





ARM EVA Planning and Activities
SBAG, July 30, 2014

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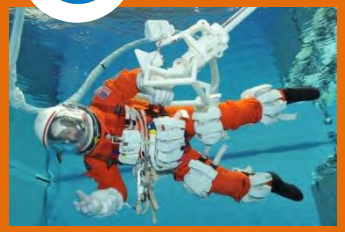
Based on AIAA 2014-1605, "*EVA Asteroid Exploration and Sample Collection Capability*", Stephanie Sipila, Zebulon Scoville, Jonathan Bowie and Jesse Buffington,

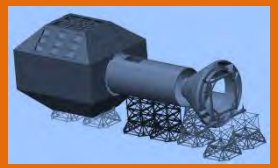
And AIAA 2014-1717, "*Asteroid Redirect Crewed Mission Space Suit and EVA System Architecture Trade Study*", Jonathan Bowie, Raul Blanco, Richard Watson, Cody Kelly, Jesse Buffington and Stephanie Sipila.

AIAA SpaceOps 2014, 13th International Conference on Space Operations,

May 5, 2014, Pasadena, California

Asteroid Redirect Crewed Mission EVA





- During the docked phase, two planned 4-hour EVAs will be conducted from the Orion capsule.
- EVA capability is added via kits designed with minimal mass and volume impacts for the Orion.
  - An EVA kit (converts the Launch, Entry, and Ascent suit to an EVA suit),
  - EVA Servicing and Recharge Kit (provides suit consumables),
  - The EVA Tools, Translation Aids & Sample Container Kit (the tools and mobility aids to complete the tasks),
  - The EVA Communications Kit (interface between the EVA radio and Orion), and
  - The Cabin Repress Kit (represses the Orion between EVAs).

EVA Architecture Requirements

Mission Requirements

- Robotic spacecraft shall enable
  - Physical access to the asteroid for the EVA crew
  - Worksite stability sufficient for sampling
  - Carry Tools necessary to extract an asteroid sample
  - Provide EVA inhibits and safety features
- Orion spacecraft shall provide
  - Capability for crew to perform EVA
  - Stow additional EVA tools necessary to obtain asteroid samples
  - Return samples to Earth

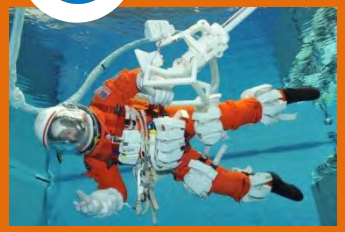
Architecture Guidelines

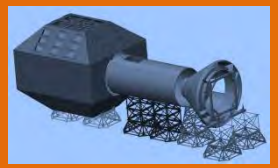
- Minimize Orion Impacts
  - Define as an add on “kit” to Orion
- Minimize Mass

EVA Related Mission Parameters

- Two Crew per EVA
- Two EVAs + One Contingency
- Short Duration (~4 hr)
- Low Complexity EVA Tasks

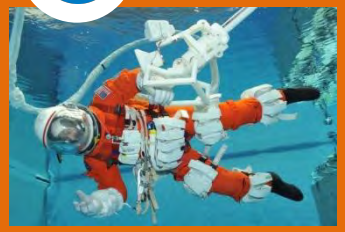
ARCM EVA challenges

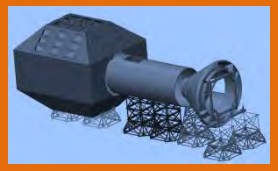




- A primary ARCM mission objective is to demonstrate deep space Extravehicular Activity (EVA) and tools, and to obtain asteroid samples to return to Earth for further study.
- First microgravity EVA to collect geology samples
  - The unknown asteroid physical properties will complicate tool use.
- First microgravity EVA on a non-engineered surface
  - Unknown asteroid properties will complicate EVA translation, tool restraint, and body stabilization.
  - The asteroid surface may introduce added safety concerns for cut gloves and debris control.
- Single Suit for launch, entry, abort ***-AND-*** Extravehicular Activity

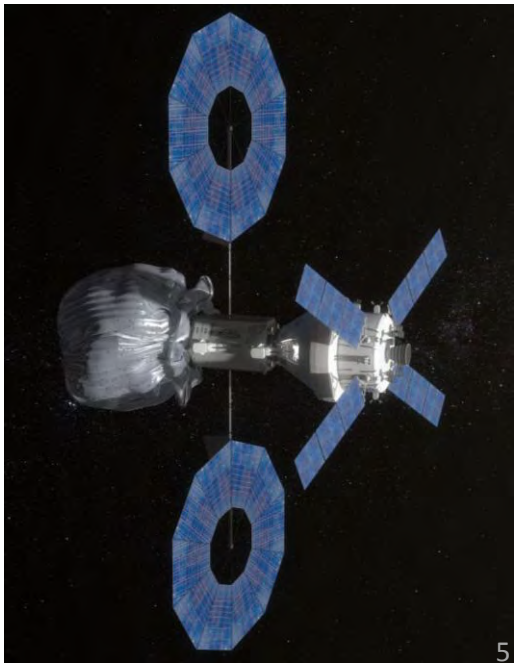
Mission Timeline



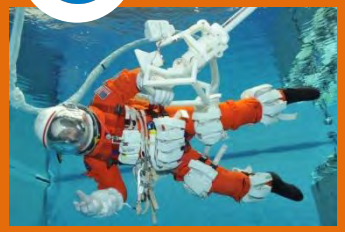


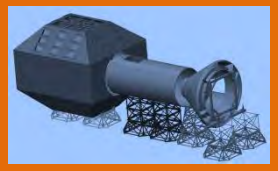
- ARM NASA video: *(credit: NASA – JSC, AMA JSC Advanced Concept Lab)* http://www.youtube.com/watch?feature=player_detailpage&v=jXvsi7DRyPI

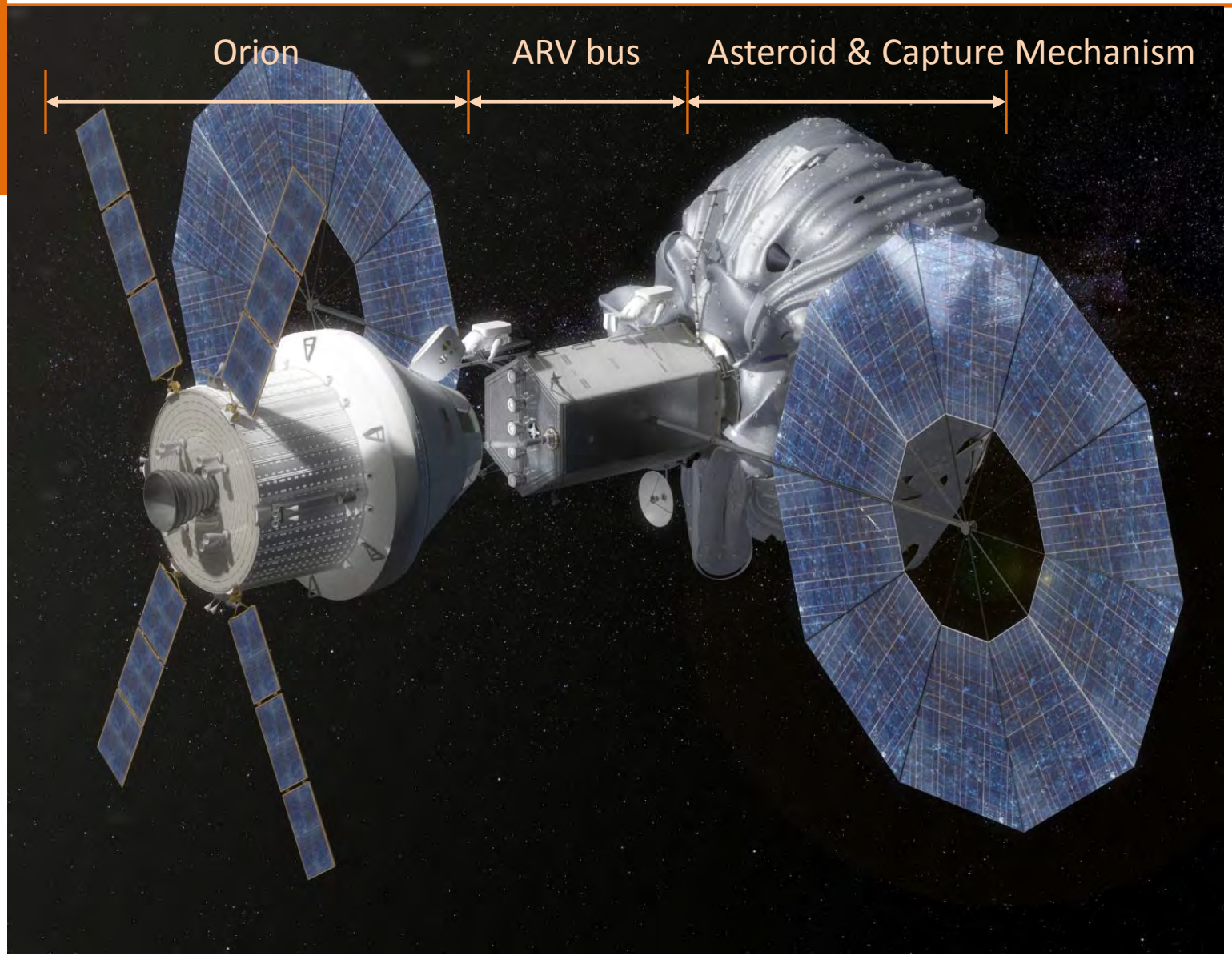
- Flight Day 1: Launch and Trans Lunar Insertion
- Day 2-5: Outbound Lunar Cruise
  - Includes depress to 10.2 psi, suit checkout and EVA dry run
- Day 8: Rendezvous and Dock Orion to
- Asteroid Redirect Vehicle (ARV)
- Day 9: EVA 1
- Day 10: EVA refurb, prep for EVA2
- Day 11: EVA 2
- Day 12: Contingency margin, departure prep
- Day 13: Undock, begin transit to Earth
- Day 26: Entry, crew recovery



