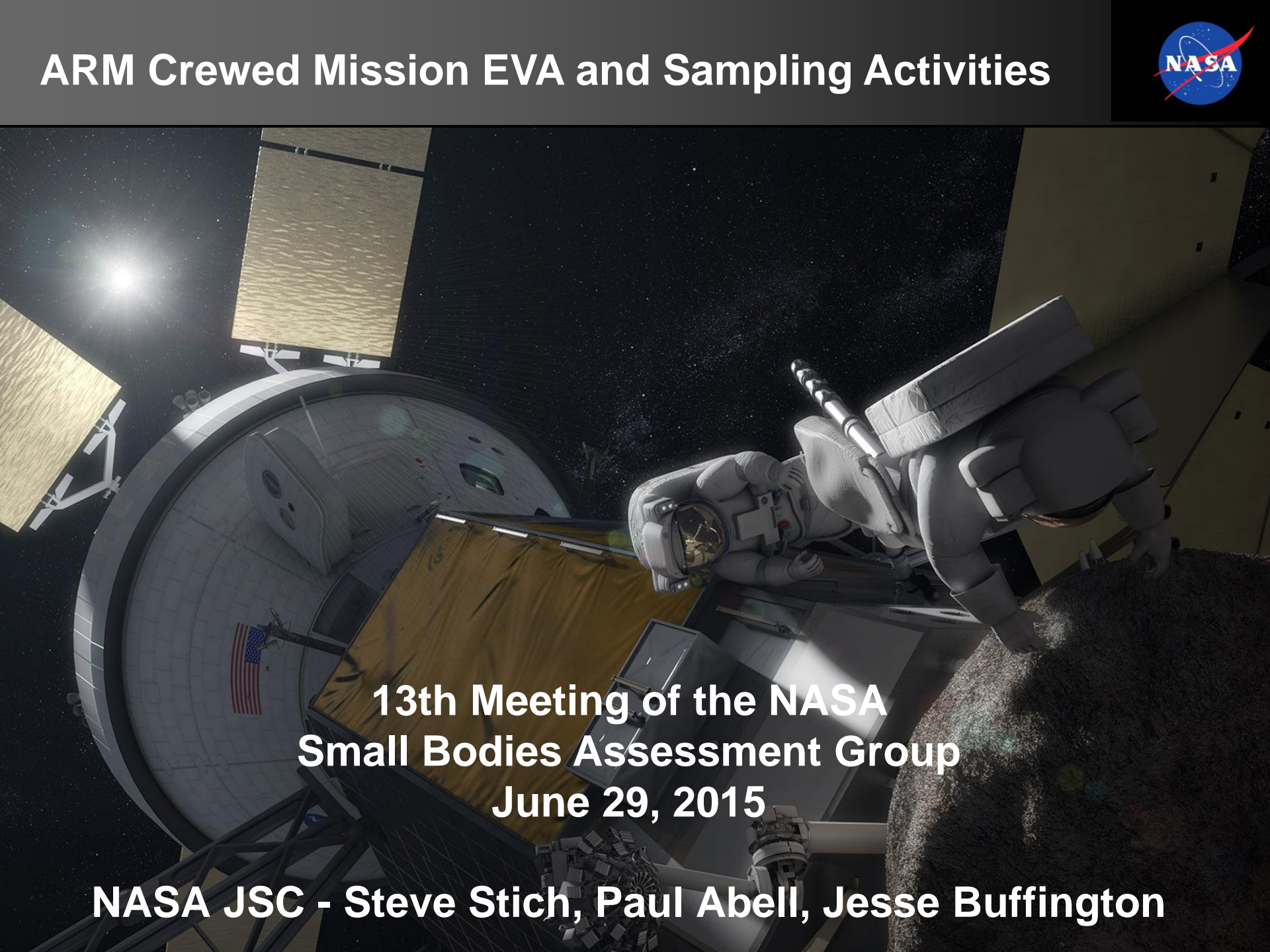


ARM Crewed Mission EVA and Sampling Activities

A detailed illustration of two astronauts in white space suits performing an EVA (Extravehicular Activity) on a space station. The astronauts are positioned in the center-right of the frame, with one slightly behind the other. They are surrounded by the complex structure of the space station, including large solar panel arrays and various equipment. The background is the deep black of space, with a bright sun visible in the upper left corner, creating a strong light source. The overall scene conveys a sense of high-tech exploration and scientific activity in space.

