II geology and lunar science crew training team, led by Dr. Cynthia Evans, included: Dr. Noah Petro, Dr. Kelsey Young, Trevor Graff, Angela Garcia, Dr. Jacob Richardson, Dr. Megan Borel, Kiarre Dumes, Dr. Marie Henderson, Dr. Ariel Deutsch, Dr. Juliane Gross, Dr. Jennifer Heldmann, Amber Turner, and Sara Schmidt.

5.2.1 Foundational Lunar Science Training: Lunar Fundamentals (May 2023)

This six-day class established a strong scientific baseline for the Artemis II crew and key FCT disciplines (e.g., flight director, capsule communicator (CAPCOM), CTO). The class included an overview of robotic and human exploration of the Moon, the Moon's geologic history, an overview of planetary processes that have shaped the Moon's surface, key scientific terminology, high-level scientific objectives for lunar exploration, and key take-away messages about lunar exploration in the Artemis era.



Figure 5.4: Artemis II crew training in field, classroom, laboratory, and operational environments. (A) C. Evans and C. Koch observing volcanic features, and (E) the field training team with the Artemis II crew in the Icelandic Highlands in Summer 2024. (B) R. Wiseman, J. Hansen, and V. Glover studying Apollo samples in the Lunar Laboratory at Johnson as part of their Lunar Fundamentals course. (C, F, H) C. Koch, V. Glover, J. Hansen, and R. Wiseman practicing lunar observations in the Johnson Orion mock-up vehicle located in the Johnson Space Vehicle Mockup Facility guided by the lunar science and geology training team and (K) Photo/TV team in Summer 2025. (D, G, I, L) N. Petro, M. Borel, A. Turner, and A. Deutsch with the crew during classroom instruction. (J) R. Wiseman, V. Glover, and J. Hansen practicing lunar observations in the Johnson Space Mission Simulation Facility. NASA IDs for images acquired by Johnson photographers in figure order: (A) jsc2024e055108, (B) jsc2023e028366, (C) jsc2025e064753, (D) jsc2025e087135, (E) jsc2024e054663, (F) jsc2025e067516, (H) jsc2025e064769, (K) jsc2025e064778, (L) jsc2023e028268. All other images acquired by members of the lunar science training team.

5.2.2 Field Training

The Artemis II crew members participated in two field training events with the geology and lunar science crew training team.

- **Field training at Kamestastin Impact Crater in northern Labrador, Canada (September 2023):** This impact site is a terrestrial analog that provides first-hand exposure to lunar-like impact structures and products in feldspathic rocks. Crew members J. Hansen and C. Koch and back-up crew member J. Gibbons made observations of impact melts, anorthositic impact breccias, and complex outcrops along the crater rim and central peak.
- **Field training in Iceland (July 2024):** This training focused on the geologic diversity of volcanic processes and products, samples, and outcrop; practice using look, observe, describe, document (Look ODD) technique; regolith observations; surface navigation; volatile-regolith mixes; an introduction to surface tools and station operations; and a capstone exercise (conduct a traverse, make geologic observations, and communicate to a support room lunar science team). The entire crew and their back-ups participated in this trip. A National Outdoor Leadership School (NOLS) instructor collaborated with the geology and lunar science crew training team to develop a NOLS-facilitated, two-day trek with the crew (NOLS Instructor: Rick Rochelle).

The crew's participation in these field deployments provided feedback to the geology and lunar science crew training team from the crew perspective in advance of training future Artemis crews to conduct surface science and science operations. In addition, the crew gained hands-on experiential knowledge about lunar-relevant geologic processes and rock types that they would be observing from lunar orbit, as well as a sense of scale of terrestrial surface features that are comparable to observable features on the Moon's surface. To support these field events, the crew received approximately five hours of focused classroom content on volcanism, samples, volatiles, and lunar observation strategies.

5.2.3 Artemis II Orbital Lunar Science and Science Operations Training

5.2.3.1 Classroom Training and Homework

The formal crew training plan for Artemis II orbital observations of the Moon consisted of a sequence of targeted courses and refreshers intended to incrementally build lunar observation readiness. The plan included:

- **Hands-on introduction to PCDs and early feedback sessions on science-support tools:** Opportunities to use flight-like hardware, including providing feedback on the evolving LTP.
- **Two four-hour courses in Summer 2025, covering:**
 - **Orbital Observations – Lunar Geography (four hours on June 18, 2025):** Artemis II science objectives and their scientific rationale; Lunar geography introduction; Lunar science team model concepts and how ground teams support crew observations; and Strategies for documenting and observing lunar features, including trajectory-dependent visibility, illumination constraints and parameters, and closest-approach considerations.
 - **Orbital Observations – Operations (four hours on June 30, 2025):** Introduction to lunar observations operations, as well as the in-cabin choreography between crew members to conduct lunar observations; Orientation to onboard hardware used for lunar observations, including cameras, lenses, PCDs, and headsets (joint with FOD trainers); Orientation to onboard digital tools, including LTP, digital lunar atlas, cue cards, and access to onboard procedures; and High-level timeline and ground planning processes.
- **Recurring 15-minute homework activities (June 2025 to January 2026):** Short, targeted practice modules in lunar geography and lunar observation operations. These homework assignments supplemented formal classroom training; provided continuous skill reinforcement; and ensured the crew remained engaged and built their proficiency in navigating the lunar surface, identifying

features, planning and practicing observations, and navigating operational timelines. The geology and lunar science crew training team assigned the crew homework 11 times and their work was reviewed by the LST, which provided direct feedback to individuals regarding their verbal feature descriptions. Later in the training flow, the lunar science and geology training team added a 30-minute LTP feedback assignment to the training plan on October 9, 2025.

- **Orbital Observations Proficiency Session (2.5 hours on December 8, 2025):** This served as the late-stage demonstration of crew readiness for lunar observation tasks. In addition to reviewing the operational timeline, the geology and lunar science crew training team provided individual coaching with crew members as they practiced making verbal descriptions of lunar features and continued to discuss how their observations support the science objectives.
- **A two-hour refresher course (March 25, 2026)** near launch focused on trajectory updates, lunar lighting scenarios, updates to candidate surface targets due to expected surface illumination, eclipse observations, science operations review, and final preparation for mission-specific observation tasks.
- **A one-hour briefing from the lunar science lead four days before launch (March 28, 2026)** focused on target specifics for the range of planned targets and a guided walk-through of visualizations that simulated the expected flyby conditions.

5.2.3.2 Simulations and Facility-Based Artemis II Lunar Science Training

Additional training events included integrated simulations from the Orion simulated crew station and stand-alone science operations sessions in the medium-fidelity Orion mockup. These simulation and facility-based events ran in parallel with the classroom training (**Section 5.2.3.1**), reinforcing concepts as they were introduced. The training team used these events to workshop the lunar science operations environment and provide crew feedback to the LST.

- **Integrated Simulation Events:** Crew participation in integrated simulations with the FCT provided additional experience in lunar science objectives. The crew training flow included simulations of multiple mission phases (ascent, entry, lunar flyby, etc.). Lunar flyby simulations enabled the crew and the FCT to practice nominal operations of the flyby phases, as well as to respond to a series of scripted malfunctions to ensure team preparation. The simulations allowed the crew to gain proficiency in their hardware and digital products, navigate the lunar targeting timeline, simulate imaging and describing lunar features, and annotating and collecting data on their PCDs. The training team accomplished this by ingesting high-resolution video of the lunar surface from a series of simulated flyby dates directly into the crew capsule simulator, along with large-format prints of the lunar surface reflecting possible flyby views. These simulations also featured crew observations in their assigned pairing for in-mission lunar flyby observations and had the crew members swapping in and out of the windows. The integrated sims allowed the crew to practice their science training under flight-like timelines and proved to be a critical way to develop observation skills and receive feedback from the LST, while also allowing the LST to observe what was and was not working well about the flyby operations plan. The LST, while receiving experiential learning opportunities in a mission-like environment, was able to work with the crew to advance the concept of operations for flyby data collection, ultimately creating a better plan and associated products for the mission.
- **Science Configuration Training:** The geology and lunar science crew training team performed Orion crew configuration sessions in Johnson's Space Vehicle Mockup Facility (SVMF). The facility contained a medium-fidelity Orion mock-up and a 10-ft-diameter inflatable Moon globe suspended from the facility's ceiling. These events focused on camera and PCD configuration—using those hardware elements to simulate lunar imaging and observations in a representative physical environment—and on developing strategies for performing the lunar flyby activities in teams of two. FOD's photo/TV trainers supported these sessions, enabling full integration of science, hardware, and operations training.

- **2.5-hour configuration session (July 16, 2025):** This training session followed the classroom orbital observations training and was the first time all four crew, with their camera hardware, PCDs, and headsets, were inside the Orion capsule. During the session, the crew began developing and implementing a configuration of the Orion cabin for lunar observations. The crew identified the challenges of physically accessing the windows with the cameras while using the PCDs and headsets to record observations. By focusing their observations on the Moon globe, mounted at a size and distance from Orion's windows calibrated to represent realistic lunar viewing conditions (**Figure 5.4C, F, H, K**), the crew could work together to establish strategies for their paired flyby operations.
- **Three-hour dark ops session (November 5, 2025):** Like the July 2025 training using the Orion mockup in Johnson's SVMF, the training team conducted this session with the inflatable Moon suspended outside the spacecraft mockup and the crew practicing lunar flyby operations in the Orion capsule in pairs. However, this training session took place in the evening. The training team worked with the SVMF team to turn off all other facility lights, illuminated the Moon, and configured the Orion capsule to properly simulate expected illumination conditions during the flyby.

