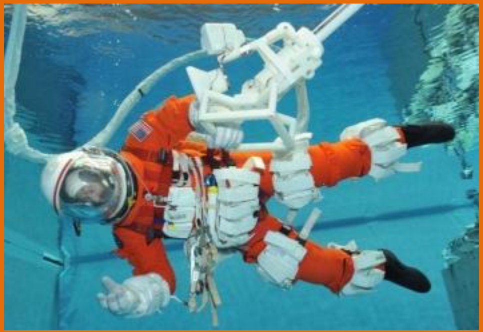

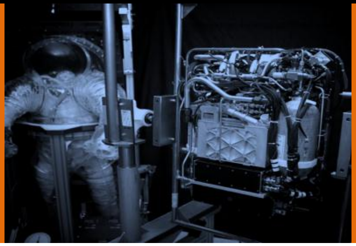

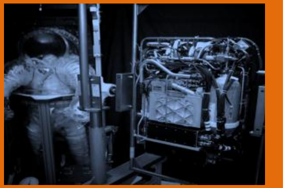

ASTEROID REDIRECT CREWED MISSION SPACE SUIT AND EVA SYSTEM ARCHITECTURE TRADE STUDY

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NASA Johnson Space Center, Houston, TX

SpaceOps 2014, May 5th-9th, Pasadena Conference Center

AGENDA





- Introduction and Background
  - Mission Requirements
  - Concept of Operations
- Trade Study
  - Pressure Garment Options
  - Life Support Options
- Proposed Architecture
  - Modified Advanced Crew Escape Suit (MACES)
  - Portable Life Support System (PLSS)
  - EVA Tools
- Validation Testing
  - MACES and Tools
  - PLSS
- Conclusion

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 and 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

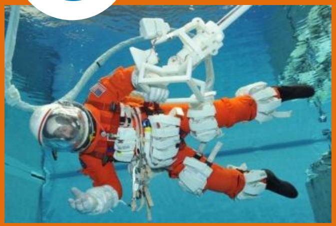
Architecture Guidelines

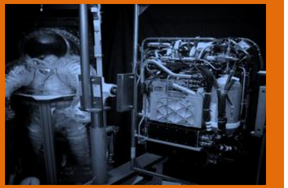
- Minimize Orion Impacts
  - Define as an add on “kit” to Orion
- Minimize Mass