**13th Meeting of the NASA
Small Bodies Assessment Group
June 29, 2015**

NASA JSC - Steve Stich, Paul Abell, Jesse Buffington

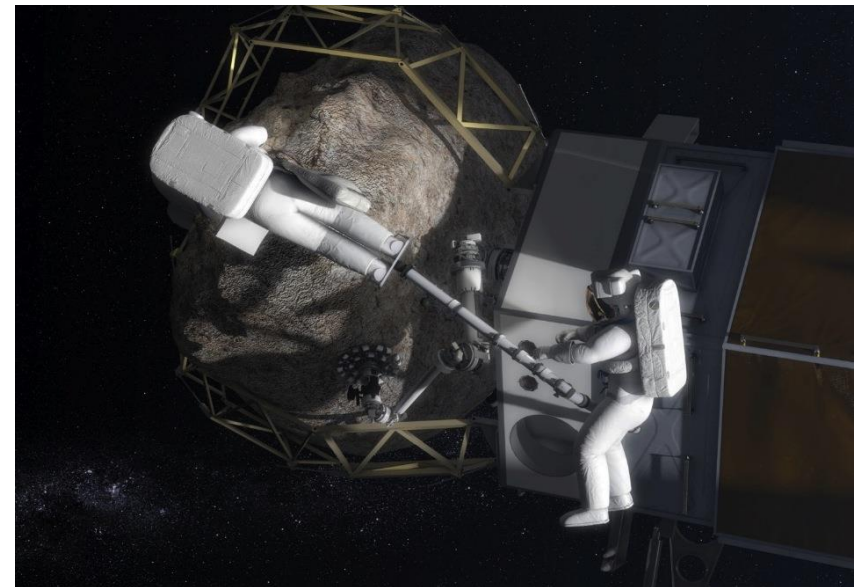
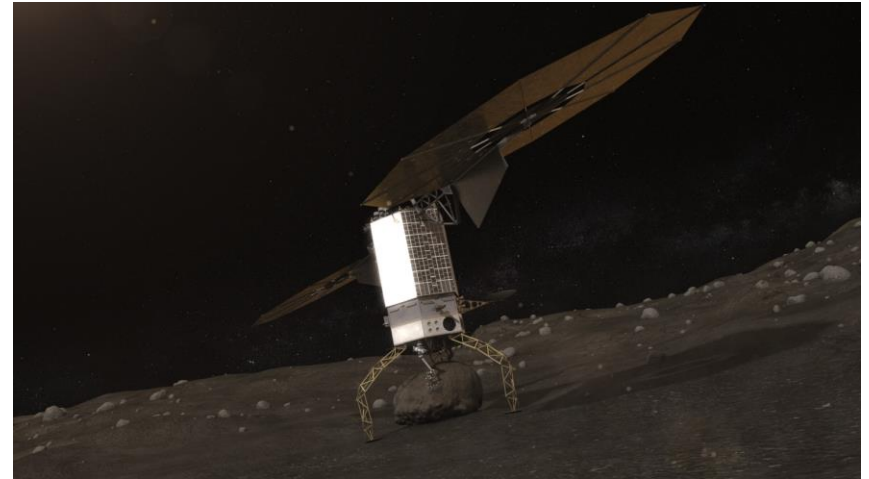


- **Key Aspects of Asteroid Redirect Mission (ARM) for Human Spaceflight**
- **Asteroid Redirect Crewed Mission (ARCM) Overview**
- **ARCM Feasibility Summary**
- **ARCM Accomplishments and Progress**
- **Crew EVA Proposed Operations**
- **ARCM EVA Hardware Development**
- **SBAG and Community Input**
- **Exploration EVA Working Group (EEWG)**
- **Conclusions**

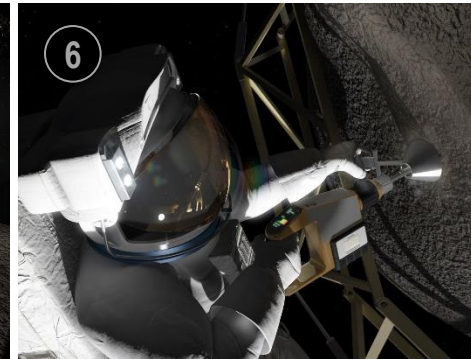
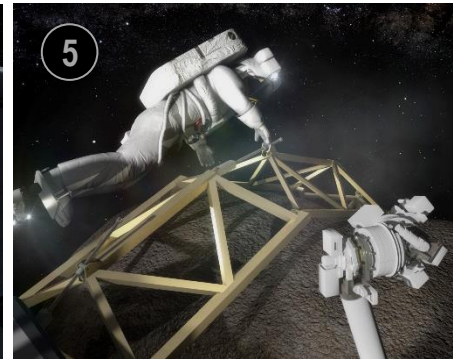
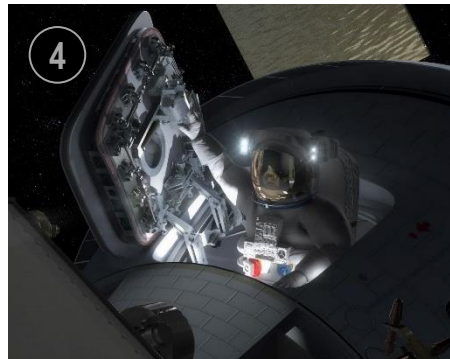
Key Aspects of ARM for Human Spaceflight



- **Through the Asteroid Redirect Mission (ARM), NASA will utilize a number of key capabilities that will be needed for future exploration purposes, as well as providing other broader benefits**
 - Advanced high-power, long-life, high through-put solar electric propulsion
 - Rendezvous, proximity operations, and docking systems
 - Deep space trajectory and navigation planning and operations
 - Advanced crew extra-vehicular activity (EVA) systems and techniques
 - Crewed sample collection and containment
 - Potential for In-Situ Resource Utilization demonstration



Asteroid Redirect Crewed Mission (ARCM) Overview



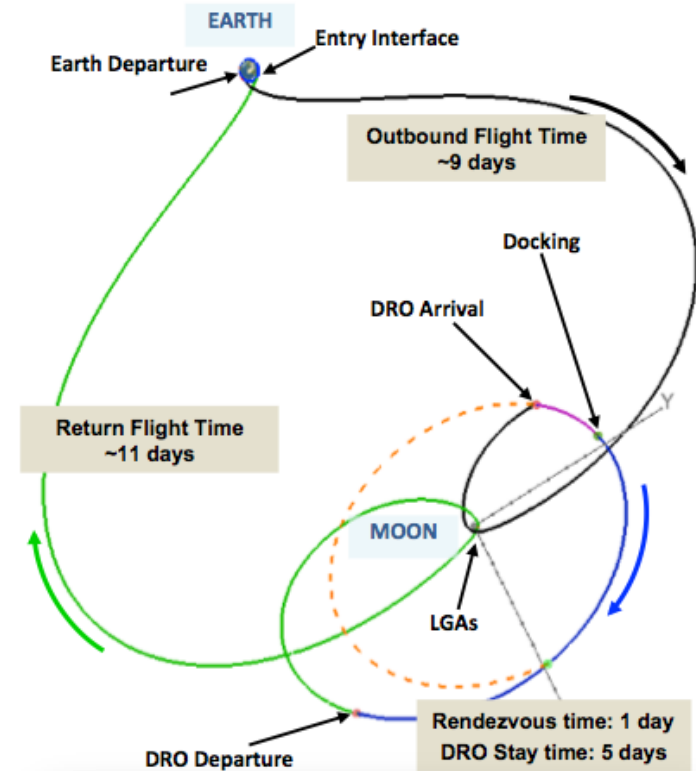
December 2025 Reference Crewed Mission Overview