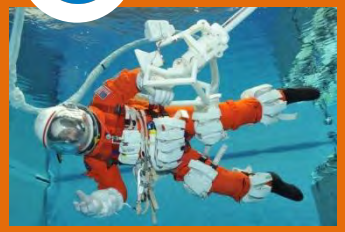
Docked Stack

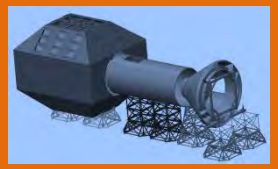






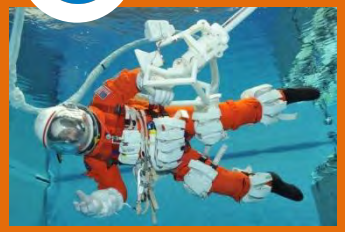
ARCM EVA OPS Con

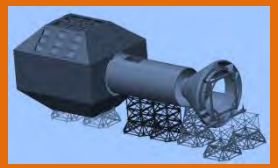




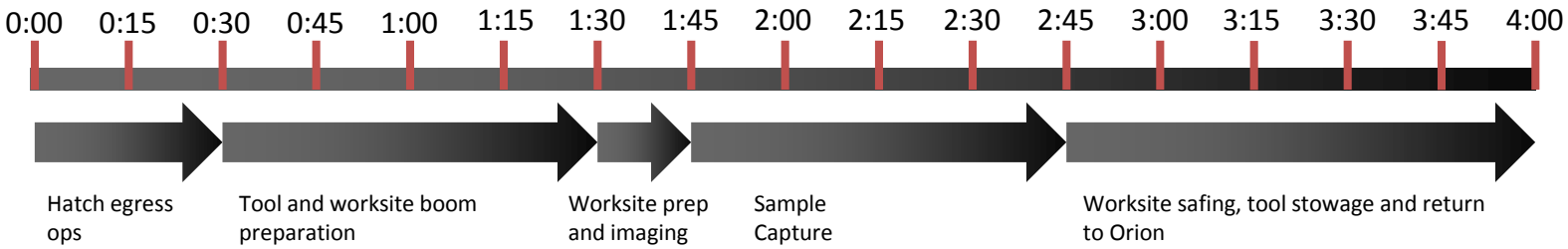
1. Don suits and tool management equipment
2. Depress cabin
3. Open hatch and place gap spanner translation aid (safety tether protocol assumed)
4. Translate across gap spanner to ARV stopping by tool stowage as required
5. Organize tools and prepare for translation to worksite
6. Set up foot restraint and/or boom for geology ops
7. Translate up boom and into foot restraint
8. Access samples through the bag (cutting may be required)
9. Geology ops (multiple types of sampling tasks and tools)
10. Tear down ARV worksite(s) and stow any tools that are to be left on ARV
11. Translate back into Orion (recover gap spanner translation aid)

EVA Timeline



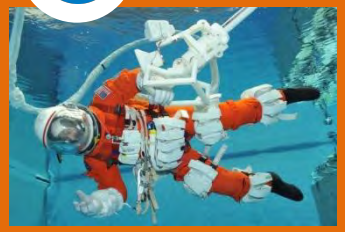


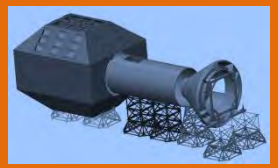
- Slew stack for favorable illumination & thermal
- Don suits
- Depress Orion cabin
- Open Hatch
- Egress

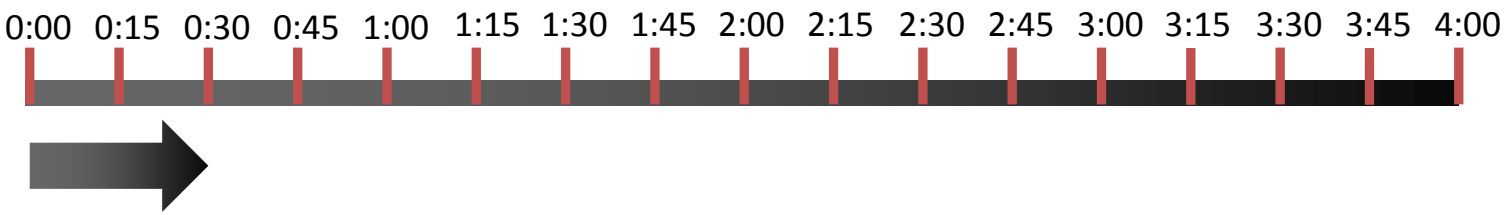


- Post EVA1 clean-up
- Prep for EVA2

EVA Con Ops – Hatch Egress Ops

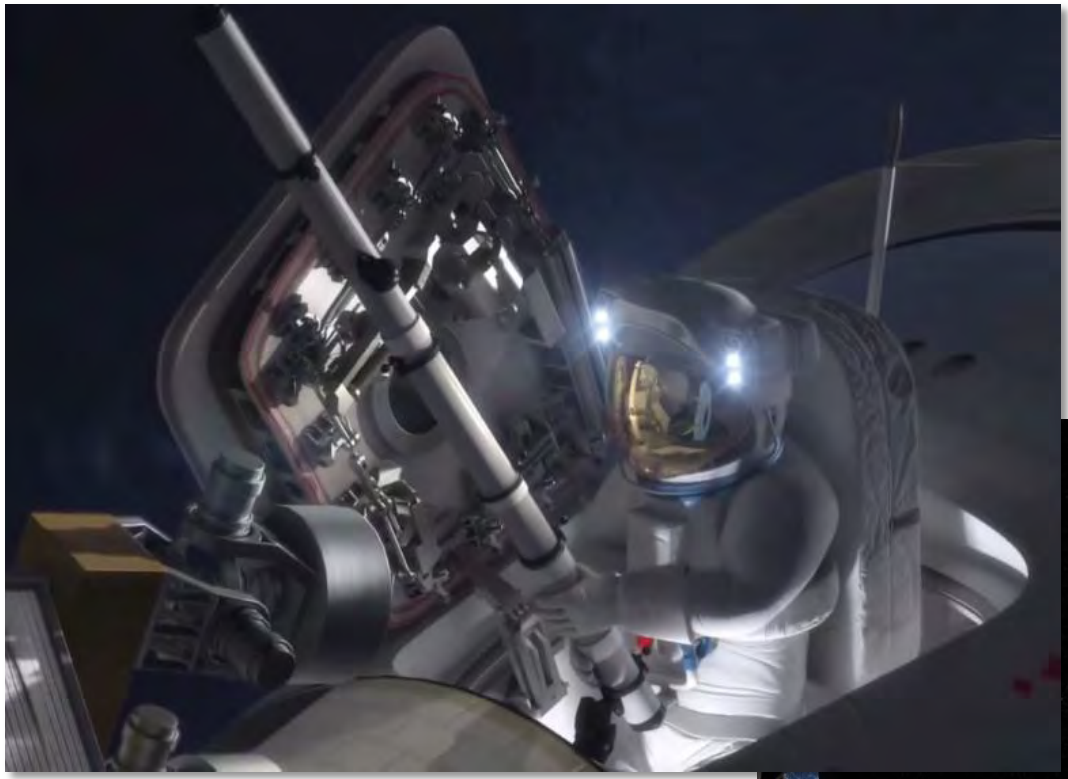




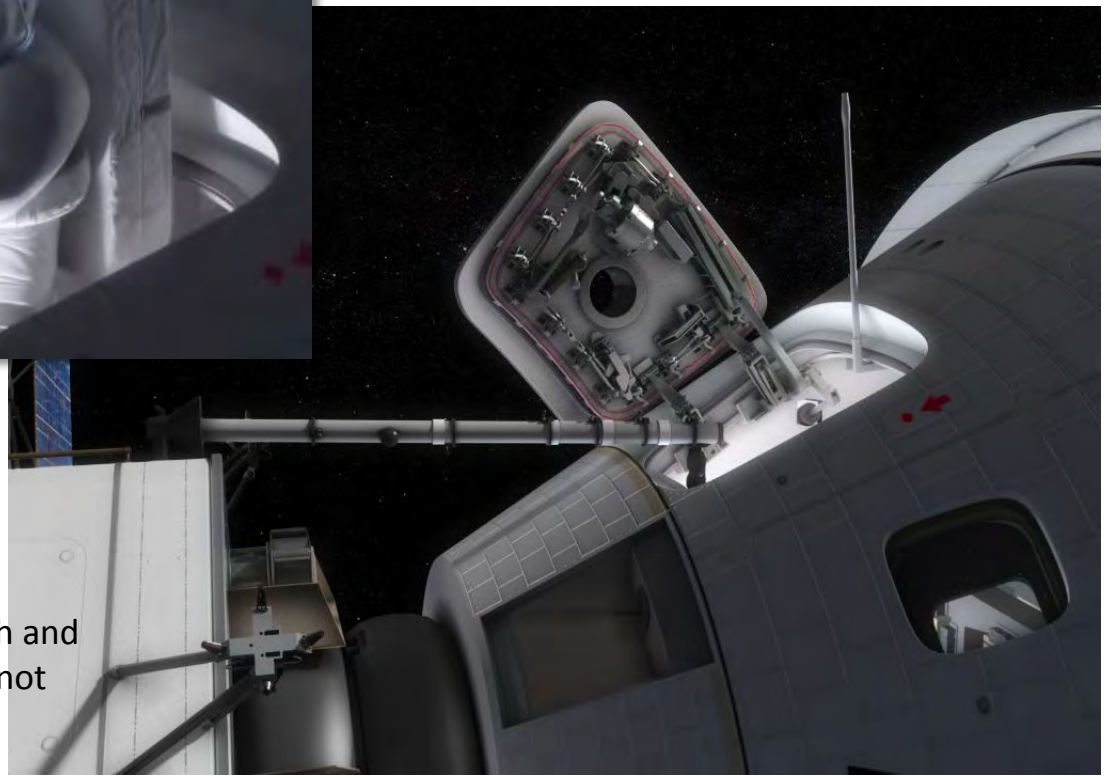


- Open Hatch
- Mount EVA antenna on pre-selected area on hatch
- Install gap-spanner translation boom from Orion across to the ARV
- First crewmember (EV1) translates across from hatch to Asteroid Redirect Vehicle (ARV) carrying sample container and geologic tools
- EV1 continues to tool stowage area on ARV while EV2 egresses from Orion and places thermal cover over hatchway