6.0 MISSION EXECUTION

6.1 Lunar Science Mission Milestones

This section outlines the lunar science mission activities for the crew, who were supported by ground teams in the FCR and the SER during these scheduled activities. Resulting LST activities and milestones are also covered, as LST activities mapped to timed mission activities. Key mission milestones are described in order of Flight Day. **Figure 6.1** depicts mission milestones for the crew and LST, mapped to the mission flight path.

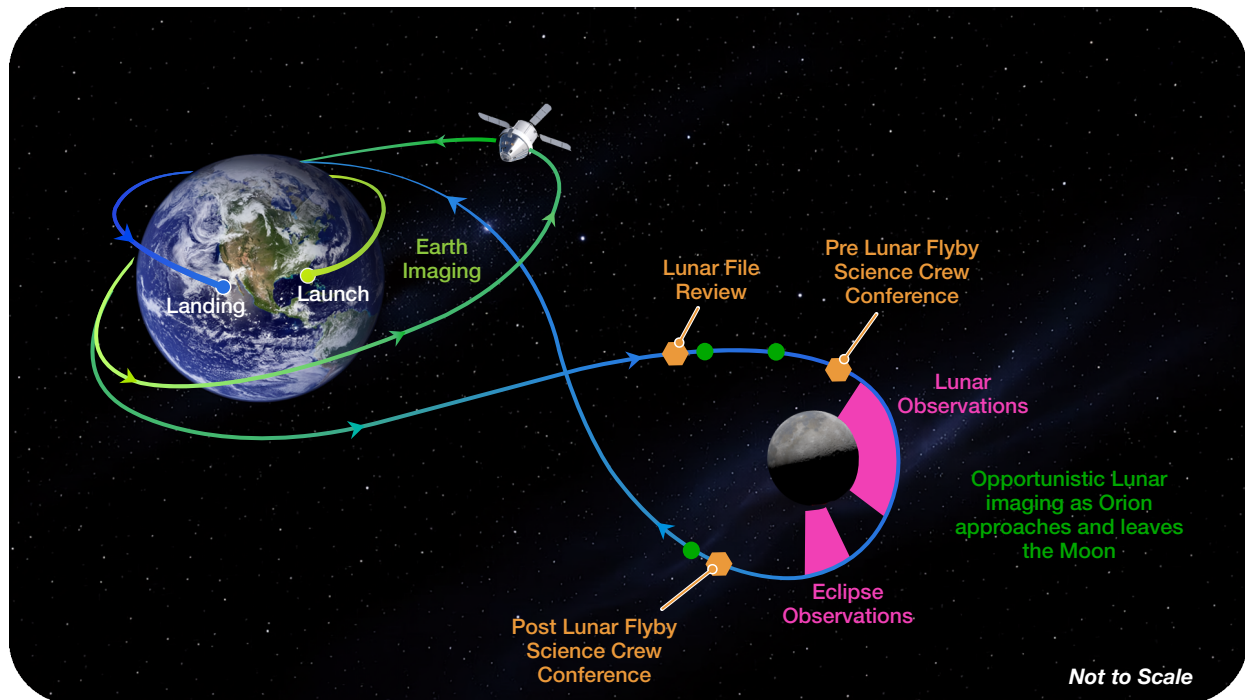


Figure 6.1: Lunar science mission milestones, mapped along Orion's trajectory. Milestone markers are for illustrative purposes only and are not drawn to temporal or physical scale.

Communications between the crew and ground teams during these milestones were broadcast on Orion-to-Earth (O/E) loops. (Detailed lunar flyby descriptions were recorded directly to the crew's tablets and not broadcast in real time.) Through these public O/E broadcasts, audiences were able to hear the SitReps, which were part of the LTP executed by the crew during the flyby (denoted by a headphone icon next to the target name, e.g., **Figure 5.3**). Communication highlights between the crew and SO during these mission milestones are captured in **Section 6.2.5**.

6.2 Lunar Science Team Mission Activities

This section provides a detailed narrative of LST support for crew activities throughout the Artemis II mission timeline, expanding on the personnel shifts and deliverables summarized in **Table 6.1**. Organized by FD, subsections describe the specific LST science support, illustrating how ground-based science operations were coordinated with, and directly enabled, crew-executed activities across the mission. The LST did not have official activities during launch and landing, therefore those FDs are not included. Personnel shifts not directly in support of a crew activity were used to prepare key LST deliverables (e.g., daily science reporting to management, uplink messages, downlinked data preliminary analysis).

Table 6.1: Summary of lunar science team shifts, activities, and deliverables by FD.

Flight Day	Key Shifts and Activities	Location	Description	Deliverables	Supported Crew Activity
02	Lunar Science Team Kickoff	SER	Reviewed mission schedule, science goals, and mission deliverables; observed TLI burn	Revised science shift schedule	
	Encounters Guide Generation	SER	CLO received post-TLI trajectory data; generated LEG	LEG for lunar flyby trajectory	
03	Target Planning	SER	LEG briefed to LST; LST began target evaluation, prioritization, and timeline scheduling for lunar flyby; drafted and reviewed the OTR	Approved target plan and draft downlink priorities; OTR database	Lunar Flyby Plan Review (FD04); Lunar Flyby Operations (FD06)
	Window Quality DFTO Review	SMOR	Supported Imagery Science and Analysis Lab analysis of window quality DFTO imagery and summarized results into a science impact report	DFTO science impact report	
	LTP Generation	SER	CLO generated a draft of LTP	Draft LTP	Lunar Flyby Plan Review (FD04)
04	LTP Finalization	SER	LST reviewed LTP and submitted minor modifications to CLO; CLO generated the final LTP; leadership approved LTP; LTP uplinked to crew PCDs	Final LTP uplinked to PCDs	Lunar Flyby Plan Review (FD04)
	Lunar Plan Review	SER	Provided support to crew during their review of the LTP	Daily science report	Lunar Flyby Plan Review (FD04)
	Lunar Image Analysis	SMOR	Evaluated opportunistic lunar images	Daily science report; crew conference inputs	Opportunistic Science Imaging (FD04–05)

Flight Day	Key Shifts and Activities	Location	Description	Deliverables	Supported Crew Activity
05	LTP Review	SER	Reviewed LTP and prepared for flyby	Daily science report	Cabin Configuration Pre-Flyby (FD06); Lunar Flyby Operations (FD06)
	Lunar Image Analysis	SMOR	Evaluated opportunistic lunar images	Daily science report; crew conference inputs	Opportunistic Science Imaging (FD04–05)
06	Flyby Documentation	SER	Captured notes from SitReps; documented any verbalized plan deltas; defined downlink priorities; delivery of downlink requests to S0; early crew conference inputs	Observation reports; notable plan deltas; downlink priorities; daily science report	Lunar Flyby Operations (FD06)
	Data Processing and Preparation	SER/ SMOR	Monitored downlink progress; initiated processing scripts when data were received	Data inventory	Flyby Documentation/ Transfer (FD06)
	Downlink I	SER/ SMOR	Inventoried audio, annotation files, and high-priority images; evaluated audio and transcripts; reviewed transcript analysis; prepared crew questions	Downlink status; transcript analysis; crew conference questions	Post-Flyby Crew Conference (FD07)
07	Downlink II	SER/ SMOR	Evaluated audio files and transcripts; generated high-priority mosaics; assessed received data; evaluated STM objectives met; generated a daily science report	Daily science report	Post-Flyby Crew Conference (FD07)
08	Downlink III	SER/ SMOR	Evaluated audio files and transcripts; generated high-priority mosaics; assessed received data; evaluated STM objectives met; generated a daily science report	Daily science report	
09	Downlink IV	SER/ SMOR	Evaluated audio files and transcripts; drafted Splashdown Science Report	Splashdown Science Report	
	Lunar Science Team Wrap Up	SER	Statused science achievements; debriefed mission science operations; reviewed forward actions	Forward timeline, actions, and deliverable dates	

6.2.1 Lunar Science Team Kickoff and Encounters Guide Generation (Flight Day 02)

FD02 marked the beginning of active LST operations following launch. The LST supported two activities on FD02: LST kickoff and LEG generation. While neither activity directly interfaced with crew, they established the foundation for the LST to support crew-facing science activities in the days that followed.

During the LST kickoff, the team reviewed the mission’s schedule, science goals, and expected deliverables for the remainder of the mission, establishing a shared understanding of priorities heading into the lunar flyby period. The LST also observed the TLI burn. Following this review, the LST revised its science shift schedule to reflect the mission’s actual timeline, ensuring the team would be properly staffed and positioned to support upcoming crew activities.

After the LST kickoff, the CLO received post-TLI trajectory data and used it to generate the LEG, detailing the lunar flyby trajectory. The LEG served as a foundational reference for the LST's target evaluation, prioritization, and timeline scheduling activities that began the following day.

6.2.2 Pre-Lunar Flyby – Cabin Configuration Development (Flight Day 03)

On FD03, after the FCT provided the preferred window for the lunar flyby observations based on results from the window quality DFTO, the crew had a timed activity to establish the ideal microgravity cabin configuration for flyby day (FD06). The crew determined the placement of physical hardware, established strategies for PCD, camera, and cord management, identified locations and techniques for stability aids, and agreed upon preferences for interior lighting. The crew also mapped out the anticipated choreography, which involved shifting back and forth between specific observation pairs: Wiseman/Hansen and Glover/Koch. To accommodate these movements and the required equipment, the crew cleaned and tidied the necessary cabin spaces to ensure a satisfactory setup. Although the crew completed comparable preparatory activities in the Johnson-based Orion mockup, this in-flight activity was critical, as many of the pre-planned crew configuration ideas were untested in the microgravity environment, which is especially important for hardware configuration development. Finally, prior to the flyby, the crew confirmed their choreography and hardware configurations during the pre-flyby crew conference (**Section 6.2.5**).