- Orion launch with 2 crew members via Space Launch System.
- Use Lunar Gravity Assist (LGA) trajectories for outbound and Earth return.*
- Total mission duration 26 Days with 5 days docked with Asteroid Return Vehicle (ARV).⁺
- Two person crew launched aboard Orion.
- Rendezvous/dock with ARV in ~71,000 km Distant Retrograde Orbit above lunar surface.
- Conduct 2 four-hour EVAs using adapted Modified Advanced Crew Escape Suits (MACES) to observe, document, and collect asteroid samples.
- DRO ops for 5 days: one day for rendezvous, one day for each EVA, one day in between EVAs, and one day for undocking/contingency.
- Orion returns to Earth on an LGA trajectory, with a skip targeted return near San Diego, CA

***LGA Flight days shown represent one possible trajectory. Other trajectories may require additional flight days.**

⁺Orion Consumables allow for a 30 day total mission duration.



ARCM Feasibility Summary

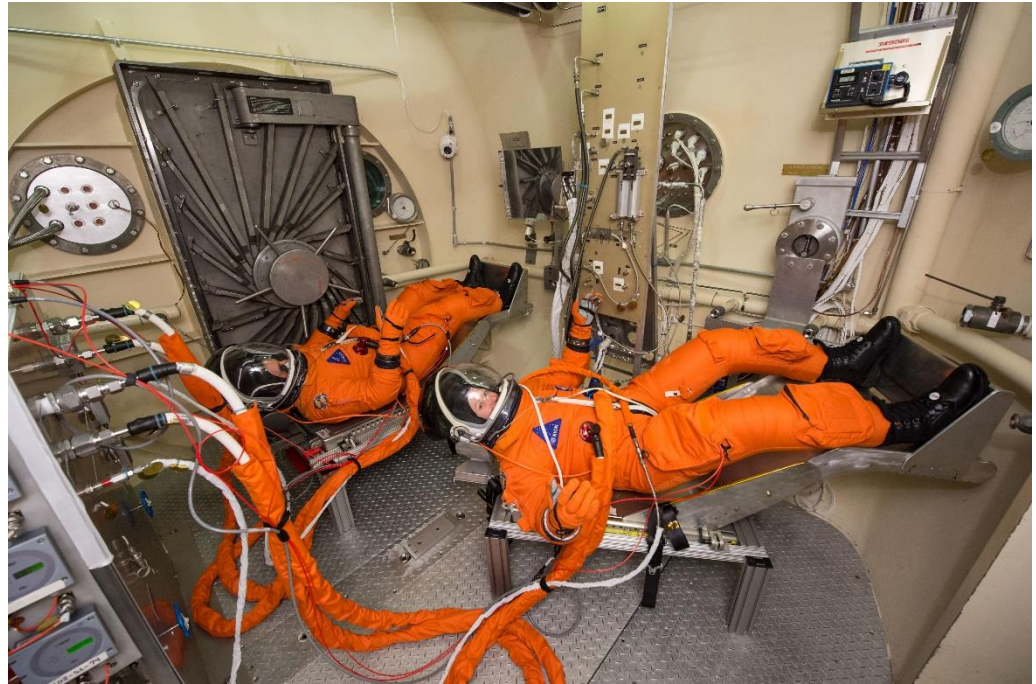


- **The Asteroid Redirect Crewed Mission Concept is feasible**
- **Trajectory, consumables, and operations within Orion and SLS capabilities**
- **Mission Kits augment Orion while minimizing mass and integration impacts for EM-1 and EM-2**
- **Mission provides opportunity for incremental expansion of Orion capabilities for more ambitious exploration missions**
 - Rendezvous and Docking Sensors use common AR&D approach to minimize development expenditure (commonality with ARV and Satellite Servicing)
 - Docking system leverages Commercial Crew Block I System under development by the ISS Program
 - Docking of Orion with the ARRV enables integrated vehicle attitude control and extensibility
 - Addition of EVA Capability is the largest development challenge
- **Initial NBL Testing shows use of MACES to perform required sampling tasks is feasible. Continued testing with variety of crew member sizes, along with incremental suit and tool enhancements is critical in order to validate concept**

Orion Modified Advanced Crew Escape Suit (MACES) Testing



- Orion completed four MACES suited evaluation in the March Vacuum Pressure Integrated Suit Test (VPIST).
- Modified ACES is an evolutionary step from shuttle crew survival suit for closed-loop crew protection for launch, entry, and aborts.
- Testing evaluated integrated performance of Orion's vehicle ECLSS hardware in a vacuum chamber.
 - 100% oxygen
 - MACES
 - Orion Suit Loop with Amine Swingbed CO2 Scrubbing
- Testing verified ability of MACES and Orion ECLSS systems to operate as designed.



VPIST Testing is first time since Apollo that developmental pressure suits have been combined with a vehicle-level closed loop ECLSS system to provide life support while test subjects are at full vacuum.

Space Suit Feasibility Prototype Testing Modified Advanced Crew Escape Suit (MACES)



Lab, Zero G, ARGOS tests



MACES EVAs are demonstrated as feasible and neutrally buoyant testing is warranted

Neutral Buoyancy Lab Series #2 – 5 tests (2, 3 and 4 hours long)



Task complexity increases while improvements are made to the suit including Extravehicular Mobility Unit gloves, drink bag, etc. Need for improved stability and work envelope

Initial NBL testing has shown feasibility of doing many asteroid retrieval sampling tasks using a MACES. Continued testing with a variety of crew member sizes, along with incremental suit and tool enhancements is critical in order to validate the concept.