EVA Related Mission Parameters

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

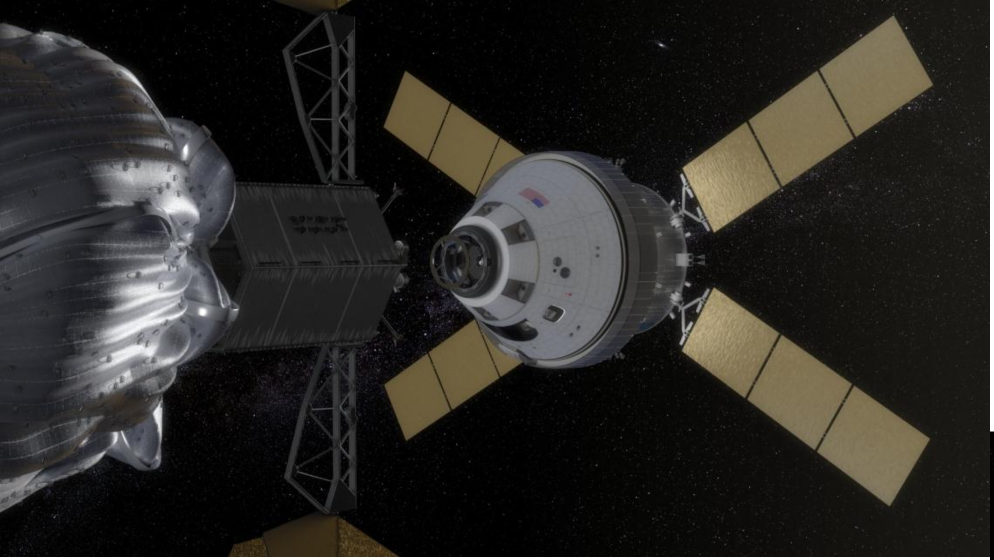
ARCM EVA OPS CON





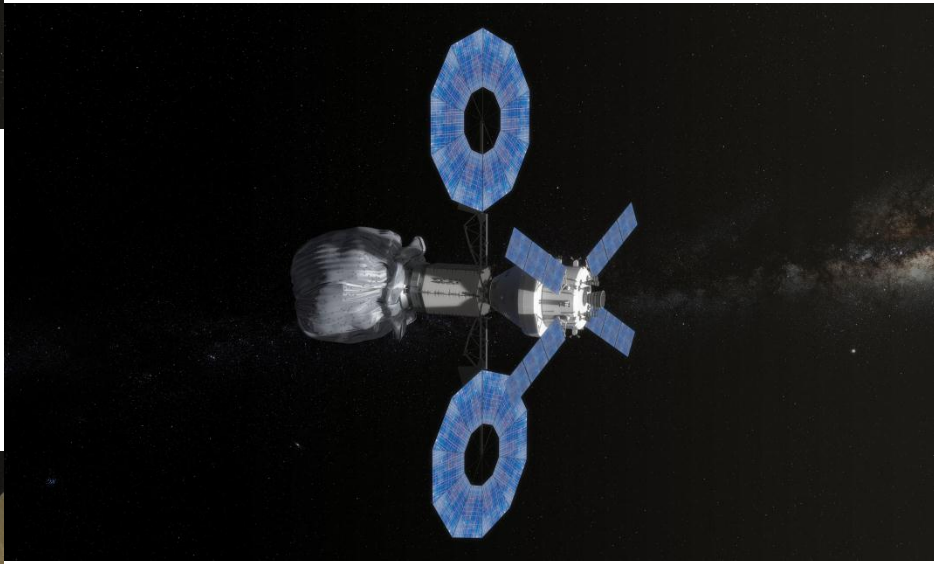
- The following slides show the notional EVA Ops Con for the Asteroid Redirect Crewed Mission

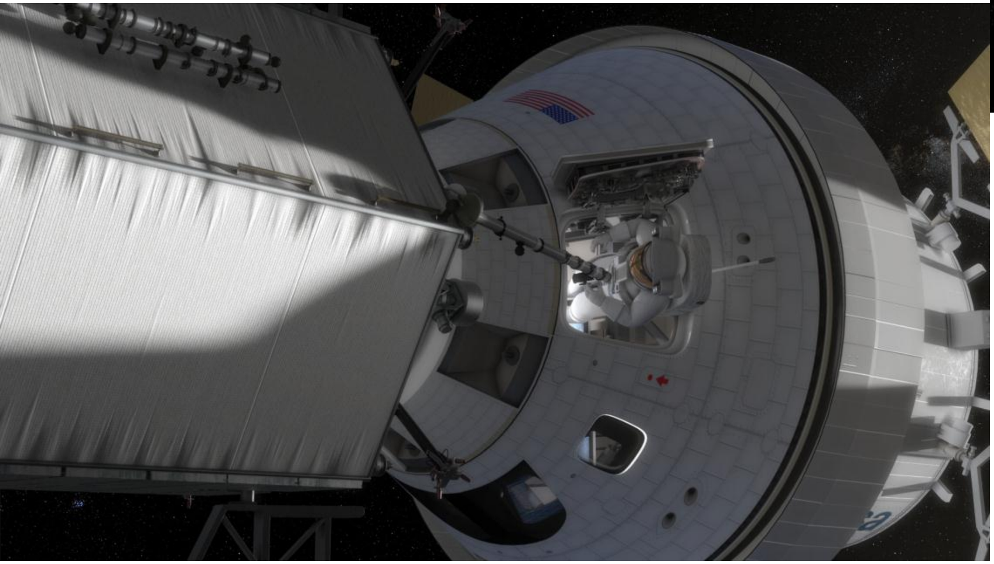
- Assumptions:
  - On SLS/Orion in 2025
  - Two crew
  - As many as 30 days total mission duration (nominal 26 days)
  - Two possible asteroid capture scenarios are being debated through the agency
    - "Small Rock": Capture an entire small asteroid (2-10 m long diameter)
      - Most likely a "gravel pile"
      - Requires a bag-like device to envelope asteroid
    - "Big Rock": Pluck a large boulder (2-10 m diameter) off of a very large asteroid (1 km or greater)
      - More of a solid rock
      - Proposed capture devices are all hard structure with more open access to asteroid