6.2.3 Lunar Flyby Plan Review (Flight Day 04)

To prepare for the lunar flyby, the crew reviewed the LTP and LGR documents on their PCDs during their journey to the Moon. A scheduled review of the lunar flyby plan allowed them to verify LTP functionality, review procedures for LTP flyby observations and data collection, and study the lunar science targets. It also provided an opportunity to ask the LST, through the SO, about LTP functionality and underpinning science fundamentals. One question from the crew addressed differences between the LTP developed pre-launch and pre-loaded on crew PCDs target list and the post-launch LTP final target list that was uplinked in-flight. As the pre-loaded LTP was created for an April 9 flyby (chosen as the flyby date that would have resulted from launching in the middle of the April launch window) and the actual flyby started on April 6, about 30 degrees longitude of lunar surface in the pre-loaded LTP was not illuminated. This resulted in six pre-loaded target features no longer being visible, while one new feature (Hertzsprung Basin) was added due to optimal illumination conditions for observation.

The crew used the LGR to refresh their knowledge of specific targets and broader surface features that could serve as navigation aids or assist with whole-Moon descriptions (**Figure 6.2**). This helped them orient themselves regardless of vehicle attitude during the flyby and provided helpful reminders for their observation actions (e.g., creating annotated maps of crater and basin morphology) and of the glossary of LTP science terms. In addition, by reviewing all data capture activities and procedures, the crew were fully prepared for the pre-flyby conference (i.e., they were equipped to ask specific questions about lunar science operations and their specific objectives).

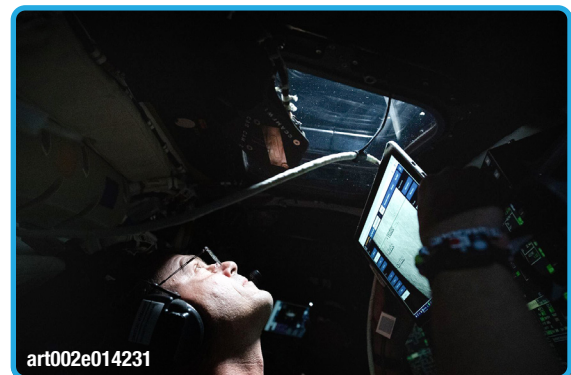


Figure 6.2: R. Wiseman looking out toward the Moon during the lunar flyby with the LGR open on his PCD. Wiseman is using the LGR view showing the west limb with maximum labels turned on, helping him to navigate and identify lunar features out of the window.

6.2.4 Opportunistic Science Imaging (Flight Days 04 and 05)

Opportunistic science imaging enabled the crew to collect observations and images of celestial objects whenever visible through Orion's windows, giving them autonomy to maximize science data collection and broaden coverage across science themes. Some of these opportunities were pre-planned, but the crew were empowered to perform this imaging outside of these preplanned blocks should vehicle orientation and other crew activities permit. This objective also allowed the crew to fully realize their role as members of the Artemis II LST, capturing observations at their own discretion throughout the mission. All data collected—even outside the dedicated lunar flyby observation window—contributed meaningfully to the mission dataset. The crew made their first detailed descriptions of the lunar surface during opportunistic imaging blocks on FD04 and FD05, building toward the pinnacle of the mission for lunar science: the lunar flyby.

6.2.5 Pre-Flyby Crew Conference (Flight Day 06)

Held during the hour before the start of lunar flyby operations, the pre-flyby crew conference was designed to ensure the crew and ground teams were fully aligned for the upcoming flyby. The primary goal of this conference was to discuss expectations, review the overarching science objectives, and resolve any open questions. During the conference, the crew kept their LTP open as a reference to help finalize their preparation for the scheduled activities.

Included are examples of the introduction, hardware reminders, and science context provided to the crew by Dr. Kelsey Young, the on-console SO, during this conference:

Introduction:

Good morning, crew. This is SCIENCE. We couldn't be more excited for a full day of lunar and planetary observations today, the first one in over 54 years. -- I did I did just want to start with a thank you on behalf of the lunar science team and the entire lunar and planetary science community, of which you are absolutely a part for what you've already done in this mission and what you're going to do today to inspire the next generation of scientists. I have to say, Moon joy is the new term that's already become our team's new motto. (K. Young, O/E-1 voice loop audio, 17:31:00 UTC)

Hardware Reminder Example:

You are go to use the full 400 millimeter zoom on the long lens, but where possible, try to keep the end of the lens flush with the window to prevent imaging through the multiple window panes at an angle. And if you have to take an image at an angle, recommend you limit the max focal length to 200 millimeters or simply acquire the images at multiple focal lengths. (K. Young, O/E-1 voice loop audio, 17:37:27 UTC)

Science Reminder Examples:

Glushko is the only feature that the same pair will view twice. That's Reid and Jeremy. That's why that's the only target you see that is marked as one of two and two of two. So, Ohm and Orientale are in there twice, but they're by different pairs, which is why you don't see them marked accordingly. (K. Young, O/E-1 voice loop audio, 17:41:02 UTC)

A reminder that if you note structure and texture as well as color and albedo, please note any correlation between the two and also reminder that negative observations are still valuable science. So a lack of color or a lack of structure associated with color is also valuable. (K. Young, O/E-1 voice loop audio, 17:41:34 UTC)

Last reminder is around earthset and earthrise, when you're viewing us back here at home, you'll be looking directly at Asia, Africa, and Oceania. (K. Young, O/E-1 voice loop audio, 17:42:13 UTC)

6.2.5.1 Cabin Configuration Pre-Flyby

In the hour before the start of the flyby, the crew prepared their hardware, including cameras, PCDs, flashcards, and 3M PELTOR tactical communications headsets, for the lunar flyby, referencing the configuration they had confirmed days prior in the cabin configuration development activity (FD03). They verified the camera configuration to ensure sufficient frames remained for the event. The crew also confirmed that the PCD times were properly synchronized and that the PELTOR headsets were connected, recording, and fully functional. Finally, they opened the LTP to verify the interface was displaying as expected and reviewed the user guide.

6.2.6 Lunar Flyby Operations (Flight Day 06)

During the several-hour lunar closest approach on FD06, the astronauts worked in pairs in a shift structure to acquire images and record scientific observations of the Moon and deep space. Following the LTP, the crew dedicated a predefined amount of time to each target for observation, annotation, and imaging. Working one pair per shift, one astronaut operated the camera while the other made unaided visual observations, with both recording audio descriptions of their observations. At any given time, the pair of crew not performing lunar observations monitored the spacecraft and supported the prime observation pair. This support included giving science SitReps over the primary O/E communications loop. These reports included a status of what the observation crew had accomplished, any hardware issues encountered, and scientific descriptions of lunar targets. SitReps enabled the LST to monitor the crew's progress, prioritize data for downlink, and begin to prepare for the following day's crew conference. They also enabled the world to follow the flyby in real time. Shift duration (i.e., the amount of time each pair was prime for lunar observations) was developed through integrated simulations to gain crew experience and feedback into the ideal amount of time to establish a working flow with the hardware and locating targets while balancing mental fatigue.

To support the crew during operations, the LST provided real-time data tracking and guidance to the crew. This communication was coordinated through the SO. The on-console SO was empowered to speak directly to the crew for the lunar science activities during the flyby, rather than the nominal communication configuration that routes communications through the CAPCOM. This unique communications configuration, which was the first time a science flight controller spoke to crew during dynamic planetary exploration, was agreed to pre-mission to maximize science return from this critical science period. The CAPCOM remained prime for all crew communications not directly related to lunar observations, with the choreography of the dynamics between CAPCOM and SCIENCE handled in the FCR. The ability for the SO to speak directly to the crew enabled immediate science follow-up in cases where clarification or further questions were needed, which ultimately created the opportunity for expanded science return. Meanwhile, the broader LST operated from the SER. Immediately after the lunar flyby, the SMOR reported for the Downlink 1 shift (**Table 6.1**).

6.2.7 Flyby Documentation/Transfer (Flight Day 6)

Immediately following the lunar flyby, the crew prepared their images and recorded observations for downlink over the Orion Artemis II Optical Communications System by transferring the data from flash cards to designated subfolders on their PCDs. As part of this data transfer activity, the astronauts clarified their annotations, added supplementary notes for science analysis, and renamed audio files using a predefined naming convention before notifying MCC that the datasets were complete and ready for downlink.

6.2.8 Post-Flyby Crew Conference (Flight Day 07)

The Artemis II post-flyby crew conference was a public-facing, globally broadcast event designed to capture the crew's immediate impressions of lunar science while their memories of observations were fresh. In this way, the conference represented a continuation of lunar science data collection rather than

a debrief. Enabling this event required coordinated preparation across the LST and FCTs well before launch and precise real-time execution during the mission.