2013

2014

May

June

July

August

Sept

Oct – Jan

February

March

April

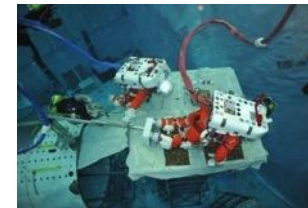
May

NBL Series #1 – 3 tests (2 hours long)

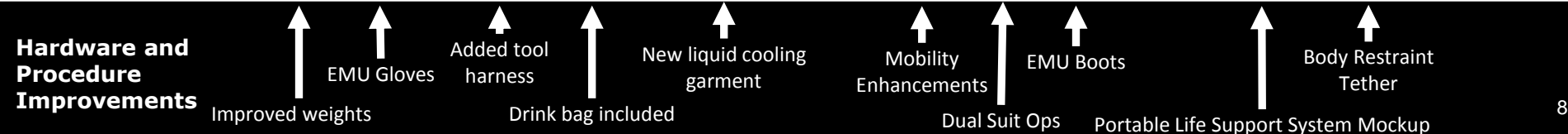


Established NBL Interface, ability to weigh-out the suit, and the subject's ability to use the suit underwater.

NBL Series #3 – 5 tests (4 hours long)



Evaluation of mobility enhancements, improved worksite stability, and testing on higher fidelity capsule mockups with tools culminating in a full ARCM EVA timeline.

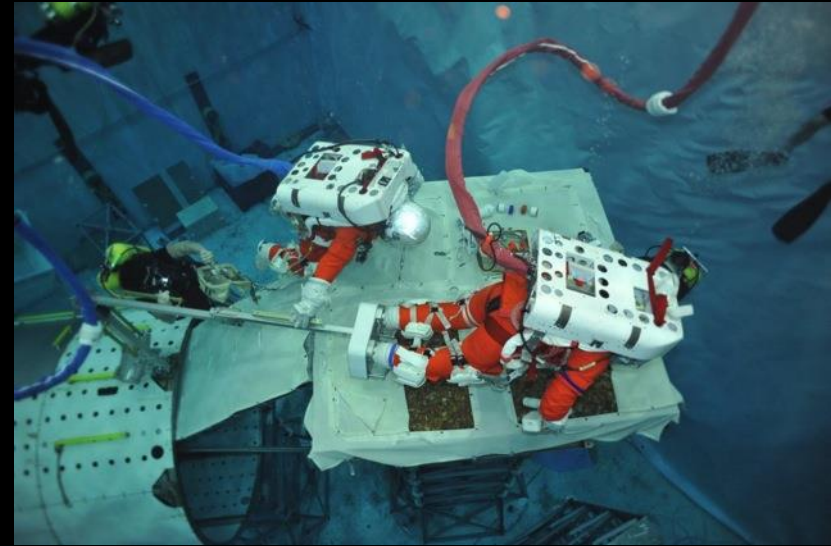


EVA Feasibility Testing

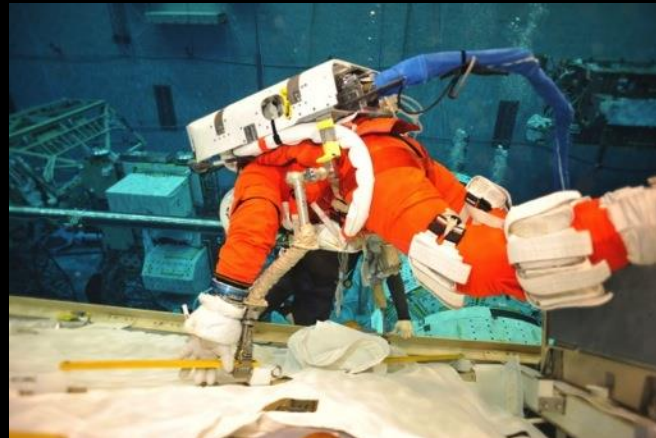
Worksite Stabilization in Neutral Buoyancy Laboratory



**Adjustable
Portable Foot
Restraint
operations were
tested and
execution is very
similar to the ISS
Extravehicular
Mobility Unit**



**Body Restraint
Tether allowed
the crew to
perform two
handed task**

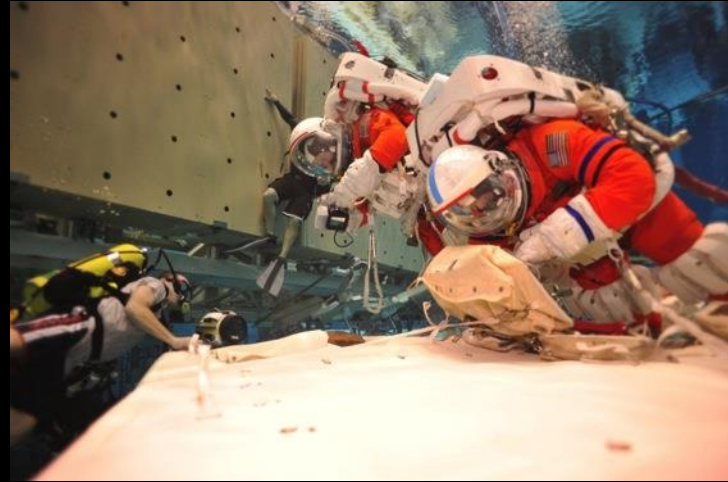


EVA Feasibility Testing

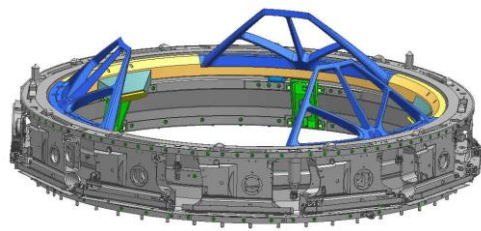
Sampling Tasks in Neutral Buoyancy Laboratory



Crew was able to perform several examples of sampling tasks including worksite imaging, float sample collection, hammer chiseling and pneumatic chiseling.