EVA Orion egress



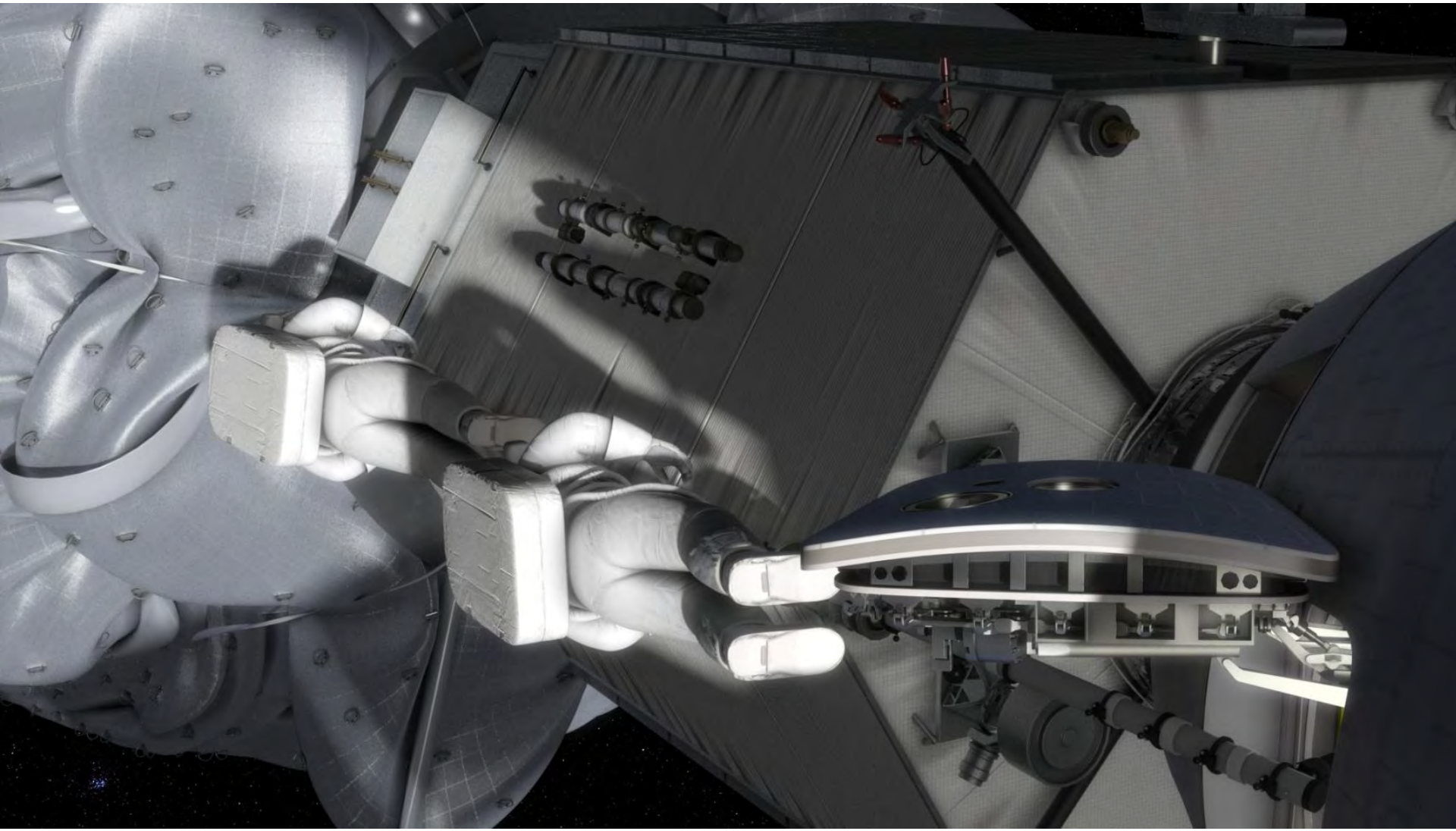
- Communication antenna install
- Gap-Spanner translation boom install
- Orion hatch thermal cover and seal protective cover install



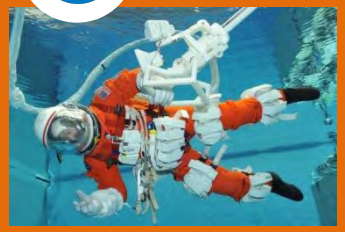
Orion hatch and seal cover not shown

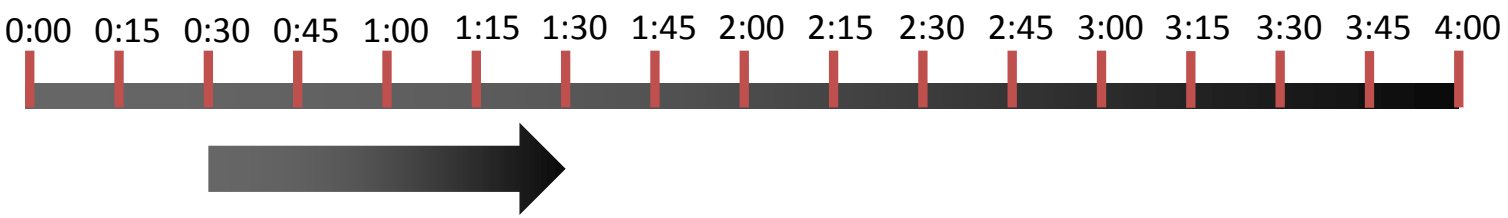
Egress Orion via boom

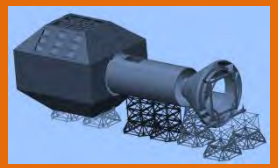
EVA translation on ARV



EVA Con Ops – Tool and Boom Prep

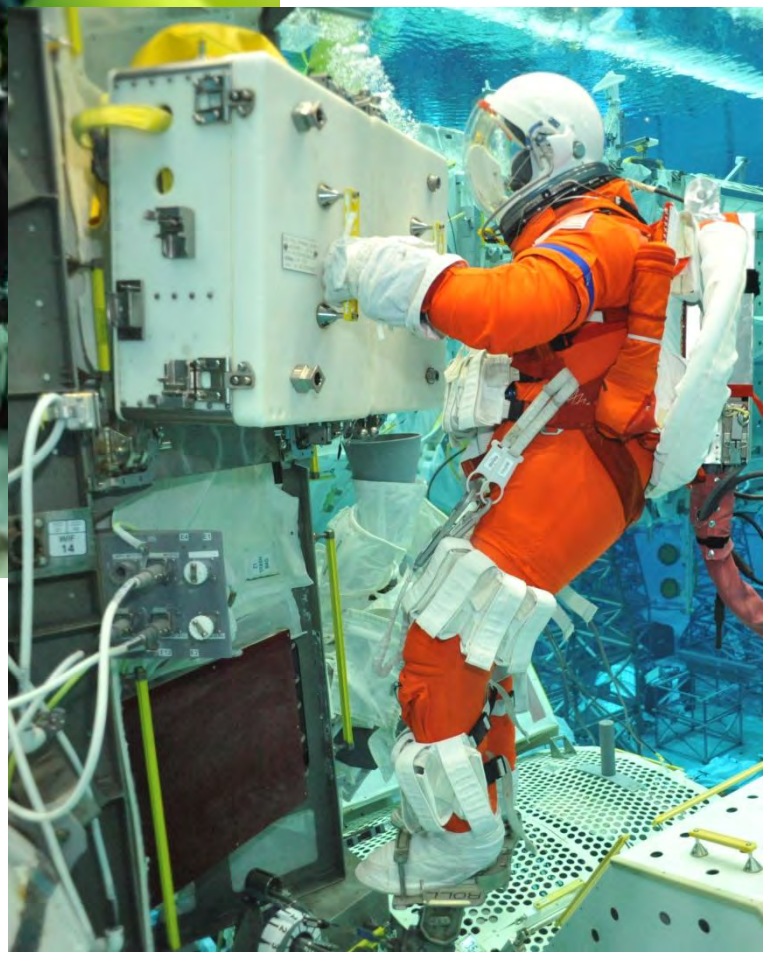






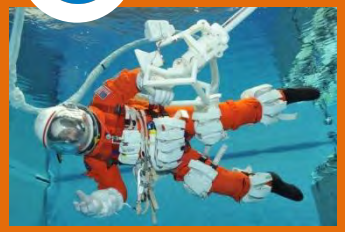
- EV1 unstows tools while EV2 unstows worksite stability boom with foot restraint from ARV.
- EV2 installs worksite boom over selected area of asteroid
- EV1 translates up boom and ingresses foot restraint
- EV2 steadies boom while EV1 assesses worksite
- EV1 ready for worksite operations

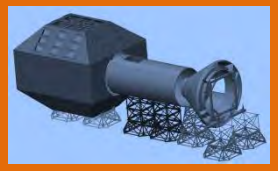
Tool Box access on ARV



- The EVA Toolbox is located on the ARV, asteroid-end of the vehicle bus structure.