This conference started at 19:03:01 UTC on April 7, 2026, and occurred on O/E-1 voice loops. The conference questions, delivered by the lead SO, were based off the first high-priority data downlink between FD06 and FD07. Downlinking these audio files, images, and annotations through the Artemis Optical Communication System enabled processing and analysis of the initial datasets in time to be incorporated into the conference. When data became available, the SMOR conducted a first-pass analysis to identify key scientific highlights and emerging themes. These findings were triaged to the SER, where they were shaped into a cohesive scientific narrative suitable for the live discussion. Utilizing rapid scientific analysis, the LST developed a set of targeted, time-aligned questions crafted to elicit detailed follow-up from each crew member. These questions were formatted and delivered to the FCT for approval, ensuring alignment with operational requirements and communication protocols.

The effectiveness of the conference relied heavily on pre-mission preparation. The lead SO worked closely with flight controllers during integrated simulations to rehearse the choreography required for a live, public-facing science conversation, as well as for the flyby's direct communications. For both events, this included practicing voice loop coordination, refining timing and pacing, and establishing clear expectations for how to transition between topics while maintaining scientific depth and operational clarity.

During the FD07 conference, lead SO, Dr. Kelsey Young, asked the crew the questions developed overnight by the LST, while the SER provided real-time support to the SO. The SERCOM remained on standby, with a direct voice loop enabled to the SO throughout the conference, while the SER lead remained on standby with the LST. The SERCOM and SER lead monitored crew comments, rapidly retrieved reference materials, and delivered verified answers or clarifications back to the SO with minimal delay. This capacity ensured the crew's questions could be addressed immediately and accurately. This support structure preserved the scientific continuity of the discussion and enabled the SO to guide the conversation. Examples of the questions asked during the conference are provided below.

Regarding the impact flashes reported during the eclipse observations, Dr. Young asked Wiseman and Hansen:

So, number one question was Reid and Jeremy each reported three impact flashes. There were audible yells of excitement in the SER. And we do not feel we have clarity on when the first four of those impact flashes occurred. (K. Young, O/E-1 voice loop, 19:04:05 UTC)

Transitioning to the earthset observations, Dr. Young asked Koch and Glover:

Okay, for Christina and Victor, during Earth's set, we heard you say that the Earth was so bright it made the Moon look dark. So, you all had the Earth in view during the majority of your flyby. Did you notice any time when the brightness of Earth began to change your view of the Moon's brightness? And can you describe how your perception of the Moon's color changed as the Earth came closer to the Moon? (K. Young, O/E-1 voice loop, 19:14:00 UTC)

Victor, we heard during your SitRep when you were in the docking window that having that orange Kapton tape in your field of view affected your color observations. That was fascinating and has a lot of impact for future Artemis missions and hardware and impacts on color. So, any other comment you want to make on how your ability to perceive color on the surface was influenced or limited by other objects of color in your view? (K. Young, O/E-1 voice loop, 19:17:48 UTC)

Through coordinated workflow, the LST and FCT ensured the post-flyby crew conference served as a productive, high-fidelity extension of lunar science data collection and a benchmark model for future Artemis mission practices.

6.3 LST Tools and Processes

The LST developed a number of tools and team processes to aid the team in all pre-mission and mission execution phases. This section describes the tools and software products built by the LST to meet each deliverable and mission milestone.

6.3.1 Live Encounters Guide

The LEG was an interactive (i.e., live) data analysis report on visibility and illumination profiles for potential targets created by the CLO team. The LEG was designed to give the LST situational awareness of trajectory-dependent factors such as illumination, incidence, and phase angle of each potential spatial target to assist in selecting targets of interest for the final LTP.

The LEG was generated by the CLO team after receiving ephemeris data from the FDO prior to launch and in-mission. Ephemeris data were combined with LST-defined features of interest and corresponding pre-defined parameters to compute viable targets, named encounters. Encounters data were collated, augmented with simulated imagery and videos (produced with STK), and delivered to the rest of the LST in a web-based format (the LEG). The LEG contained details on all targets that were within view of Orion throughout the flyby period and illuminated. Details included the timestamps and duration of illumination, phase, and incidence angles.

The LST utilized the LEG to select targets for inclusion in the LTP. These selections were reviewed by the full SER, targeting prompts were edited by the observation planners, and all targets were assigned a requested observation time and corresponding sequence number by the Timeline Manager. The selections were packaged in the OTR database (i.e., outgoing from SER), where it went through final reviews for SO concurrence. After SO concurrence, the OTR database was delivered to the CLO team, and the LST reviewed the file and used it to feed the LTP generation process.

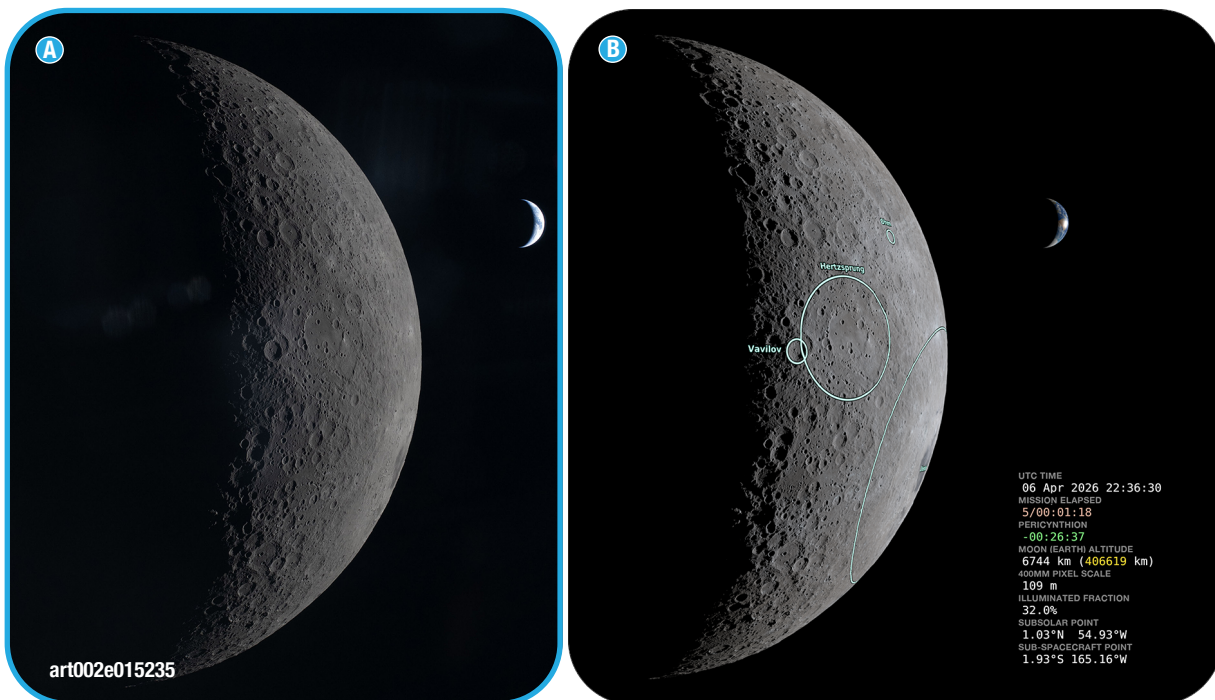


Figure 6.3: (A) Crew image art002e015235 taken at April 6 at 22:33:56 UTC compared with (B) LST video visualization at 22:36:30. The actual trajectory moved the flyby earlier by roughly 2 minutes compared to the post-TLI ephemeris.

6.3.2 Video Visualizations

Animated photorealistic visualizations of the lunar flyby, under a variety of illumination conditions, were used for observation planning, Artemis II crew training, and public engagement. A final visualization based on the first available post-TLI spacecraft ephemeris was created and used by the LST. The labeled movie, synchronized with the flyby, was played on the big screens in the SER and FCR. The fidelity of the illumination and geometry is illustrated here by comparing an Artemis crew photograph with a generated movie frame (**Figure 6.3**).

6.3.3 Lunar Targeting Plan

To create the LTP, the CLO team used the exported OTR database (see **Section 6.3.1**), which provided all the data needed to populate the LTP interface. The OTR database defined each requested target along with its start and end times, duration, prompts, additional features to label, and the required timeline icons. These details were imported into the LTP using internally developed Python scripts. All LTP imagery was generated to match the targeting times, illumination conditions, phase angles, and any additional labels requested by the LST.

Once a draft of the LTP was completed, the SER reviewed the text and provided edits. The CLO team incorporated these changes and packaged the final version. After approval, the LTP was delivered to the SO for uplink. Due to uplink bandwidth limits, the team designed for only essential and updated data, such as new images and target info, to be part of the uplink.

Post-mission verification of the LTP against downlinked imagery highlighted the similarity between expected and actual views (**Figure 6.4**).

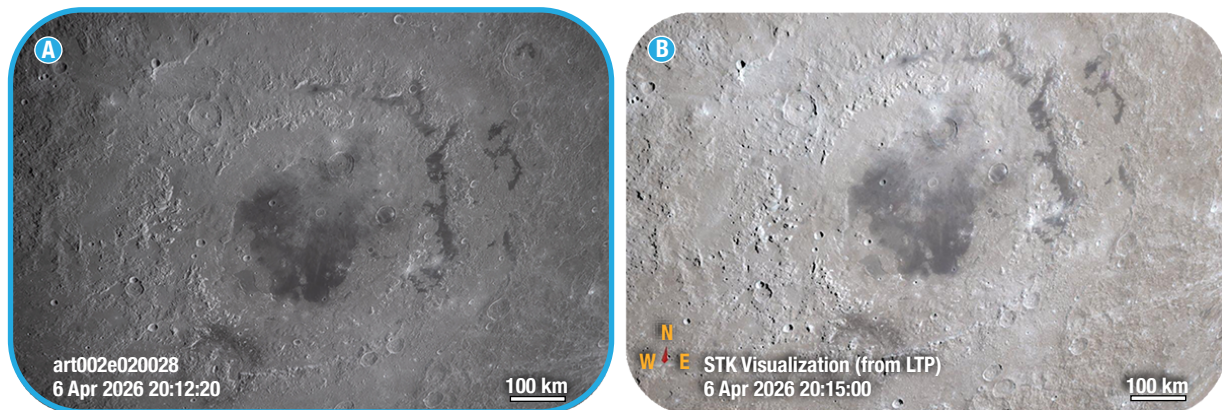


Figure 6.4: (A) Crew image art002e020028 taken with 400mm focal length lens acquired on April 6, 2026 20:12:20 UTC, compared with (B) simulated LTP image with 400mm focal length for expected view at April 6, 2026 20:15:00 UTC.