ARRM Crewed Mission Accommodations (Docking)



IDSS IDD-Compliant Docking Mechanism

Passive docking mechanism on ARRM
(active mechanism on crewed vehicle)



Rendezvous Aid

- Orion-compatible low-rate S-band transponder



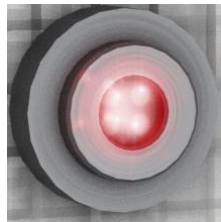
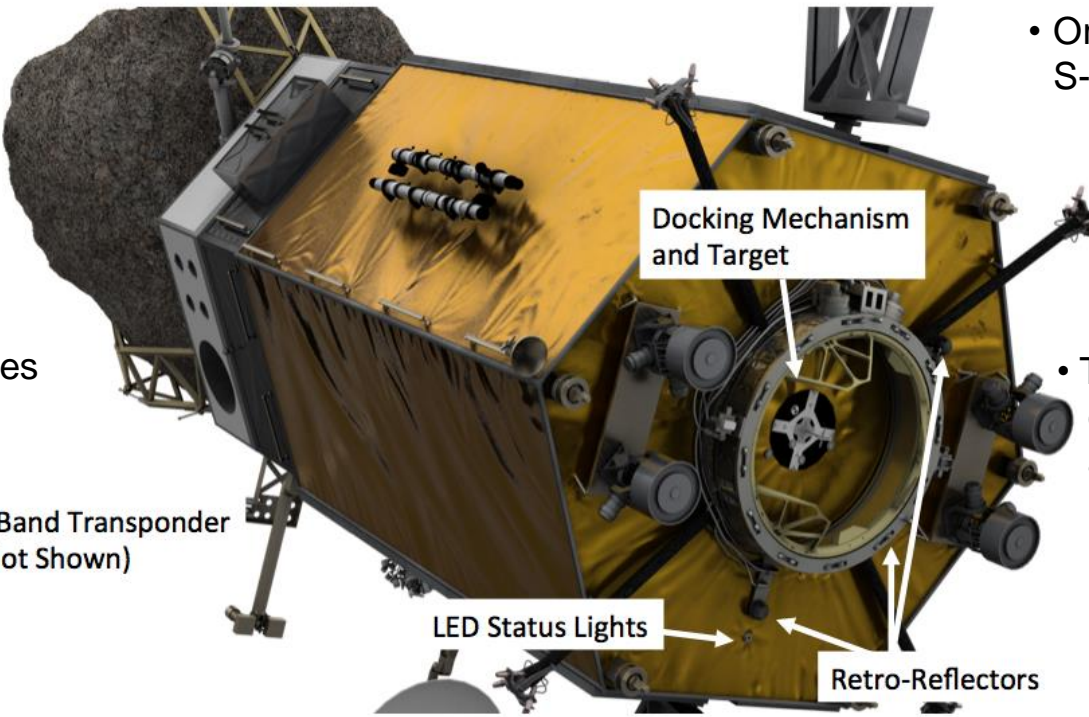
Retro-Reflectors

- Tracked by the LIDAR during rendezvous and docking



Docking Target

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



LED Status Lights

- Indicate the state of the ARRM systems, inhibits and control mode

Power and Data Transfer

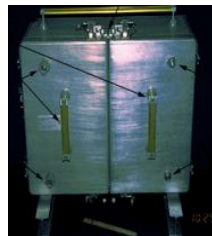
- Power and data connectors integrated into the docking mechanism.
- Data transfer used during ARCM
- ARRM power transfer is available for future missions.

ARRM Crewed Mission Accommodations (EVA)



EVA Telescoping Booms

- Telescoping Booms for positioning the EVA astronaut on the boulder (~3 m in length)



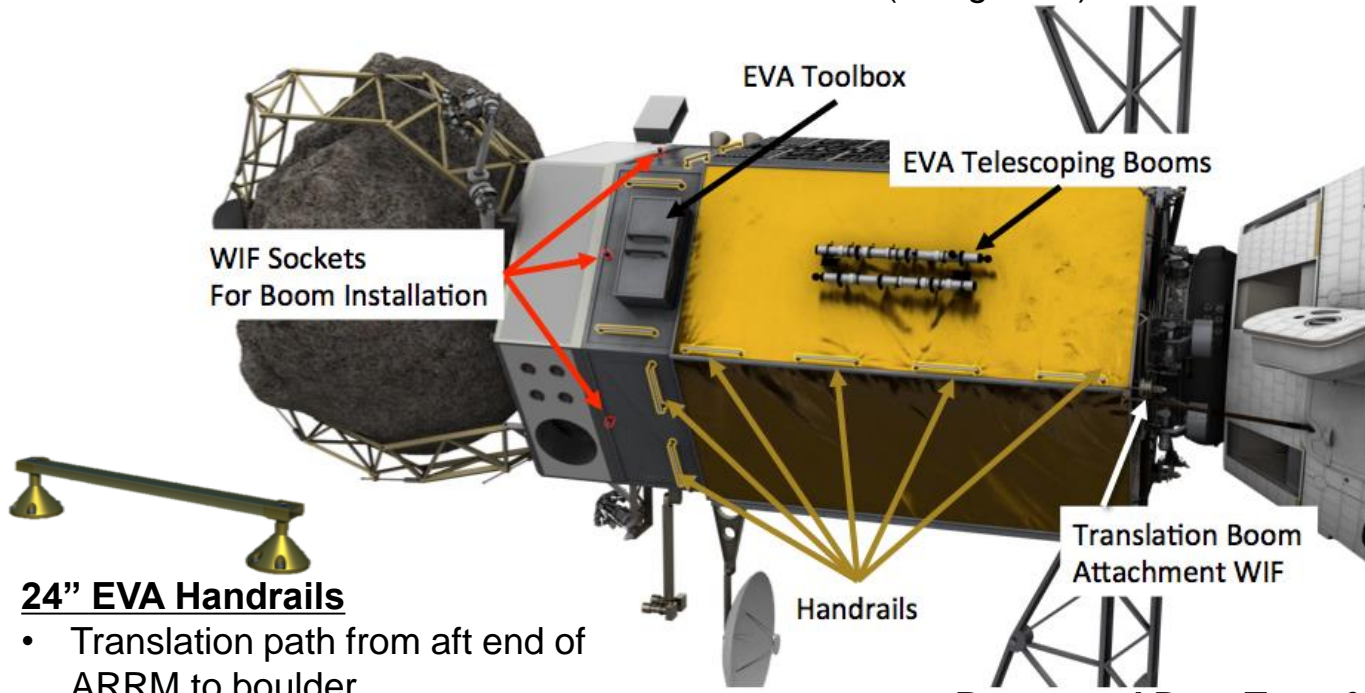
EVA Tool Box with tools

- Tool box to offset Orion mass (85 kg tools)



Worksite Interface (WIF) Sockets

- Provide boom attach points to ARRM.