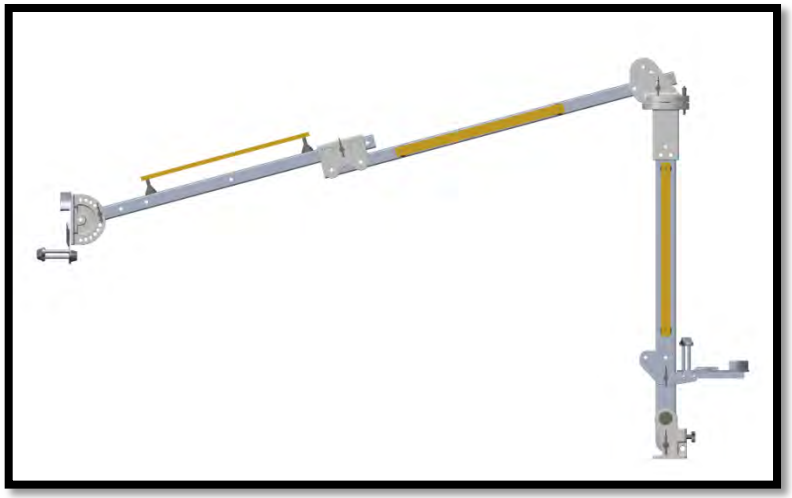
Tools



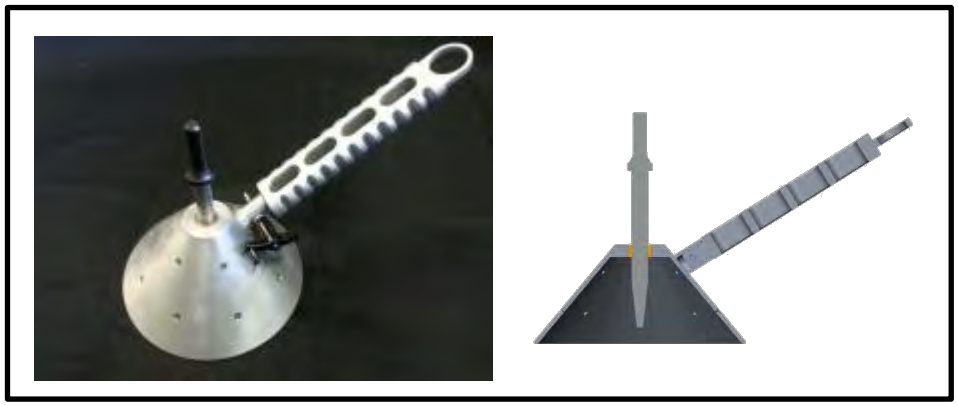


- The function of EVA Tools is to establish EVA Worksites and perform Microgravity Geology tasks:
  - Integration of Crew-deployed translation paths, Foot Restraints and Geology Sampling equipment

Crew-deployed translation paths – "Gap Spanner Boom"



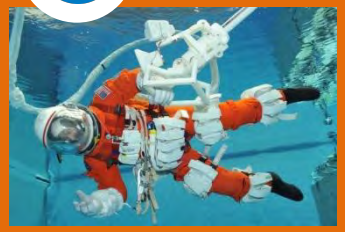
Crew-deployed translation paths – "Stabilization Boom"

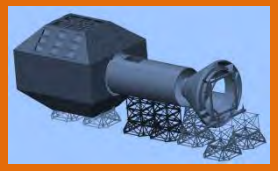


EVA Geology–"Hammer Sampling Cup" for chip containment

EVA Geology–"Shallow Linear Core Tube"

Tool Kits

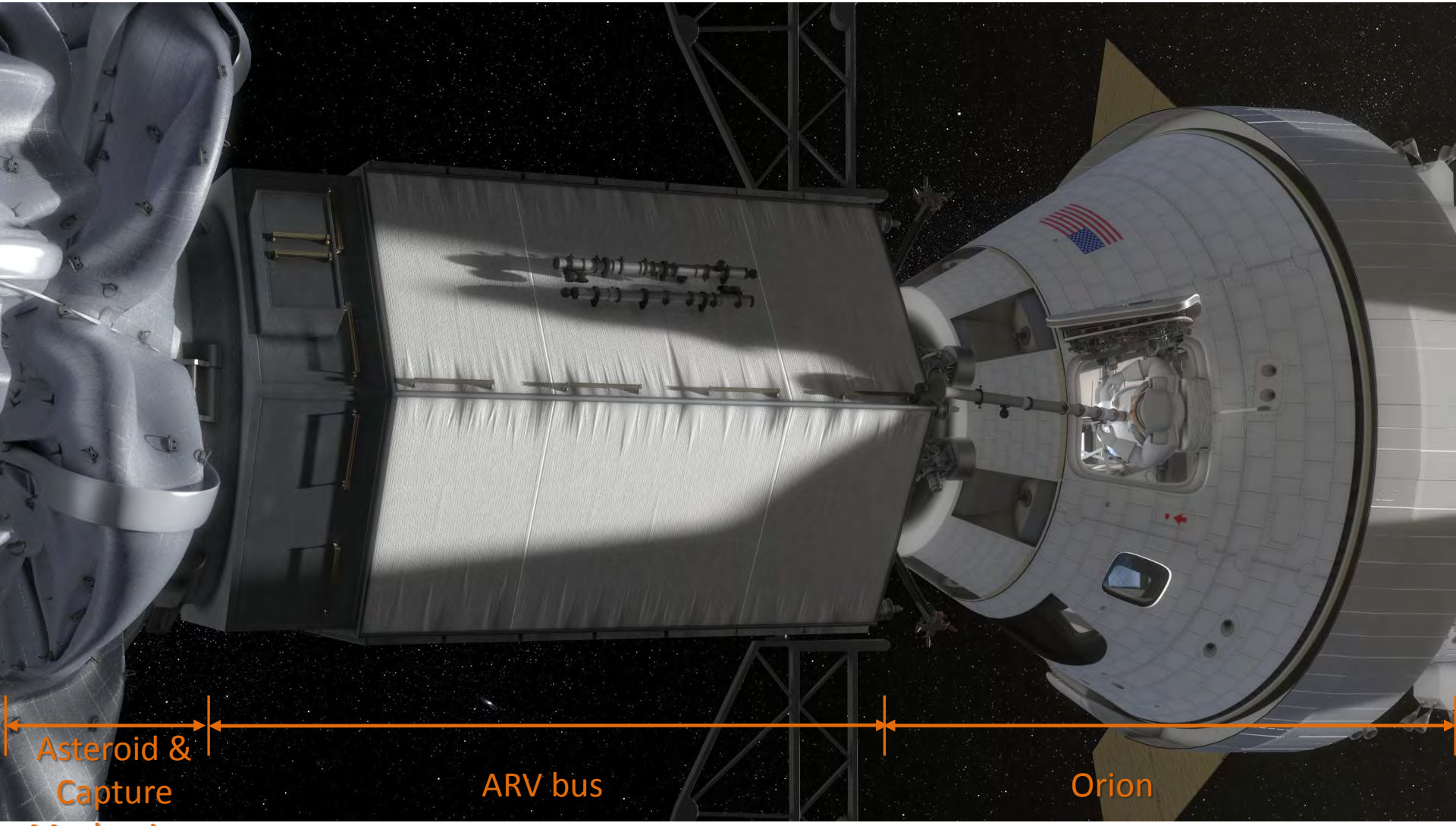




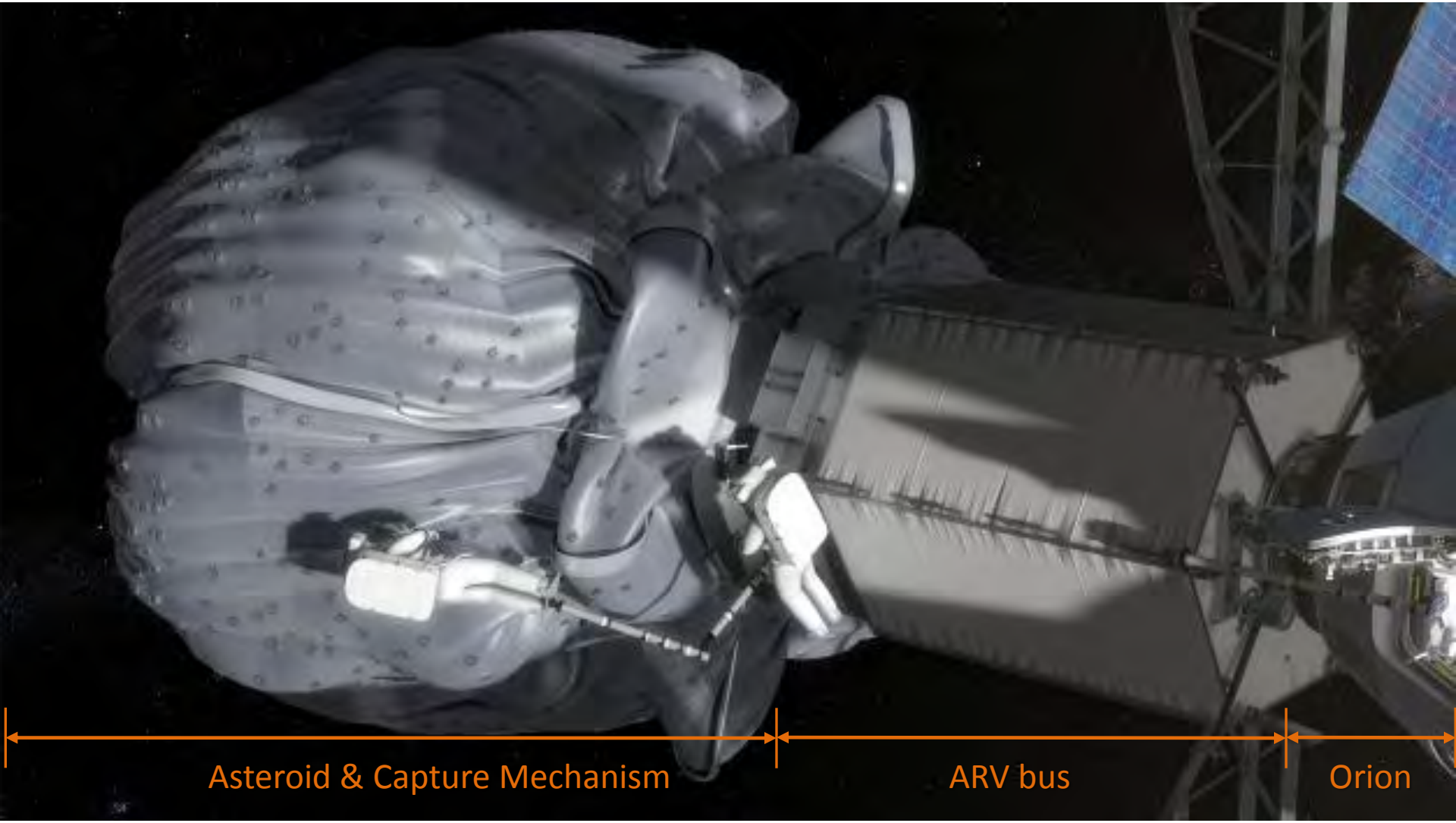
- ARV-launched tools
  - Geological Sampling Tools
  - Sample Container Caddy
  - Booms, worksite access
  - Boot plate
  - Tethers and bags