6.3.4 Flyby in Real Time

The LST also provided Flyby in Real Time, a real-time video visualization for ground team situational awareness. This video visualization was generated after delivery of the LTP and before lunar flyby. The video was distributed to, and used in, the FCR, SER, and SMOR as the flyby progressed. The video followed the lunar flyby, second by second, showing the Orion ground track and highlighting targets during their observation times on a two-dimensional illumination-conditioned lunar map. The visualization contained a timeline of shifts, targets, and countdown/up timers aligned to major flyby milestones (**Figure 6.5**). The video was not included in the LTP due to file size and uplink constraints. A pre-mission version of this visualization based on the LTP and pre-loaded onto the crew's PCDs pre-launch was also included in the briefing given to the crew by the lunar science lead four days before launch.

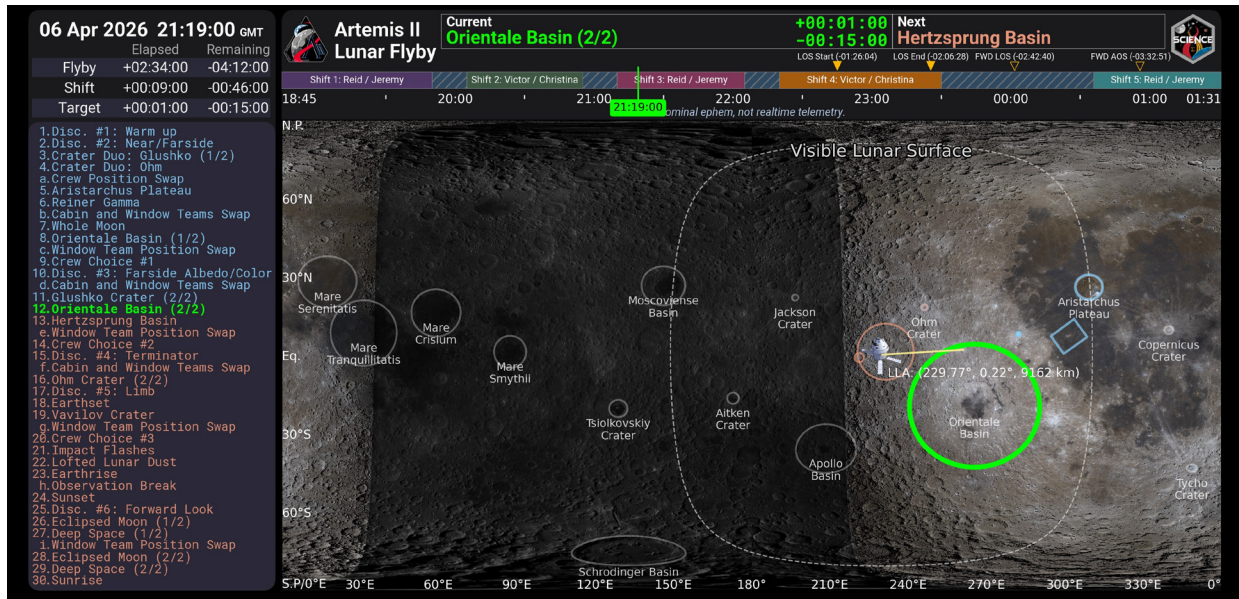


Figure 6.5: Flyby in Real Time video at 21:19:00 UTC on April 6, 2026, during Orientale Basin (2/2). The left panel of the view shows the target list corresponding to that in the LTP, with targets color coded in relation to the current time (blue = past, green = current, peach = upcoming). Above this is a timing section which has elapsed and countdown timers per milestone. The main map shows a 2D representation of the current viewing geometry. The header across the top shows the shift timeline.

6.3.5 Additional Support Tools

6.3.5.1 Transcript Readout Tool Launcher

The transcript readout tool launcher (TRTL) is a browser-based tool that enabled the crew data analysts in the SMOR to quickly search, filter, and ingest transcripts created from crew audio recordings on Orion. The CLO team created the TRTL to host all available mission transcripts in one location and in chronological order for the entire LST to access, as needed. The CLO team updated the TRTL as transcripts were generated.

6.3.5.2 Scripts and Packages

A comprehensive suite of custom scripts and automated processes was designed and implemented by the LST tools sub-team to meet the specific operational needs in the SER and SMOR across the mission timeline. Built primarily in Python, the tools rely on standard open-source packages and were built to enable rapid data analysis and visualization. When required, external libraries (e.g., ExifTool, Ffmpeg) were integrated into workflows.

6.4 Data Flow In-Mission

The Artemis II mission generated a substantial volume of science data, requiring thorough processes for uplink, downlink, storage, and archiving. This section summarizes the end-to-end flow, from acquisition onboard Orion to public release via PDS. For detailed technical workflows and instrument specifics, refer to the SMD Artemis II Lunar Science OSDMP.

6.4.1 Data Sources/Types

Science data for Artemis II came from a diverse set of sources including: crew-operated handheld cameras such as the Nikon D5 DSLR, Nikon Z9, and iPhone 17 Pro Max, which captured still images and audio; vehicle-mounted systems like the solar array wing, cabin, and docking cameras, which produced still images and video; mission audio recorded on PCDs, O/E voice loops, and Nikon cameras;

crew-generated annotations saved in OneNote and PDF formats on PCDs; and environmental measurements of cabin temperature and humidity captured in CSV files. Each data stream was managed by its corresponding NASA organization and delivered in a wide range of formats, including NEF, JPEG, PNG, MP4, MXF, M4A, MP3, WAV, and CSV, reflecting the varied tools and systems used throughout the mission. Additional details are provided in the OSDMP and Data User Guide.

6.4.2 Uplink

The LST uplinked two primary types of files during the mission for use by the crew: the LTP and crew uplink messages.

6.4.2.1 Lunar Targeting Plan Uplink

The final ('LTP Final') was the single uplink product planned to be sent by the LST to the crew during the mission. The LTP Final was an updated version of the pre-launch load of an initial LTP (LTP1). LTP1 was created pre-mission based on a single, notional launch date and ephemeris within the expected launch period. The LTP Final replaced LTP1 and featured the post-TLI ephemeris, corresponding updated visualizations, and any changes to the science plan made by the LST after launch.

6.4.2.2 Crew Uplink Messages

The LST also provided the crew with images and recommendations via crew uplink messages (DOC or PPT files). Examples of uplink message use included providing the crew with their images taken during the 'lunar cabin config – develop' activity, as well as responses to any questions about the LTP. Crew messages were viewable on the crew PCDs and organized by FD.

6.4.3 Downlink

Science data were stored in two locations: on the PCDs (Nikon D5/Z9 images and audio files, voice recordings, and OneNote annotation files) and the Orion camera controllers (for mounted vehicle cameras). The storage location determined the downlink pathway for the data. Data were downlinked in-mission so the LST could assess progress toward mission objectives and make any necessary in-mission adjustments to data collection (e.g., based on imagery from opportunistic imaging, the window optical quality DFTO, and the lunar flyby).

Following the lunar flyby, the crew transferred data collected with the Nikon cameras (images and audio files) to the PCDs for downlink from Orion. Additionally, the images and video taken via the Orion-mounted external cameras (e.g., Solar Array Wing (SAW) Cam 3) were transferred from the cameras to the camera controller by MCC-based flight controllers. The data could be downlinked from the PCD to the ground through either S-band antennae (~2 Mbps) or optical communications (Optical Comm; ~60 Mbps) antennae. Optical Comm was planned for testing during a DFTO on FD02. If S-band was the only viable communication method, the amount of data that could be downlinked in-mission would be limited. If Optical Comm proved successful, a significantly higher volume of data downlink would be achievable. Optical Comm was successfully tested and enacted in-mission via the DFTO, enabling the LST to receive almost 114 GB of data downlinked during the mission.

6.4.4 Data Prioritization

Prior to the mission, the LST developed a data prioritization framework in the event that in-mission downlink was not available at significant quantities post-flyby. The audio files of lunar observations recorded on the PCDs during the flyby were the highest priority, both because the data within could be used to inform the following day's post-flyby crew conference, an active science data collection opportunity, and because the PCDs are more susceptible to radiation damage than the Nikon camera cards, introducing possible risk for data loss. Following the audio files, the LST prioritized images from specific observations in the LTP during the lunar flyby from the crew and the vehicle cameras. The prioritized images were those that captured the nuances of human observations, including color (e.g., Aristarchus

Table 6.2: Summary of science data received by the LST, including crew images, vehicle camera images, mission audio files, crew annotation files, and temperature/humidity data. Listings include the received source format, volume (in GB), and archival format.