24" EVA Handrails

- Translation path from aft end of ARRM to boulder
- Ring of handrails around the Mission Module near the boulder

Crew Safe Certification

- Spacecraft designed for Crew Safety including EVA kick loads, sharp edge, safety inhibits and Caution and Warning annunciation.

Power and Data Transfer

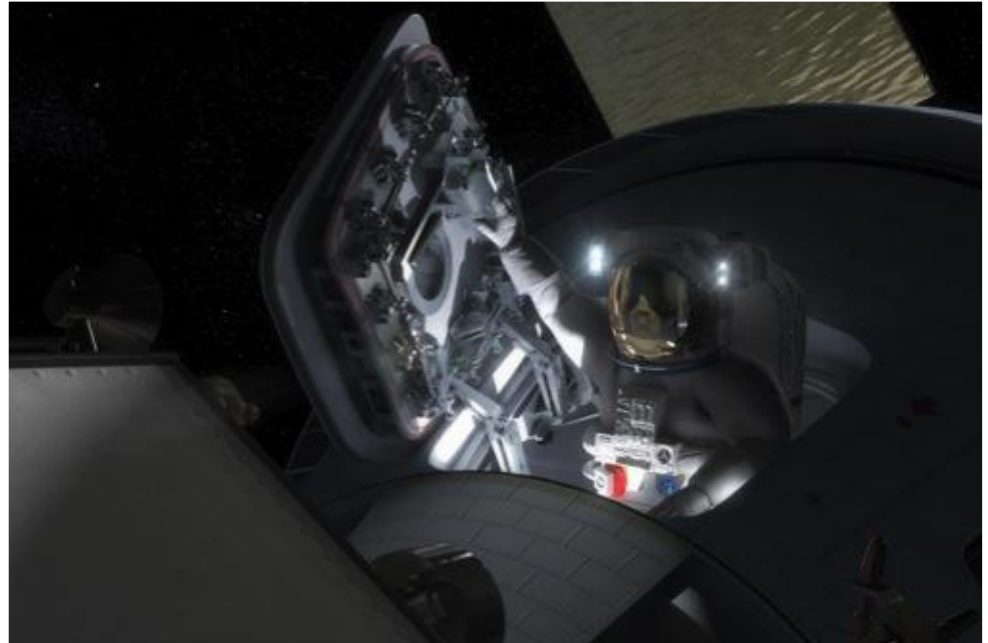
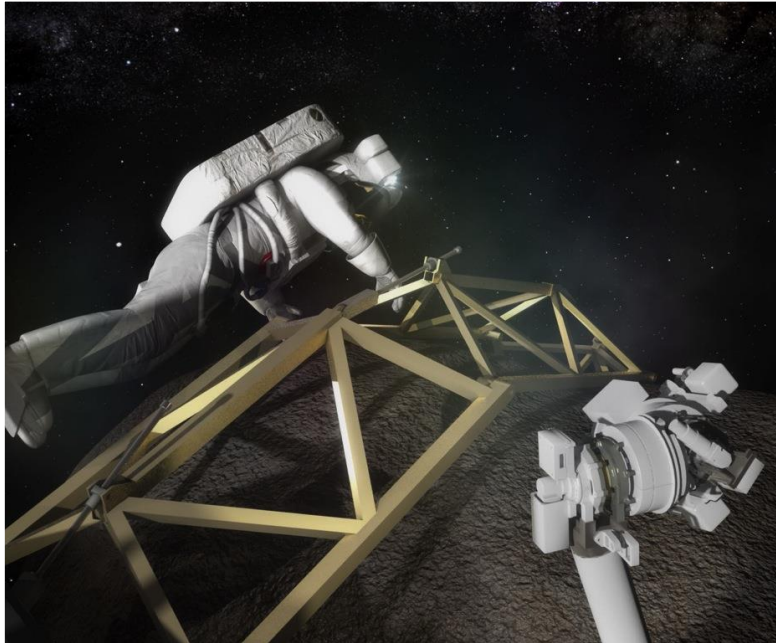
- Power and data connectors integrated into the docking mechanism. Data transfer used during ARCM.
- ARRM power transfer is available for future missions.

Proposed Crew Operations During EVA



- Prior to each EVA, Orion rotates the stack to place the sample site into a thermally favorable location.
- The EVA commences when the Orion hatch is open and the crew is operating on the Exploration PLSS.
- Boulder specific sampling tools and containers are carried out of Orion.
- Crew will deploy an EVA communication antenna and a translation path between Orion and ARRV using a telescoping boom launched with Orion.