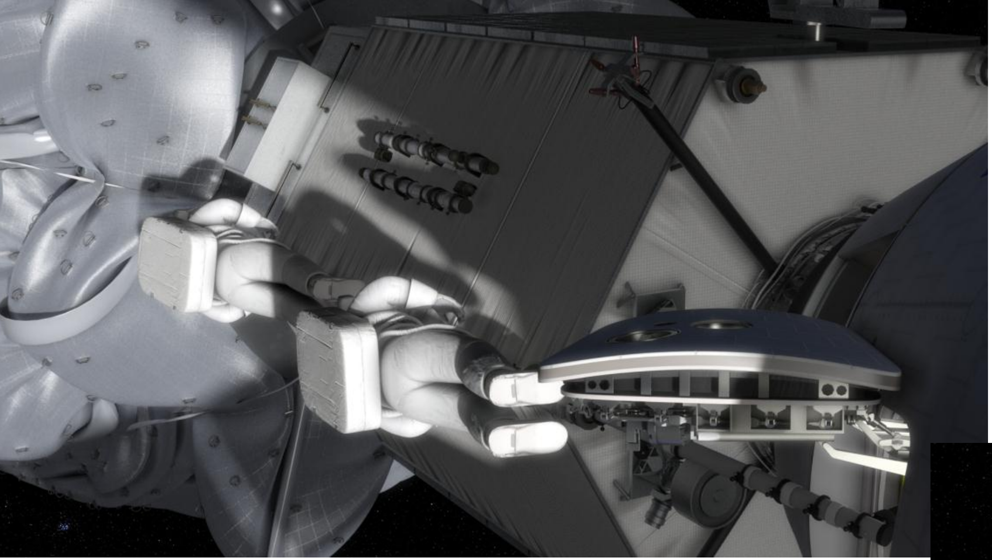
Orion takes approximately 9 days to arrive at Asteroid Redirect Vehicle in a Lunar Distant Retrograde Orbit. EVA checkout and preparations can be done during transit. Here Orion makes the final approach before docking.

On the day of EVA, the Orion vehicle rotates the stack to light the translation path from the capsule to the asteroid. This is done for lighting and thermal conditioning of worksite.



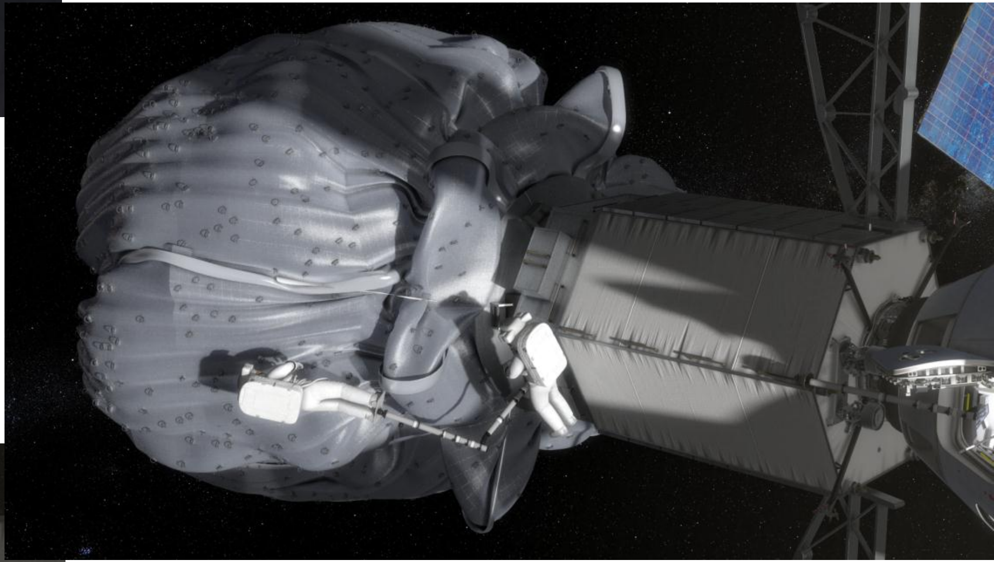


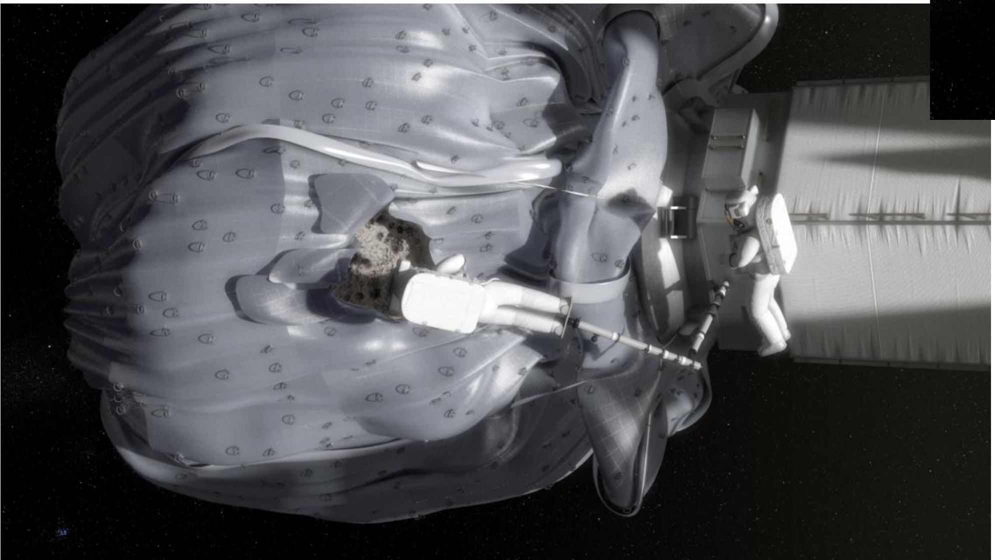
After donning the suits, depressurizing the cabin and doing the final safety checks, one astronaut places a gap spanning boom creating a bridge from the cabin to the ARV.