Total Mission Science Data	File Count	Volume (GB)	Source Format	Additional Archive Format
	11591	814.51		
Crew Camera (Serial Number)				
Nikon D5 (3500015)	7011	118.05	NEF	TIFF
Nikon D5 (3500017)	553	10.23	NEF	TIFF
Nikon Z9 (3920019)	2775	79.71	NEF	TIFF
iPhone 17 Pro	68	2.30	DNG, JPEG	TIFF
Total Crew Camera	10407	210.29		
Orion Camera (Still)				
SAW Cam 2	10	0.02	JPEG	TIFF
SAW Cam 3	189	0.50	JPEG	TIFF
SAW Cam 4	12	0.03	JPEG	TIFF
CAB Cam 2	176	0.39	JPEG	TIFF
OpNav	404	2.00	TIFF	TIFF
Docking Cam	249	0.20	PNG	TIFF
Total Orion Camera (Still)	1040	3.14		
Orion Camera (Video)				
SAW Cam 3 (Video)	22	598.20	MXF	MP4
Total Orion Camera (Video)	22	598.20		
Mission Audio				
PCD Audio	53	0.70	M4A	M4A
Orion/Earth 1, 2 Voice Loops	20	2.10	MP3	MP4
Nikon Audio	42	0.06	WAV	*see Notes
Total Mission Audio	115	2.86		
Mission (Other)				
Crew Annotations	5	0.02	OneNote, JPEG	PDF
Temperature/Humidity	2	0.00	CSV	CSV
Total Mission (Other)	7	0.02		

*Notes: For the data archive, the brief transcriptions of Nikon audio WAV files were added to the metadata of associated Nikon images. Separate transcripts in CSV and SRT format were also prepared for PCD and voice loop audio files.

Plateau, Glushko, Orientale). These targets were prioritized because they could influence the post-flyby crew conference activity. Data prioritization was therefore also carried over into subsequent shifts where high-priority downlinked data were the first to be analyzed. The post-flyby crew conference presented the opportunity to ask questions and clarifications about nuanced observations. The prioritized list of images for downlink priority and analysis priority needed to support the crew conference was completed by LST members staffed during the transition between the end of the lunar flyby and the start of the post-fly-by SMOR shift. Handover discussions and materials allowed quick and direct input from the LST members in the SER during the flyby to guide identification of Image IDs for high-priority LTP targets, and moments during the flyby, to create a prioritized list for downlink and immediate analysis by the incoming SMOR shift in preparation for the crew conference. For data collected in time periods outside the flyby (e.g., opportunistic imaging), downlink was coordinated by the SO with the other FCT consoles to downlink data as bandwidth and other downlink priorities allowed.

6.4.5 Data Volume and Summary

Table 6.2 summarizes the scale and distribution of the data collected through the Artemis II mission, showing the total number of files, data volume, and contributions from each instrument and sensor. Also provided are the additional file formats prepared for the data archive in the PDS.

7.0 FEED FORWARD

The Artemis II mission team and all subdisciplines conducted rigorous pre-mission and post-mission debriefs. Lessons learned were compiled across the mission to preserve the historical record of the mission and to inform future missions, including the upcoming Artemis III mission. The LST compiled best practices based on six science operations topics, including several recommendations for future Artemis missions, which are highlighted to inform the broader community of this experience.

7.1 SER and SMOR Facilities Best Practices

The SER and SMOR were critical facilities for the success of the lunar science and exploration capability objectives of Artemis II. As such, the LST assembled in-flight shifts within the SER and SMOR to support science deliverables. Staffing of these facilities was designed to enable the LST to successfully meet its science and exploration objectives, and roles within each facility and shift were intentionally aligned with the schedule of mission deliverables and support needs. Although most staff had technical expertise in science or the construction of science plan deliverables, important staffing roles also included asset managers and staffing support. These dedicated roles, along with a dedicated science documentarian, allowed other roles to focus on their primary tasks without needing to manage other related parts of the science or SER infrastructure.

- **Recommendation:** Although Artemis II SER and SMOR roles were developed specifically for an orbital observation science campaign, future Artemis missions should develop similarly appropriate roles specific to their science mission scope and major activities. Roles should be developed in multiple ways, for example, through integrated sims and analysis based on science objectives.
- **Recommendation:** Continue to have staffing coordinators and asset managers integrated with the LST as much as possible—to allow relationship building and a shared understanding of combined team goals and constraints. Ensure there are enough individuals trained and staffed in these roles to cover the team and rooms as needed, with redundancy.

The SER and SMOR had voice loops to directly communicate with the SCIENCE console, and each room shared console IT access on select computers that enabled communication to FCR positions, primarily SCIENCE. For Artemis II, the communication pathway between the SER and the SCIENCE console was heavily coordinated, and personnel in the SERCOM position were trained during all integrated simulations. This setup increased the value of the SER's support role. SMOR communications were designed to hand over findings and support activities in the SER.

- **Recommendation:** In addition to the SER's support role in the mission, events and staffing within the SMOR during future Artemis missions should be intentionally designed to support SCIENCE directly. If SMOR activities remain data-analysis-focused in future missions, a SMORCOM training and certification pathway, similar to the SERCOM's training in Artemis II, would be beneficial.

The modular nature of the SER and SMOR facilities benefitted the LST, whose activities varied widely throughout the mission. For each activity type, different room setups created an optimal way for sub-teams to meet and coordinate work efficiently. The large number of displays enabled consistent situational awareness of schedule, comms, and crew activities without requiring individual team members to manage limited screen space. Console positions were limited to SER lead, SERCOM, and asset managers, who needed this interface with SOs through the mission; other team members used government IT without the need for, or access to, console IT.

7.2 In-Mission Scheduling Best Practices

Shift scheduling during Artemis II was coordinated in response to the mission's science activities and the in-mission staffing level of the LST. Mission-shift scheduling for LST members followed two frameworks: a 24/7, three-shift approach (Orbit 1, 2, and 3) and a crew- and activity-centric approach. Within the first approach, SOs were staffed continuously from FD02 to FD09. This support was found to be critically important for scheduled and longer-term needs. It enabled collaboration, troubleshooting, and replanning between the LST and other FCT disciplines, as well as immediate response to any incoming questions from the crew or the on-console Flight Director. The rest of the LST followed the activity-centric approach. Thus, since the SER and SMOR were not staffed continuously, there were times when SCIENCE did not have support for key tasks if they did not overlap with pre-planned activities.

- **Recommendation:** The LST would have benefitted from having SER and/or SMOR staff following the 24/7, three-shift scheduling approach. Future Artemis science teams should accommodate three-shift scheduling to increase the speed and capacity of SCIENCE activity support throughout the mission.

The LST was mainly staffed daily through ~8-hour shifts in the SER and/or SMOR. Staffing schedules generally overlapped, although did not have the same start and end times. In addition, SER and SMOR shift changes did not coincide with SCIENCE shift changes. Instead, SER and SMOR shifts were scheduled according to significant mission events: either crew-centric activities (e.g., window quality DFTO, opportunistic imaging, lunar flyby, crew conferences) or those related to data downlink occurrences. This schedule was developed to provide the most response capability to known science mission milestones, as well as to accommodate staffing level realities. Other necessary LST activities were more schedule-independent (e.g., LTP staffing was a multi-day process without direct connection to scheduled mission events on some days). These shift-agnostic activities were also completed during regular SER and SMOR shifts.

- **Recommendation:** If scheduled events have uncertainty, explore ways for staff schedules to respond flexibly, either through on-call, three-shift, or other approaches.
- **Recommendation:** If staffing levels allow, roles should be dedicated to distinct foci. Longer term analysis needs should be performed in their own shifts/facilities rather than doubling up on existing support shift needs.

7.3 Team Communication Best Practices

When not supporting the mission, the LST members were geographically dispersed across multiple NASA centers. To address this distribution (as well as varying stakeholder and collaborator cultures) ahead of and after the mission, multiple communication strategies were implemented, including:

- A common LST-shared drive (Microsoft SharePoint pre- and post-mission; Box in-mission to accommodate mission-specific file management needs);
- A shared chat space (Microsoft Teams) and group chats (mobile phone, in-mission); and
- A wiki environment to document major activities and workflows.

This multifaceted approach to documentation was imperative to the team's success. Before the mission, meeting notes, crew training documents, desk instructions, and procedures were developed on the shared drive before final documentation in a NASA wiki space or in the appropriate mission environment. During the mission, the LST relied on pre-designed templates for shift kickoff meetings, shift wrap-up meetings, documentarian reports, shift role summaries, console logs, and activity support documents. Post-mission, the team relied on collaborative environments for meeting notes and recordings, science publications and reports, and data archival activities.

- **Recommendation:** Proliferation of documentation before, during, and after the mission necessitated creative solutions to maintain discoverability of data and documentation. Documentation awareness and management (e.g., document trees, increased cadence of communication about file structures) should scale naturally with the complexity of the mission development environment.

In preparation for the mission, and following standard operating procedure for human spaceflight missions, operational interface procedures (OIPs) and crew procedures were developed with other mission collaborators. During the mission, dedicated science communication voice loops included:

- A 'Science Coord' loop for other FCT consoles to interface with SOs;
- A 'Science Plan' loop for communication between the SO and the SER and SMOR; and
- A 'SMOR Coord' loop for SER to SMOR communication.

All loops were implemented throughout the mission. Handovers between SER and SMOR were conducted on the SMOR loop.