- Orion-launched tools
  - Safety tethers
  - Equipment tethers
  - Boom, gap spanner boom
  - Geological Sampling Tools
  - Sample Container Caddy
  - Orion hatch seal and thermal cover
  - Digital camera

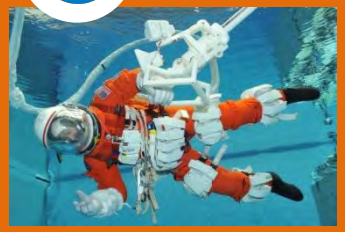
Worksite Booms

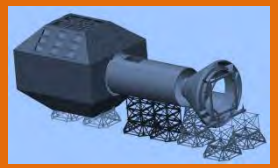


Worksite Access boom set-up

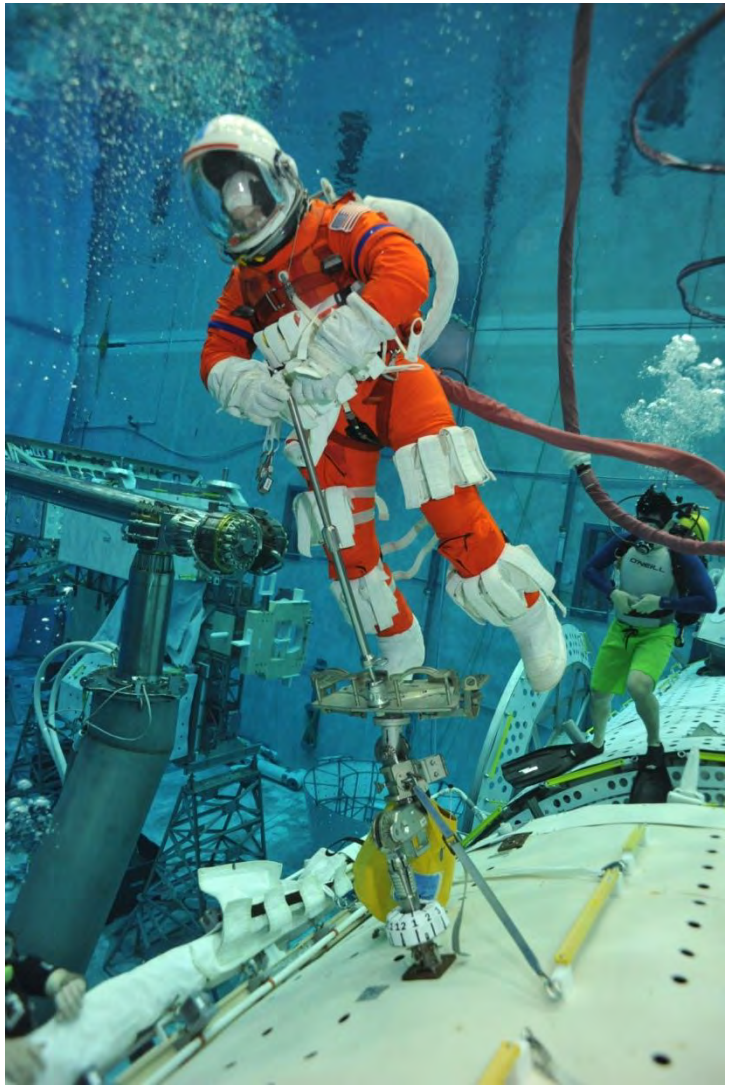


Foot Restraints



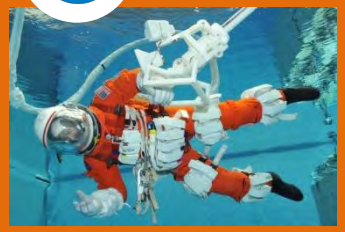


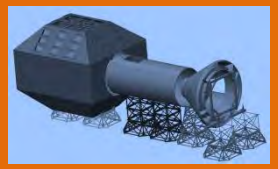
- Bag opening, sample collection, and instrumentation deploy will be difficult EVA tasks, requiring two-handed operations.
- A foot restraint will be integral to the worksite access boom.
- Crew use of the foot restraint allows for two-handed operations.



Worksite access via boom and foot restraint

EVA Con Ops – Worksite Prep and Imaging





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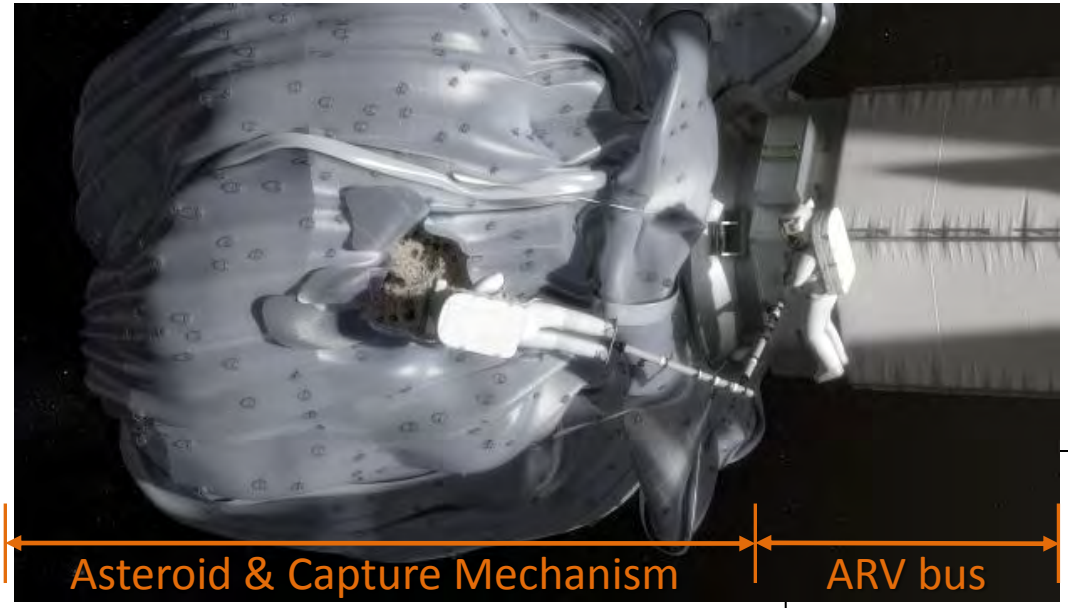
- EV1 begins worksite preparation
- Bag capture device ops
  - Cut bag open with standoff cutting device
  - Pull bag open and secure with clips
  - Assess condition of the asteroid
  - Image using multi-spectral imaging device
  - Begin sample capture

--- OR ---

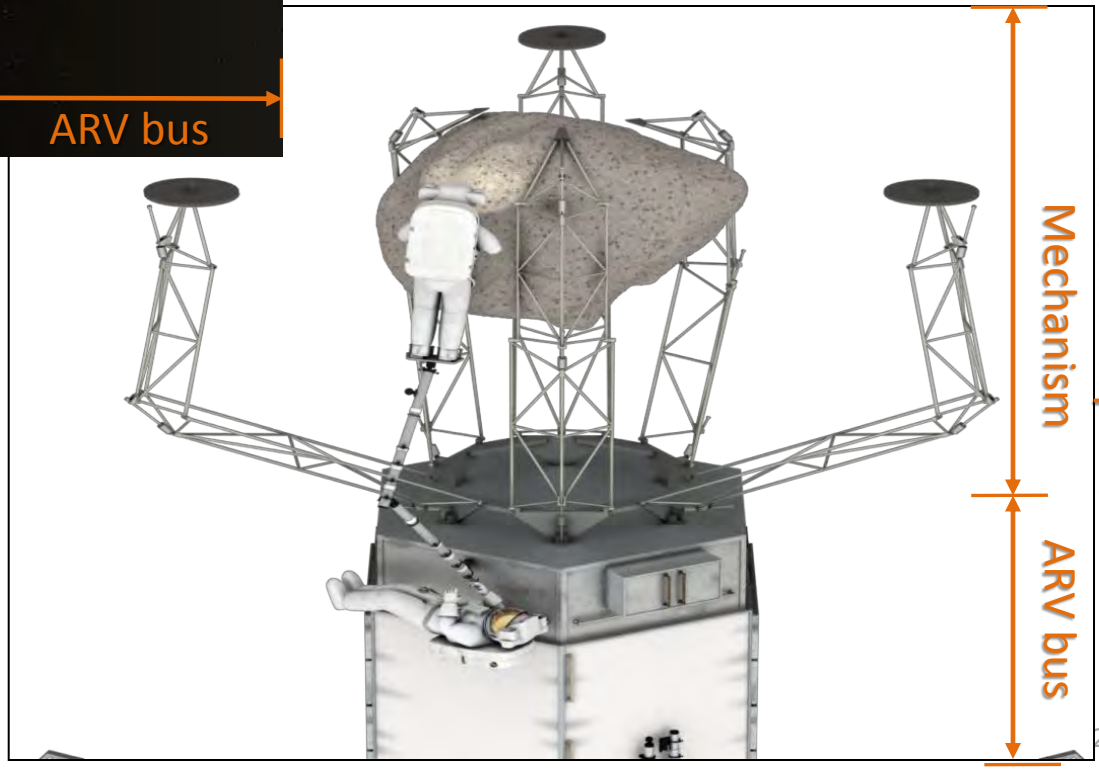
- Hard structure device ops
  - Image surface of rock
  - Assess structural condition of hard structure. Hard structure may be used for worksite stability if safe and available near area of interest
  - Find safe area to access
  - Begin sample capture

Comparison of Capture Mechanisms

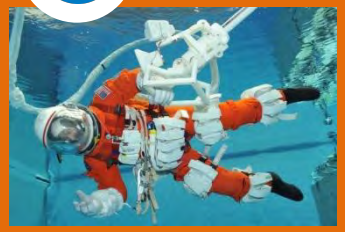


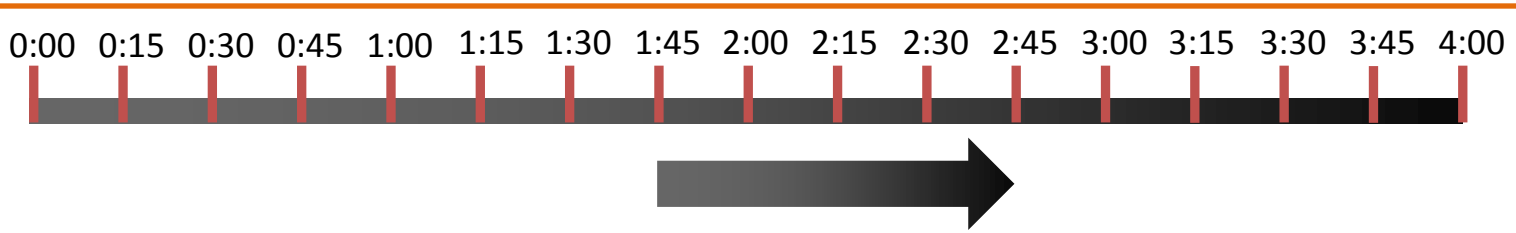
EVA crew member accessing asteroid on Small Boulder Capture concept.