Proposed Crew Operations During EVA

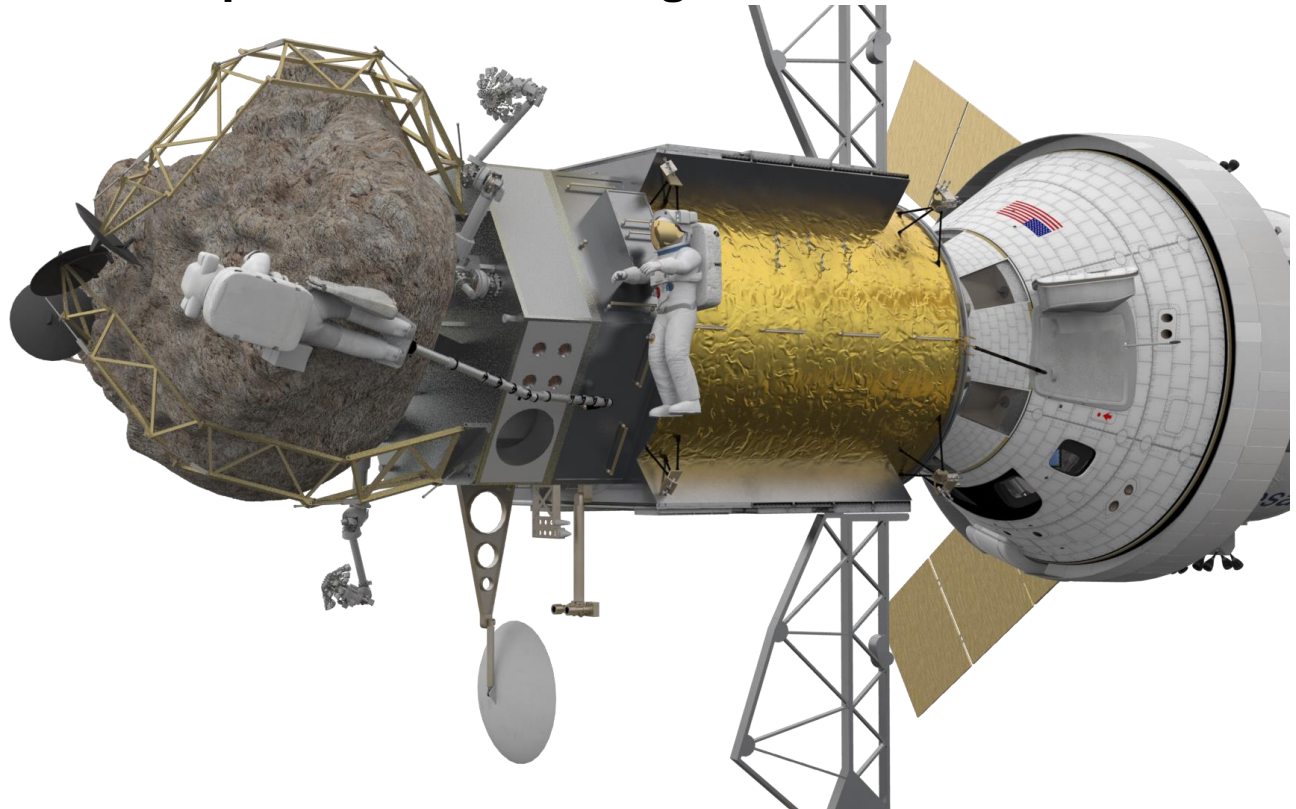


- **Using the translation aids mounted to the ARR.V, crewmembers make their way to the EVA toolbox located on the ARR.V.**
- **The crew will deploy the telescoping booms with integrated foot restraints stowed on the ARR.V and collect EVA tools pre-deployed in the EVA toolbox.**
 - Boom is attached to ARR.V using pre-integrated boom socket located on ARR.V.
 - The sample retrieval worksite is chosen in conjunction with the science and EVA communities based on sample value and ease of collection.
- **Sample collection activities are conducted and samples placed in appropriate containment for stowage in Orion**
- **Worksite is made safe, basic EVA tools are stowed, and the crew returns with sample containers to Orion**

EVA Access for Activities on and around Boulder

- The robotic spacecraft contains WIF sockets located around the perimeter of the mission module near the captured boulder.
- Crewmembers can attach the EVA booms to the WIF sockets to reach virtually any sample location on the boulder (except under the Contact Restraint System (CRS) legs for crew safety).
- Options are being evaluated for retrieving the geologic context samples collected by the touchdown pads on the CRS legs.

EVA Boom attach points and handrails on all faces around ARV near capture mechanism to allow access anywhere on the boulder