Text-based Microsoft Teams chats complemented these voice loops as a real-time communication tool. A single large group chat supported the full team, alongside smaller group chats organized around specific deliverables. These chats remained active throughout the mission; a new, larger in-mission group chat was also created specifically to archive discussions and keep conversations focused on mission deliverables and issues as they arose.

Within the SER, voice remained the primary means of communication, though not all SER personnel were enabled for voice loop communications; for these individuals, and for cases requiring longer or more detailed explanations, chat served as the primary channel. Between the SER and other rooms (e.g., the FCR and SMOR), voice loops were the primary means of coordination, with the team pivoting to written communications when a topic required more detailed explanation than voice allowed. No significant gaps in documentation or lost information from rapid voice communication were identified.

- **Recommendation:** Future missions should consider maintaining voice loop communication as the primary channel for SER to FCR coordination, reserving text-based communication for longer messages or information requiring more permanent documentation.

7.4 LST Training Best Practices

Week-long face-to-face meetings, integrated sims, and longer-term, online meetings to work through flight processes in sequence over weeks (slow sims) were integral to ensuring LST readiness. The mantra

“train like we fly and fly like we train” begets best practices in determining simulation-based training objectives. These included:

- Committing to realistic shift and activity schedules in simulations;
- Committing to sequential milestone-based tasks in slow sims; and
- Ensuring simulation roles were filled by team members likely to be assigned to those roles during the actual mission while taking opportunities for cross-training when possible.

Workflow testing was also achieved via simulations and process walkthroughs (e.g., slow sims). Building flexibility and intentional trade evaluation into sims, as appropriate, enabled gap identification, which was subsequently filled by a role, a tool/resource, or both. Flexible role staffing also was beneficial at times (e.g., to cross-train roles).

Certification of SOs followed flight controller standards, and for SER leads and SERCOMs followed an informal feedback structure that mimicked this certification. Following integrated simulations that included nearly all LST participants, the readiness of the science operations team as a whole was certified by the lunar science lead to NASA SMD and FOD. These readiness and feedback strategies were appropriate for the Artemis II mission, but future missions with higher-complexity science support requirements may need to revisit feedback and certification strategies to determine a best fit for those missions.

- **Recommendation:** Certification procedures, along with training and feedback expectations, varied across science operations roles for Artemis II. Future missions should standardize these processes and set a clear, realistic standard that consistently prepares operations support team members for success.

7.5 Mission Data Best Practices

The Artemis II data collection plan was designed in response to several factors, including science objectives, lunar features of interest, flyby schedule and distance, onboard cameras and PCDs, the post-flyby crew conference, and data downlink opportunities. Collection of mission science data—crew and vehicle images, audio description files, and annotations—was planned to maximize long-term science return post-mission, while also enabling preparation of a post-flyby crew conference, and validating the imagery plan pre-flyby through in-mission activities (e.g., window quality test).

- **Recommendation:** In addition to a post-flyby conference and a two-month post-splashdown debrief with crew members, crew perspectives about science investigations should be shared as soon as possible after splashdown. Some perspective meetings should be conducted with the entire crew and some LST members, although most interactions could be accomplished with single crew members at a time.

The orbital, crew-captured image strategy enabled capture of single images and mosaics. Necessary mosaic overlap training followed best practices from robotic and space station imaging experience, including a snaking pattern and sufficient overlap. The resultant mosaicked images provided value in multiple ways: overlapping images enabled synchronous views from regions or the entire Moon, and crew mosaicking exercises guided crew observations. Cameras were also configured to provide bracketed exposure images (i.e., to maximize the capacity of images to capture bright and dark features on the Moon and in space). Derived products, such as mosaic image collages or HDR images, will likely also be created by future data users.

- **Recommendation:** Crew camera best practices are heavily dependent on training. Experience levels vary significantly, with some crew members having significant orbital experience using cameras. Future missions should enable experienced crew members to modify the data collection strategy in real time, provided they clearly communicate these changes as they occur to help maximize science return.

- **Recommendation:** In addition to its use as an imager, the Nikon D5 DSLR served as a valuable monocular for crew to compare unaided-eye views and zoomed-in views. The Nikon Z9, which uses a computer screen for a viewfinder, could not be used in the same manner. In a post-flight debrief, the crew commented on the difference between the Z9 live images and what they were seeing with the unaided eye. D5 images also captured subtly different surface characteristics than what was perceived by crew, further highlighting its value as a pass-through monocular. Future missions should consider retaining at least one optical-viewfinder camera in the mission manifest to preserve this pass-through monocular capability, particularly for tasks that benefit from direct unaided-eye to zoomed comparison.

Crew members were tasked with annotating computer visualizations on PCDs to support other observations. This was accomplished by providing a static document of lunar target visualizations on an onboard instance of OneNote. Although annotation training was limited, these served as valuable geographic markers to help the LST understand areas being observed—both for static features and impact flashes. Some annotations also provided clear geographic boundaries between perceived differences in the lunar surface.

- **Recommendation:** Future training should expand on the value of digital annotations to encourage more observational sketching. With current technology and given limited observation time, it is difficult with digital sketches to match the detail and intent of traditional field sketches. Solutions to this gap should enable better annotations and sketches in the future.

Audio descriptions were recorded on PCDs during the lunar flyby. Immediately post-flyby, these data were ranked as the highest-priority data to downlink. This prioritization reflected upcoming science activities for the mission, primarily the post-flyby crew conference. As the intent of this conference was to continue to gain observational information from the crew perspective, audio was understood to best match the state of the crew's perspective during the flyby. Some images were also intended to be downlinked to provide context for the coincident audio descriptions (in reality, data rates were high enough that more audio and image data were delivered before the conference than this minimal prioritization plan).

- **Recommendation:** Artemis II science data downlink priorities were driven by the next science milestone of the mission for which data were needed. Surface missions and future orbital missions should perform similar operational prioritizations for data downlink in support of science replanning and future activity planning for extravehicular and intravehicular activities.
- **Recommendation:** The Artemis II lunar science data downlink plan was designed to triage data for downlink and then process a limited amount of data immediately, with the understanding that some or most data would be delivered post-splashdown. However, with sufficient bandwidth, a significant amount of science data were returned in-flight. Future missions should design science processes that are flexible to small and large volumes of data being returned in-flight.

Collection of vehicle images was planned to support crew observations and to make independent observations of the Moon. Although crew observations were made, external SAW vehicle camera images and videos provided context of the view (whether live or later downlinked to Earth). The collection of vehicle images was also planned to complement crew images, since SAW cameras did not have a cabin window in the way. SAW camera videos enabled monitoring of the lunar surface over time, which relieved the crew from a potential responsibility of having to systematically image the entire Moon with distinct periodicity.

- **Recommendation:** Vehicle camera science return should be improved in future missions, so that vehicle camera capabilities can be traced to specific science objectives. One key area would be impact flash monitoring, where vehicle camera videos would need to have spatial and frame rate resolutions adequate to sense ephemeral flashes.

7.6 Collaborative Exploration

The productivity and scientific success of the Artemis II crew during the lunar flyby was due in part to their ability to work as a team. Like conducting field exploration on Earth, scientific exploration is best done as a team, where field scientists have the ability to work collaboratively, sharing ideas and hypotheses with each other while at the field site. The LST worked hard to preserve this aspect of collaborative exploration, developing a concept of operations for the lunar flyby that enabled the crew to work in pairs. Comments made by the crew, in real time during the flyby and in post-flight debriefs, highlight the positive impact of this collaborative exploration. As an example, the Artemis II crew were, mid-flyby, discussing multiple working hypotheses with each other. One person's observations would inform more nuanced observations made by the next person. Enabling this scientific dialog while still in the field (i.e., cislunar space) maximizes scientific discovery. This was enhanced by the SO's ability to speak directly with the crew during the period of scientific discovery, allowing immediate and nuanced science follow-up. This success is contingent on having the SCIENCE console in the MCC front room. By training lunar scientists and geologists in flight control and developing their operational skills, we ensure that science return from Artemis missions will be maximized, while not detracting from crew and vehicle safety or operational efficiency.

- **Recommendation:** Future Artemis missions should, whenever possible, allow for crew members to work in pairs during scientific exploration activities (e.g., orbital observations, surface activities).
- **Recommendation:** The SO's location in the MCC FCR was critical to mission science return and should be maintained in future missions. Whenever possible, the SO should be able to talk directly with the crew during periods where science is the primary focus (while always deferring to the flight director and primary CAPCOM before, during, and after this direct communication).

8.0 SUMMARY

Artemis II represented a significant step in a new era of crewed exploration beyond our planet. Standing on a foundation of more than 50 years of scientific discovery generated by Apollo and subsequent uncrewed lunar missions, the mission successfully executed high-priority lunar science objectives and associated requests for crew and vehicle observations. Four crew members, trained extensively in lunar science and geology, served as members of the LST. These field explorers worked as a team to observe the Moon, the Earth, the Sun, and deep space. Back on Earth, the entire mission support team, the FCT, and the LST effectively integrated lunar science into the fabric of operations, both in mission preparation and execution.

The development and integration of a new flight controller position (the first time a console focused on science ever populated the Mission Control front room in an exploration mission) and two new science flight control rooms all contributed to the science success of the Artemis II mission. These achievements thus serve as the basis for the scientific success of future missions.

We go to the Moon to learn about ourselves, our own planet, our Moon, our Solar System, and our place in all of it. We go together, and we will go again.