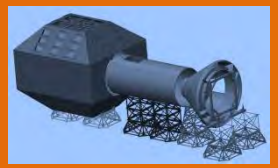
EVA crew member accessing asteroid on Robotic Boulder Capture concept



EVA Con Ops – Sample Capture





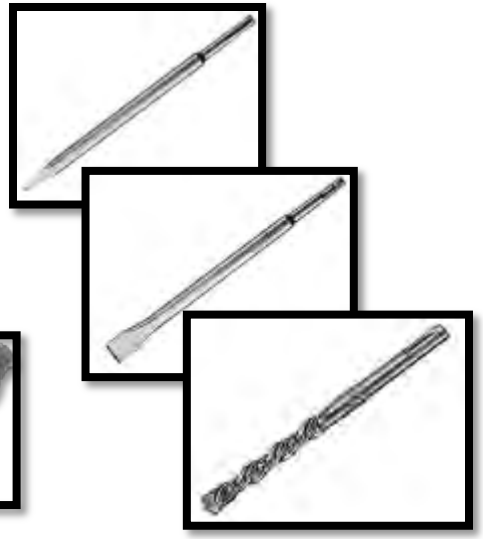


- First sample – Contingency sample; first available item placed in sample bag and stowed
- Second sample – Cut a swath of capture bag for control
- Third sample – Contact pad sample from surface of rock
- Remaining samples are
- Float samples (loose rock)
- Chip samples (smaller parts broken from larger rocks)
- Subsurface samples (drilled from large rocks)

Supporting EVA Equipment

- A full system of EVA Tools & Equipment has been deployed to support development testing:

- Pneumatic Drill
- Pneumatic Hammer
- Pneumatic Wrench



- Bull pt. Chisel Bits
- Spade Bits
- Masonry Drill Bits

- Core Tubes
- Hammer Cup
- Instrument Anchors

- Neutral Hammer
- Apollo EVA Hammer
- COTS Geology

Continued ->

Supporting EVA Equipment

- EVA Tools System, continued from previous:

- Sample Bags
- Bag Dispensers
- Crew Lock Bags

- Clamshell Scoops
- Coin-Holder Container
- Wire Ties

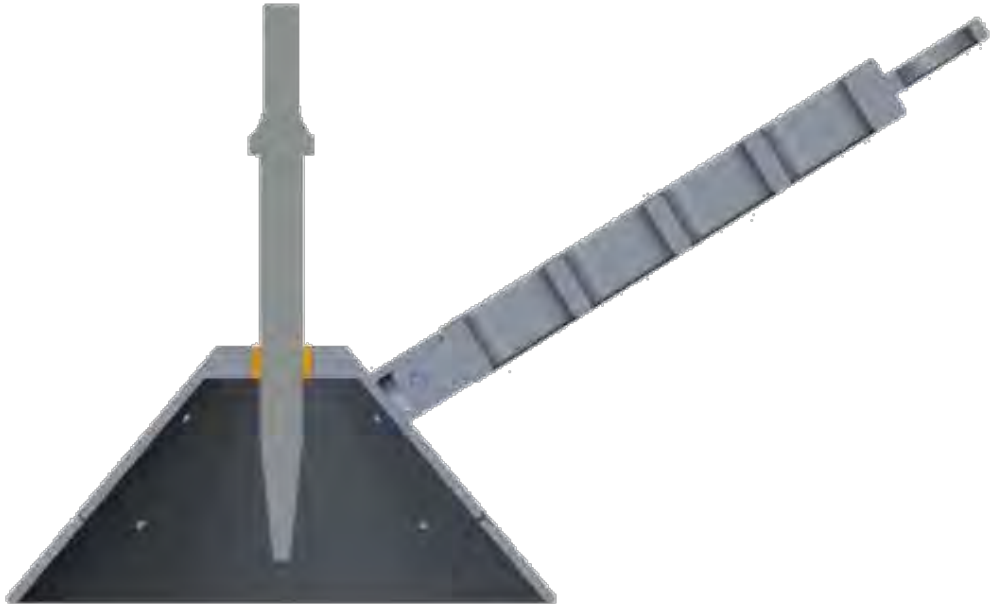
- Workstations
- Body Stabilization (BRT)
- Adjustable EVA Tethers

- Equipment Hooks
- Basic Ascenders
- Handled Asc.

Continued ->

Hammer Sampling Cup

- The Hammer Sample Cup is a conceptual design for trapping/collecting “Chip Samples” without having to deploy a “Hammer Blanket” (previous concept evaluated in FY12)
- Driven by the Pneumatic Hammer, the Sample Cup is lined with a Stainless Steel Wool to entrap particles
- Such devices represent solutions to the Requirement that the EVA Sampling System capture the sample when it is created
- Without such containment, most samples break off at escape velocity and are lost during the very act of obtainment

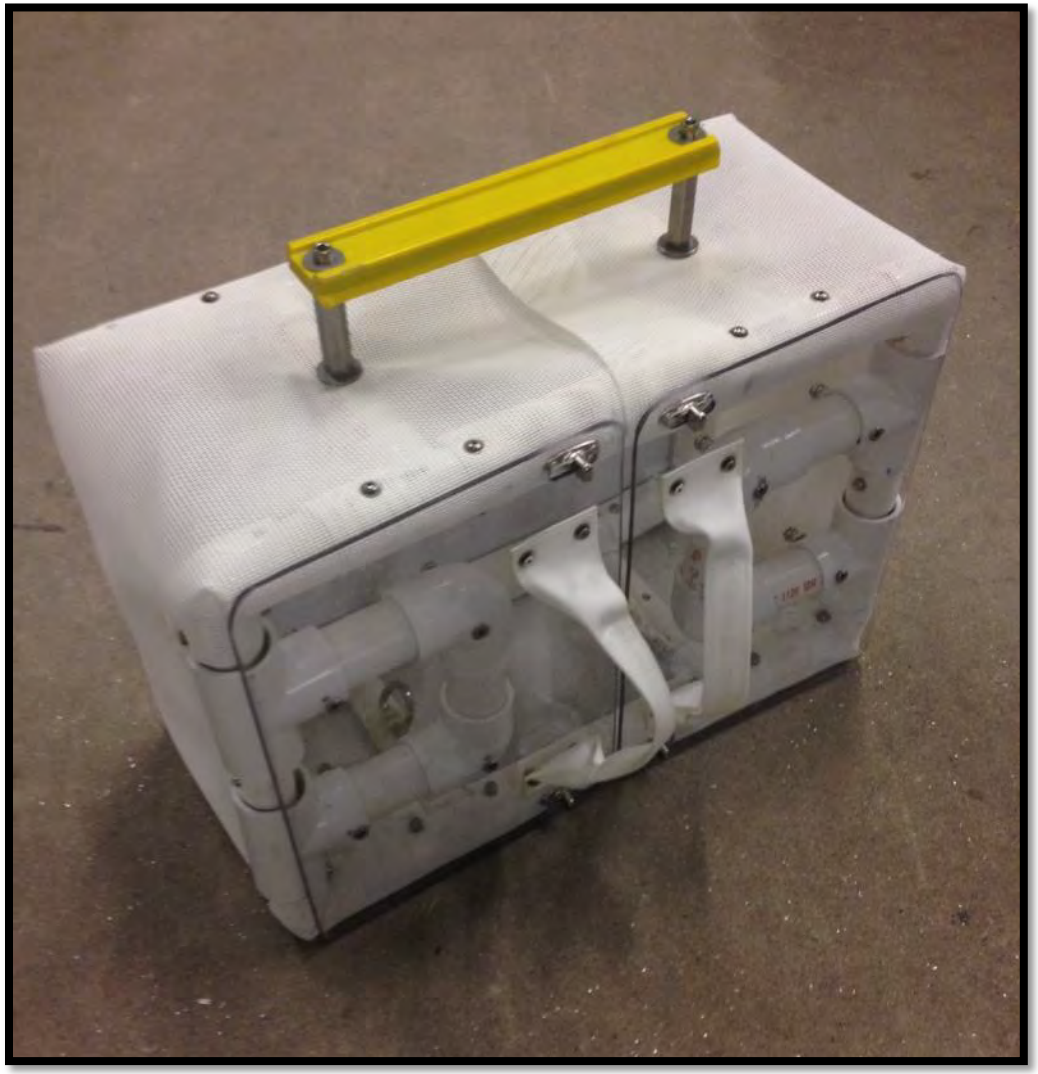


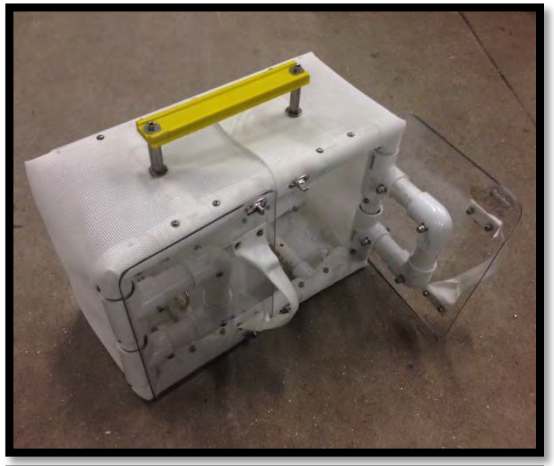
Supporting EVA Equipment

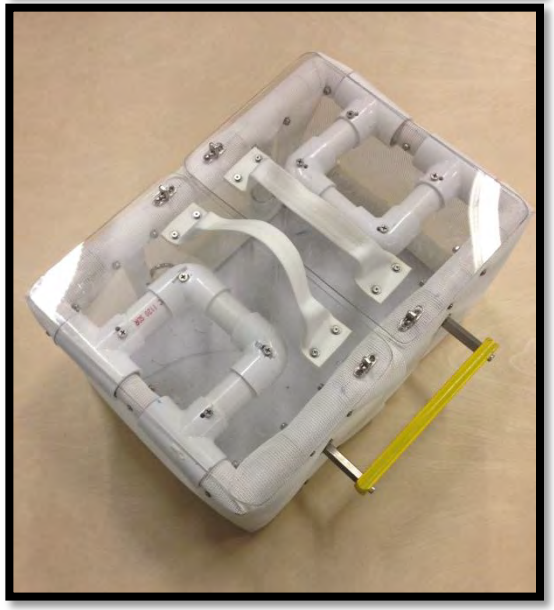
- Updated Sample Bag Dispenser:

Supporting EVA Equipment

- Updated Crew Lock Bags:



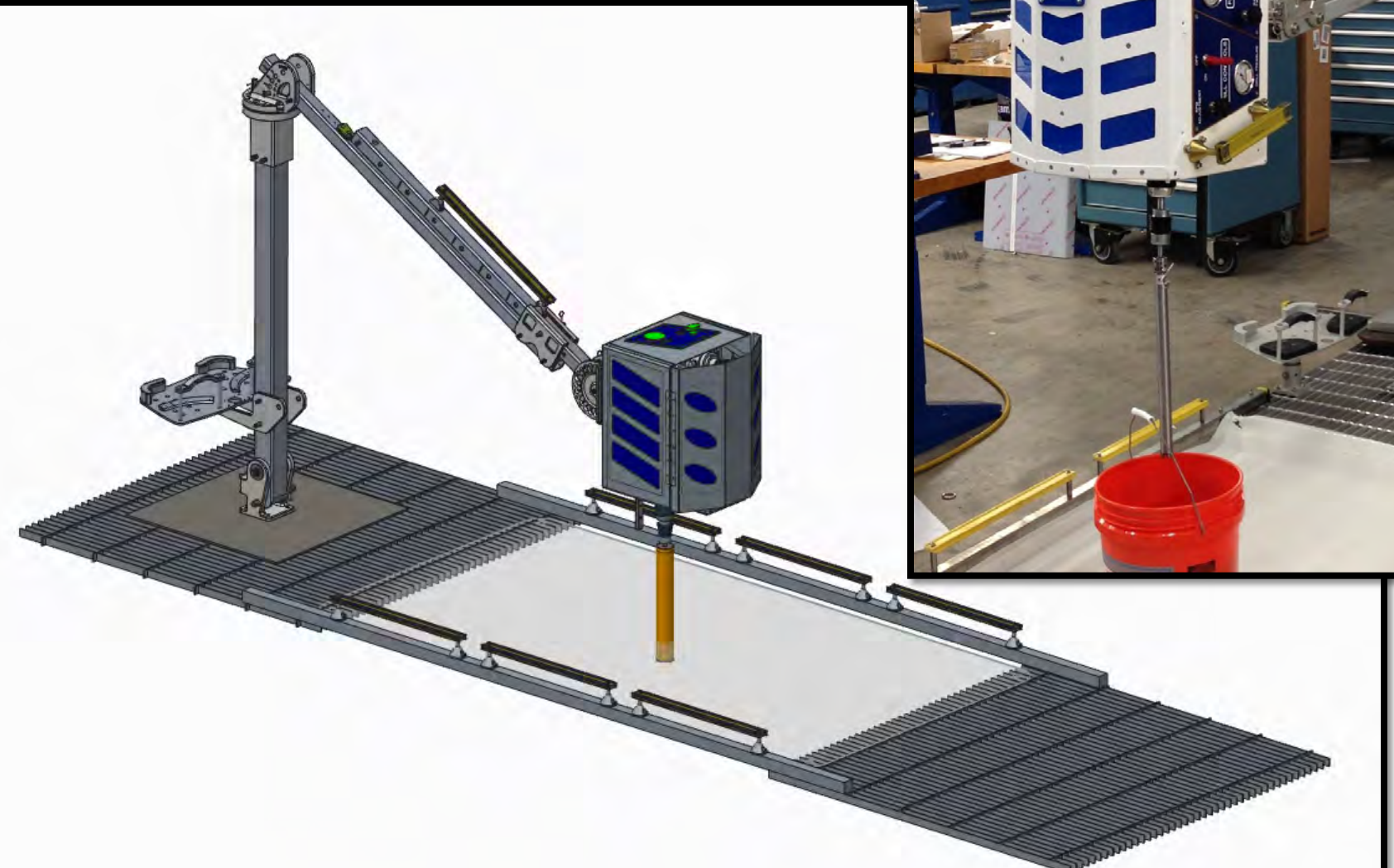




Core Sampling

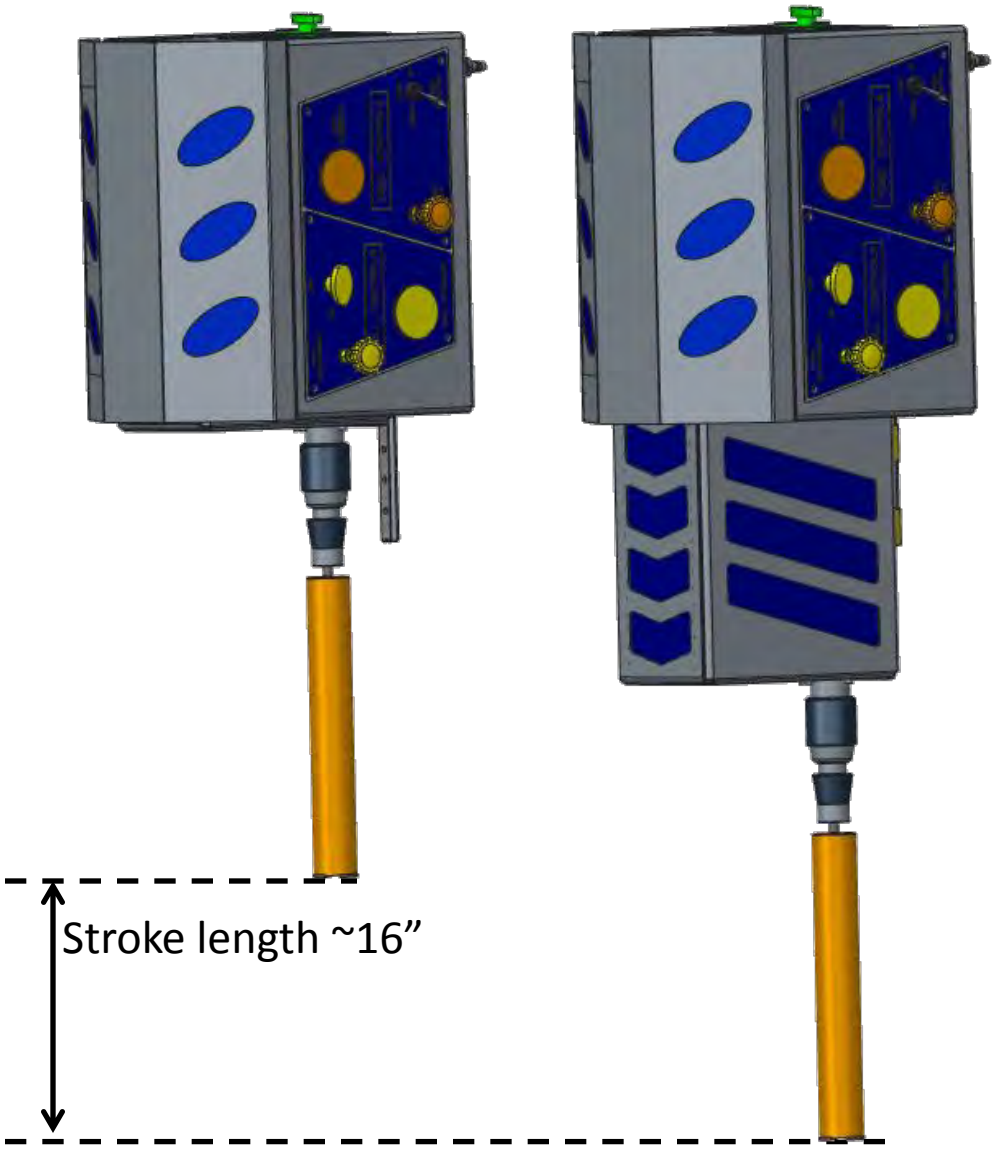
- Core Tube assembly, evaluated for both “Hammer Driving” and “Torque Driving”

Core Drilling in micro-g

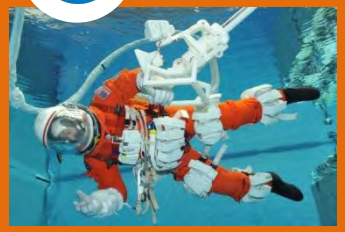


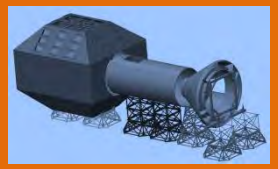
Core Drill Kit Design

- The team has designed a pneumatically-powered Core Drill Kit
- The Core Drill mounts to the Stabilization Boom to transmit loads
- The Core Drill provides a clear (Lexan) safety shield with door to preclude inadvertent access to the drill (not pictured)
- The door may be opened in order to “stack” segments of the Core Drill (see following slide)
- The system requires 3 segments to reach the desired depth of ~1m