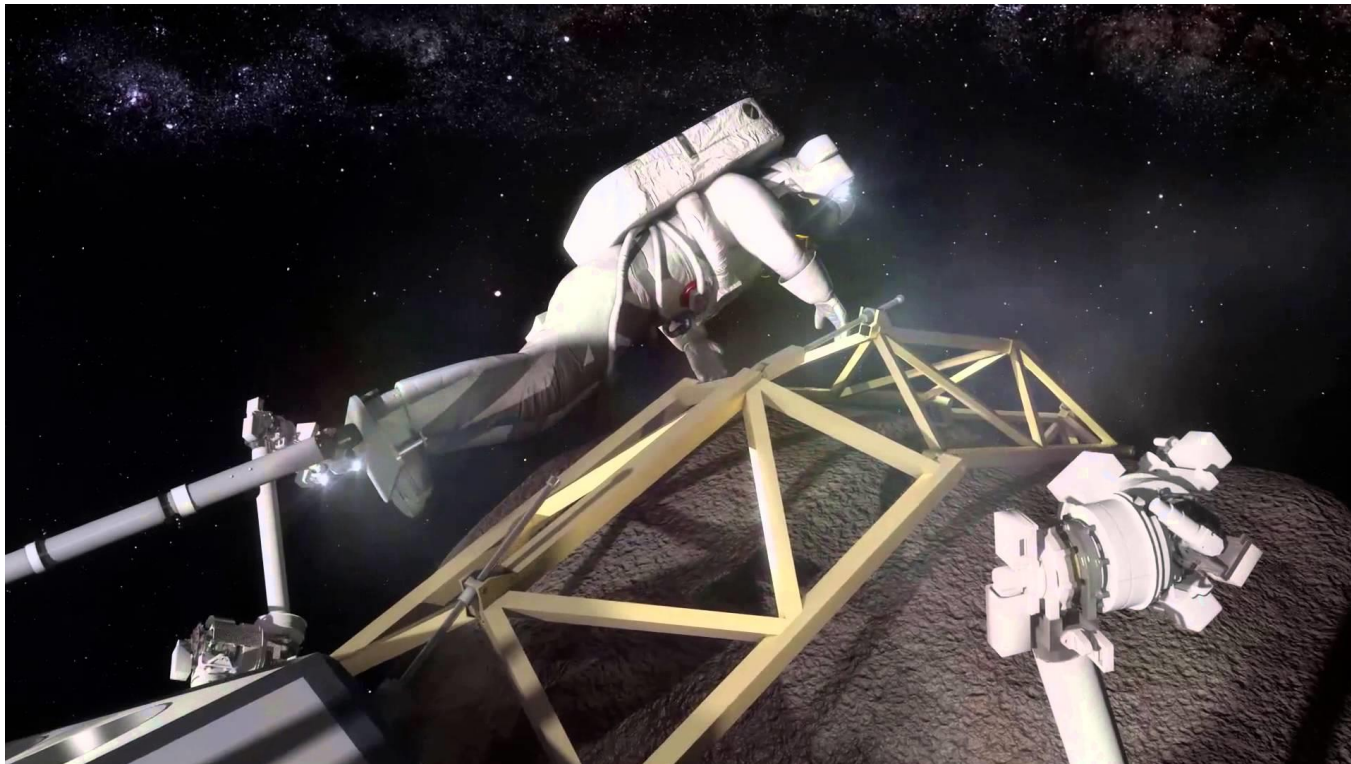
ARCM Mission Kit Status – EVA Hardware

- Early concepts of various EVA Sample Collection tools have been discussed and considered in order to establish fundamental feasibility of EVA sampling ops
- This work addressed the question of “Do we think EVA Crew can actually conduct the required tasks given the architecture constraints?”
- With confidence that the EVA worksites can facilitate sampling operations, the next steps focus on transitioning to the first set of development for the ARV-launched EVA hardware such as the toolboxes and Worksite Stabilization Booms
- Detailed sampling hardware is planned for the next phase of development corresponding with arrival of initial precursor data from the ARV capture of the target
- This approach assumes that science community analysis and feedback based on data from the unique target will drive EVA Sample Hardware design and EVA Protocols



EVA Hardware – Next Steps

- The first set of EVA hardware, slated for launch on the ARV in December 2020, is currently scheduled for development starting in FY16
- Other EVA hardware flying in Orion will be developed later in support of the 2025 Crewed Mission (i.e., plenty of time for input and refinement)
- The EVA Hardware Development Community needs extensive communication with the Science, ISRU, and Technology Communities in order to influence design and operations





SBAG and Community Input (1/2)

- **The SBAG and Science, ISRU, and Technology communities will have opportunity for providing input to the ARCM.**
- **The EVA Community wishes to collect input on specific protocols that will be most effective for the interaction with, and collection of, materials from the boulder.**
- **The EVA Community strongly desires to understand and accommodate design constraints applicable to EVA Tools that will come into contact with samples.**
- **For example, this would include materials selection, methods of construction and pre-flight cleaning protocols as well as in-flight procedures.**
- **This would also influence sample container design, in-flight stowage and handling constraints, and any other parameters that might influence the quality of samples and context data.**
- **Thus, there is a need to deeply engage with the science community on further definition of sampling hardware requirements and design constraints.**
 - Definition of these items would be recorded in Design and Construction specifications that would directly influence EVA Hardware
 - Time has been intentionally allocated beginning in FY16 to both develop these specifications and apply their intent to EVA hardware launched on both the early un-crewed Asteroid Redirect Vehicle as well as the later Crew-launch of Orion



- **The SBAG and Science, ISRU, and Technology communities will have multiple opportunities for engagement**
 - ARM Formulation Assessment Support Team (FAST)
 - ARM Investigation Team (IT)
 - Concept solicitations
 - Topical Workshops
 - Special Action Team Reports (SBAG, CAPTEM, etc.)
 - EVA Exploration Working Group (EEWG) (see next slide)

- **Specific topics relate to the following key areas:**
 - EVA Operation Protocols Development
 - EVA Tool Development
 - Sample Site Selection (on boulder)
 - Sample Acquisition
 - Sample Containment and Curation

- **Engagement by the EVA community will be an ongoing process throughout all phases of the ARM (e.g., ARRM and ARCM).**

- **This will ensure that a robust and coordinated approach for EVA implementation is conducted, which will return the maximum value for all stakeholders.**

- **The Exploration EVA Working Group (EEWG) is the venue for which all stakeholders can engage in the development of future EVA capabilities**
- **The EEWG chair serves as the Deputy of NASA's EVA Systems Maturation Team (EVA SMT) and also chairs the EVA International SMT (EVA ISMT)**
 - This provides for comprehensive coordination across the EVA Exploration community both “inside” NASA as well as to our International Partners
 - This includes identification of EVA “Knowledge Gaps”, their risk-reduction plans and coordination of efforts
- **The EEWG invites participation from the Planetary Science, ISRU, and Technology Communities**
 - Contact the EEWG Chair, Jesse Buffington, for additional information
 - jesse.a.buffington@nasa.gov
 - You can also visit the EVA Homepage to see the latest:
 - <https://portal.nasa.gov/group/eva/office>



- **The ARCM, utilizing the Orion spacecraft, will rendezvous with the Asteroid Redirect Robotic spacecraft in a distant lunar retrograde orbit.**
- **The current plan is for the crew to conduct 2 EVAs to extract samples of the collected boulder and return the samples to Earth.**
- **NASA has successfully conducted a number of studies to analyze EVA techniques and equipment for the ARCM (e.g., spacesuits, life support systems, etc.).**
These studies demonstrate that EVAs of the returned boulder is feasible.
- **The EVA Hardware Development Community needs extensive communication with the Science, ISRU, and Technology Communities across a number of parameters that will influence design and operations.**
- **The SBAG and Science, ISRU, and Technology communities will have multiple opportunities for input to the EVA community utilizing a variety of methods and venues.**
- **Engagement by the EVA community with the outside community will be an ongoing process throughout all phases of the ARM (e.g., ARRM and ARCM).**