Acknowledgements

The lunar science of Artemis II was made possible through the dedicated efforts and close collaboration of numerous individuals and teams across and beyond NASA. The Lunar Science Team gratefully acknowledges the contributions of our partners, whose expertise and support enabled this team's scientific success, and expanded the scope of Artemis II lunar science beyond its initial objectives. The Lunar Science Team is also grateful for the broader lunar and planetary science community for defining lunar science priorities that helped guide this mission's STM, and for future analyses that will continue to advance understanding of the Moon through the Artemis II data.

In addition to the individuals and teams who made the Preliminary Science Report possible, we acknowledge here the efforts of the crew, the Flight Control Team, and the NASA and Lockheed Martin Orion Teams who developed and flew this mission, working with the Lunar Science Team to maximize science return wherever possible. We also thank the Flight Director Office for their support in developing and certifying the Science Officer console, as well as groups across the Flight Operations Directorate for their support in developing and certifying the Science Evaluation Room. We also acknowledge the decades of development that Apollo, ISS, and multiple analog mission teams contributed to the operations work described in this report.

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9.0 APPENDICES

9.1 Relevant Operational Nomenclature (OpNom)/Glossary

<u>Abbreviation</u>	<u>Phrase</u>
AGI.....	Analytical Graphics, Inc.
BPS.....	Biological and Physical Sciences
CAPCOM	Capsule Communicator Console
CLO	Crew Lunar Observations Team
CSA	Canadian Space Agency
CTO	Chief Training Officer
DVICE	Digital Voice Inter-Communications Equipment
FCR.....	Flight Control Room
FCT	Flight Control Team
FDO	Flight Dynamics Office
FOD	Flight Operations Directorate
FOR.....	Flight Operations Review
FOV.....	Field(s) of View
INCO	Integrated Communications Officer
ISAG.....	Imagery Science and Analysis Group
LEG	Live Encounters Guide
LGR.....	Lunar Geography Review
Look ODD	Look, Observe, Describe, Document
LST.....	Lunar Science Team
LTP.....	Lunar Targeting Plan
MCC	Mission Control Center
NOLS	National Outdoor Leadership School
OESC	Orion Electronic Still Camera
OSDMP	Open Science Data Management Plan
OTC	Outbound Trajectory Correction
OTR.....	Outgoing Target Request
PAO.....	Public Affairs Office
PCD	Portable Computing Device
PDS	Planetary Data System

<u>Abbreviation</u>	<u>Phrase</u>
SAW.....	Solar Array Wing
SER.....	Science Evaluation Room
SERCOM	SER Communicator
SitRep(s)	Science Situation Report(s)
SLS	Space Launch System
SMD.....	Science Mission Directorate
SMOR.....	Science Mission Operations Room
SMORCOM.....	SMOR Communicator
SO	Science Officer
STK.....	AGI Systems Took Kit
STM	Science Traceability Matrix
SVMF	Space Vehicle Mockup Facility
TLI	Translunar Injection

9.2 LST Major Training Events

This section lists significant LST training and team development events. All events took place at Johnson, except where denoted in the event name. Smaller events (e.g., mini-sims) are not included.

Event Name	Date(s)	Science Team Focus
January Virtual Simulation	January 22-23, 2025	Early practice on workflows, LTP familiarization, voice loop structure, and process walkthroughs
Target Visualization and Data Downlink (Goddard)	April 7–9, 2025	First major exercises of science- to-ops workflows, visualization reviews, and downlink analysis
Targeting Shift and Data Downlink I	June 2–5, 2025	First use of SER and SMOR; team trained real-time data flow, cross-room coordination
A-II Orbit Trajectory Correction Burn Simulation (Lunar File Review)	June 17, 2025	Practice executing the Lunar File Review activity integrated with operations
A-II Orbit Trajectory Correction Burn Simulation (Second Run)	July 1, 2025	Continued training on file review workflows and mission product handoffs
Lunar Flyby-1 Integrated Simulation	July 11, 2025	First full-scale lunar flyby sim; SER/SMOR staffing, visualization, CLO, asset management, and timeline workflows
A-II Orbit Trajectory Correction Burn Simulation	August 5, 2025	LTP review; training on timeline interfaces and LTP integration
Lunar Flyby-2 Integrated Simulation	August 12, 2025	High fidelity run with crew surrogates; expanded SER/SMOR/B5 participation; first SO certified
Lunar Flyby-3 Integrated Simulation	September 23, 2025	Malfunction-rich scenario rehearsals; strengthened coordination between SER, SMOR, and FCT
October LST Face-to-Face + Three Simulations	October 6–10, 2025	In-person team alignment, workflow validation, tool refinement, and multi-sim training
Lunar Flyby-4 Integrated Simulation	October 17, 2025	Real-time operations practice during FD06; cross-discipline malfunction resolution; workflow validation
Lunar Flyby-5 Integrated Simulation	November 21, 2025	Second SO certified; full SER/SMOR/science team participation
Lunar Flyby-6 Integrated Simulation	January 12, 2026	FCT/crew proficiency run; Final SO certified
February LST Face-to-Face	February 10-12, 2026	Mission Phased Based Proficiency run for Target development, data downlink, and flyby conference preparations
Lunar Flyby-7 Integrated Simulation	March 17, 2026	Lunar flyby practice with eclipse; first time SO implemented direct crew communication during a flyby simulation

9.3 Crew Training Events

Event Name	Date(s)	Training Objectives
Lunar Fundamentals	May 3-10, 2023	Establish a foundational scientific baseline in lunar geology, exploration history, planetary processes, and terminology for crew
Kamestastin Crater, Labrador, Canada Field Training Event	September 1-12, 2023	Provide hands-on exposure to lunar-analog impact geology, practicing observation of impact melts, breccias, and crater outcrops
Pre-Iceland Science Training	June 7, 2024	Review of sample types and sample strategy found at the field site
Iceland Field Training Event	July 24 – August 6, 2024	Build proficiency in volcanic geology observation, field description technique (Look ODD), regolith and surface navigation skills, and team science communication
Targeting Plan Development Training	October 2024	Introduce and gather crew feedback on LTP functionality ahead of product finalization
Orbital Observations – Lunar Geography	June 18, 2025	Introduce Artemis II science objectives, lunar geography, the ground-team support model, and strategies for documenting features under trajectory and illumination constraints
Orbital Observations Operations	June 30, 2025	Train crew on in-cabin choreography, onboard hardware and digital tools, and high-level timeline/ground planning processes for lunar observations
Orbital Observations – Lunar Geography Homework Activity	July 2025	Reinforce lunar geography knowledge and feature-identification skills through short, targeted practice modules
Orbital Observations – Lunar Geography Homework Activity	October 2025	Reinforce lunar geography knowledge and feature-identification skills through short, targeted practice modules
Orbital Observations – Lunar Geography Homework Activity	early November 2025	Reinforce lunar geography knowledge and feature-identification skills through short, targeted practice modules
Orbital Observations – Lunar Geography Homework Activity	late November 2025	Reinforce lunar geography knowledge and feature-identification skills through short, targeted practice modules
Orbital Observations – Lunar Geography Homework Activity	early December 2025	Reinforce lunar geography knowledge and feature-identification skills through short, targeted practice modules
Orbital Observations – Lunar Geography Homework Activity	late December 2025	Reinforce lunar geography knowledge and feature-identification skills through short, targeted practice modules
Orbital Observations – Lunar Operations Homework Activities	June 2025	Review an assigned target by recording a verbal description following the cue card format and submitting it to the LST for feedback, reinforcing observation and description proficiency

Event Name	Date(s)	Training Objectives
Orbital Observations – Lunar Operations Homework Activities	October 2025	Review an assigned target by recording a verbal description following the cue card format and submitting it to the LST for feedback, reinforcing observation and description proficiency
Orbital Observations – Lunar Operations Homework Activities	November 2025	Review an assigned target by recording a verbal description following the cue card format and submitting it to the LST for feedback, reinforcing observation and description proficiency
Orbital Observations – Lunar Operations Homework Activities	December 2025	Review an assigned target by recording a verbal description following the cue card format and submitting it to the LST for feedback, reinforcing observation and description proficiency
A-II Lunar Flyby #1 Integrated Simulation Event	July 11, 2025	Practice nominal lunar flyby operations and contingency response with the FCT, building proficiency in hardware use and data collection procedures
Artemis Lunar Imaging Orion Crew Configuration	July 16, 2025	Develop and validate crew hardware configuration (cameras, PCDs, headsets) and paired observation strategies inside the Orion cabin mockup
Lunar Targeting Plan Feedback Homework	October 9, 2025	Gather crew feedback on LTP functionality and reinforce familiarity with the Lunar Targeting Plan ahead of the mission
Artemis Lunar Imaging Orion Crew Configuration (Dark Ops)	November 5, 2025	Validate crew hardware configuration and observation procedures under realistic low-light conditions expected during the flyby
A-II Lunar Flyby #5 Integrated Simulation Event	November 21, 2025	Continued refinement of flyby operations proficiency incorporating updated trajectory/targeting data
Orbital Observations Proficiency	January 8, 2026	Demonstrate and assess crew readiness for lunar observation tasks through individualized coaching on verbal feature descriptions and timeline execution
A-II Lunar Flyby #6 Integrated Simulation Event	January 12, 2026	Continued refinement of flyby operations proficiency incorporating updated trajectory/targeting data
Orbital Observations – Lunar Geography Homework Activity	early January 2026	Reinforce lunar geography knowledge and feature-identification skills through short, targeted practice modules
A-II Lunar Flyby #7 Integrated Simulation Event	March 17, 2026	Final flyby readiness checks ahead of launch, incorporating final trajectory/targeting updates and eclipse timeline

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