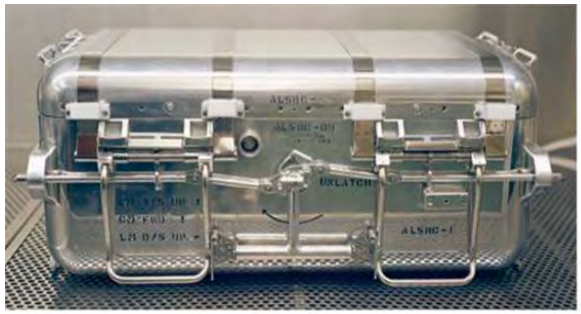


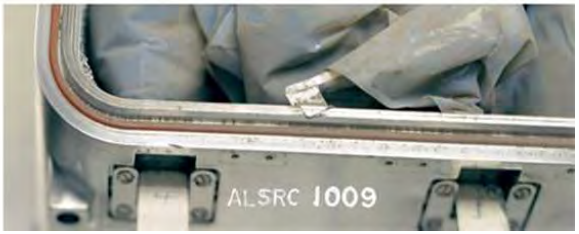
Asteroid Sampling



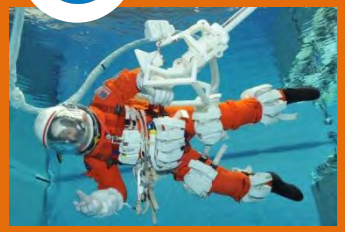


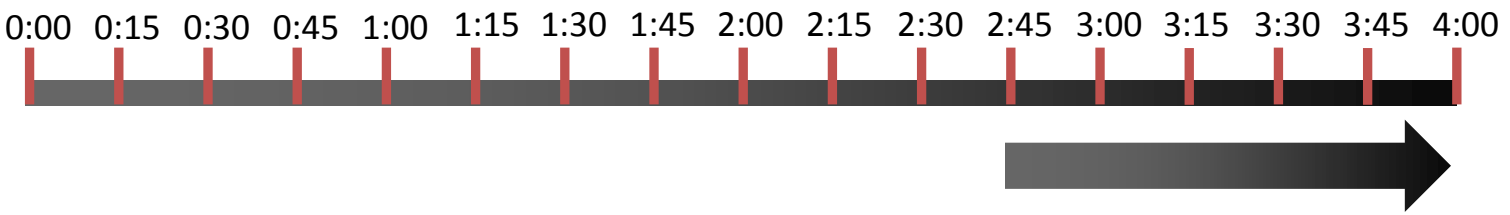
Sample collection containers

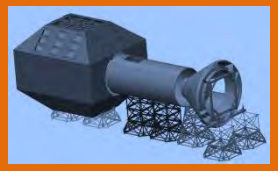




EVA Con Ops – Return to Orion





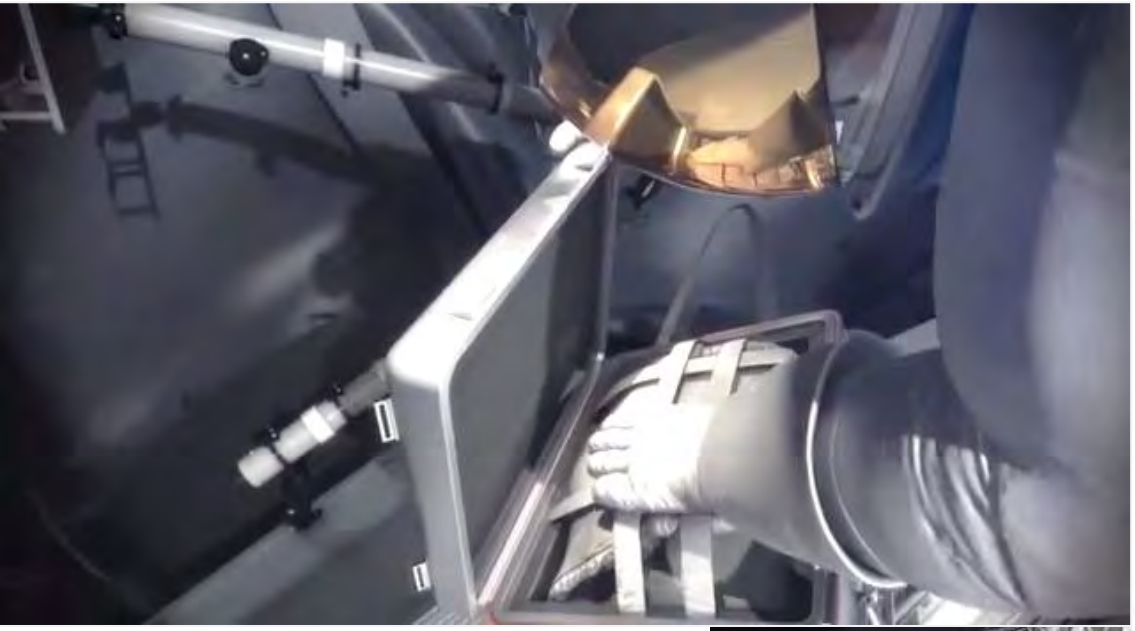


- All samples are stored in separate sample bags which are placed in an airtight sample container
- After samples are collected, a cover is placed over the worksite using clips
- Tools and worksite booms are stowed on ARV
- Crew translates to Orion
- EV2 removes hatchway thermal cover and stows it
- EV1 follows EV2 into hatch, uninstalls translation boom and uninstalls EVA Communication antenna
- Hatch is closed

- EVA ARCM animation (PLAY)
  http://www.youtube.com/watch?v=1OwmZYrTsGY

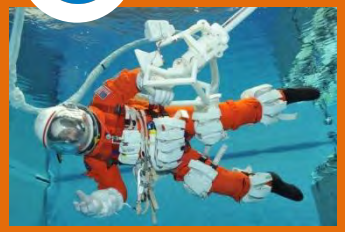
  (credit: NASA – JSC, AMA JSC Advanced Concept Lab)

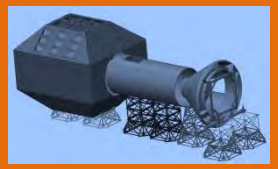
Return to Orion



- Samples are stored in separate sample bags which are placed in an airtight sample container
- Sample containment protects the crew, the Earth and the sample.

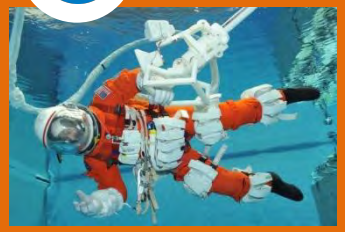
Upcoming Work

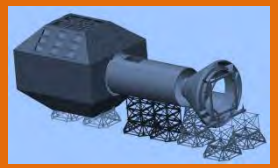




- Content presented today has been based on (1) the ARCM Ops Con developed to support MCR (July 2013) and (2) development work over the past year.
- Work continues to mature the EVA ops con and further the development of the EVA System (Suit, PLSS, & Tools) in preparation for MFR (Feb 2015).
  - Summer 2014, mature the ARCM EVA timelines, incorporate CAPTEM findings to timelines, and incorporate experience from development work to date.
  - Sept 2014, NBL testing, MACES feasibility testing with new crewmembers to finalize plans for first custom suit design.
  - FY14 Q4 and FY15 Q1, BAA to Honeybee Robotics to study a “NANODRILL AND CACHING SYSTEM” EVA tool system, and develop system design concepts.
  - FY15, Q1&Q2, design and fabricate first custom-sized MACES suits in prep for dedicated NBL testing in Spring 2015.

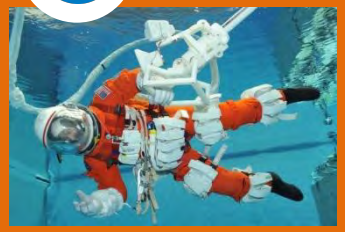
Looking forward

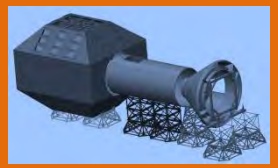




- Initial assessments demonstrate that an Orion vehicle, MACES suit, Exploration PLSS, and functionality kits are feasible for conducting EVA objectives on a captured asteroid.
- As the Asteroid Redirect Mission (ARM) program continues in development, EVA operations will evolve.
  - The potential addition of a habitable module with airlock capability will enable longer docked crewed missions (30-90 days) with more frequent, longer duration EVAs (i.e. multiple EVAs/week).
  - An Exploration EVA suit could be worn by the crew, replacing the MACES worn for the first ARCM EVAs.
  - Additional EVA worksites on the asteroid are anticipated to provide a diversity of samples to the scientific community.
  - There is the potential that EV1 and EV2 will work simultaneously at separate worksites.
- Further maturation of the science objectives for sample collection, and development of the sample collection tools will refine the EVA timelines.
  - Request SBAG input regarding additional EVA-performed science objectives, and priorities of tasks.

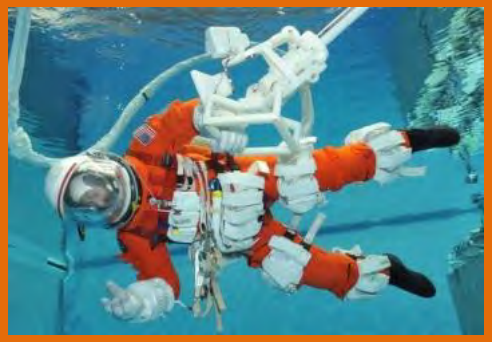
Credits





- Presentation template: Jonathan Bowie
- Animations and Renderings: NASA – JSC, AMA JSC Advanced Concept Lab
- Photographs: MACES NBL test project team and EVA Tools development team.

Questions?







Backup

MACES Testing: Validate suit capabilities for EVA

Lab, Zero G, ARGOS tests

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

NBL Series #2 – 5 tests (2, 3 and 4 hours long)

Task complexity increases while improvements are made to the suit including EMU gloves, drink bag, etc.

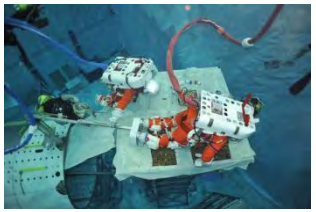
Need for improved stability and work envelope

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 (Current series)



Evaluation of mobility enhancements, improved worksite stability, and testing on higher fidelity capsule mockups with tools that will more accurately represent an asteroid type EVA.

Hardware and Procedure Improvements

- Improved weights
- EMU Gloves
- Added tool harness
- Drink bag included
- New liquid cooling garment
- Mobility Enhancements
- Dual Suit Ops
- EMU Boots
- PLSS Mockup
- Body Restraint Tether