The crew travels down the ARV using in place handrails toward a set of prepositioned tools in a tool box. Located next to the tool box are up to two worksite stabilization booms.

The crew uses the worksite stabilization booms to reach multiple locations on the asteroid.





The crew retrieves samples and places them into a sample container for return to Orion.

The crew will use a variety of tools to capture asteroids samples.

The crew places the samples in an airtight container that will protect the samples in the Orion cabin.

The crew stows the sample container. Crew returns to Earth carrying the samples with them.

ARCM Space Suit and EVA System Architecture

TRADE STUDY

SPACE SUIT OPTIONS

- The following suits were considered for ARCM:
  - Shuttle ACES
  - Orion Modified ACES (MACES)
  - Extravehicular Mobility Unit
  - Exploration Suit (Z-series)

Shuttle ACES

Orion MACES

EMU

Exploration Suit (Z-series)

SPACE SUIT OPTIONS

Shuttle ACES

Orion MACES

EMU

Z-Suit

Suit	Per Crew Mass (lb)	Accounted for in Orion Mass?	Suit Design Focus	Applicability for dual use?
Shuttle ACES (full gear)	~90	No	Launch/Entry Survival	--
Modified ACES (Orion Baseline less umbilical)	~35	Yes	Launch/Entry Survival	Minor mods for EVA-capable prototyped
EMU**	~140	No	Microgravity Mobility	Not appropriate for launch and entry
Exploration Suit**(Z-series)	~140	No	Planetary Mobility	Not appropriate for launch and entry

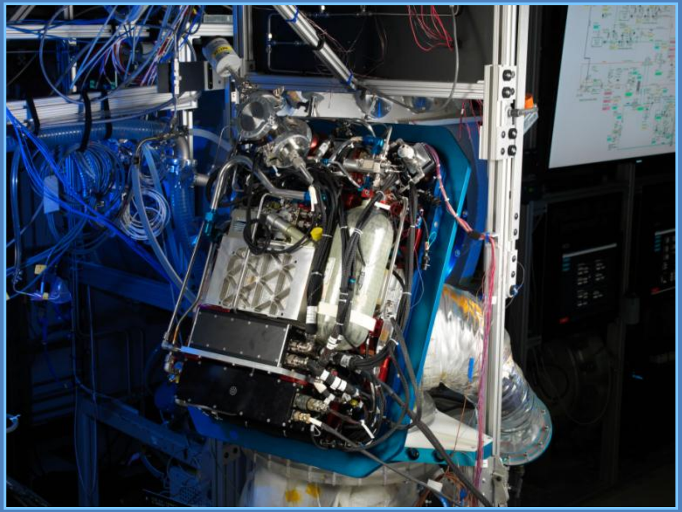
Modified ACES suit selected:
Orion launch/entry suit; mass is already accounted for in Orion baseline
Minimal EVA-capability with minor mods being tested to increase EVA capability

EVA LIFE SUPPORT SYSTEM OPTIONS

- The following Life Support options were considered for ARCM:
  - Short Umbilical Closed-loop
  - Long Umbilical Open loop
  - EMU Primary Life Support System (PLSS)
  - Exploration Portable Life Support System (PLSS)


EMU PLSS

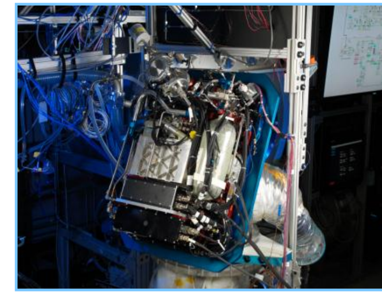

Apollo Open Loop Umbilical


Exploration PLSS

EVA LIFE SUPPORT SYSTEM OPTIONS

EMU PLSS

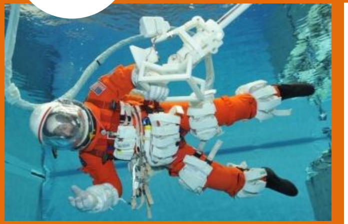
Apollo Open Loop Umbilical

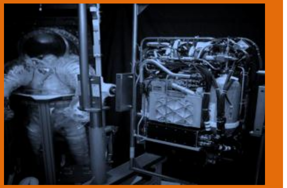


Exploration PLSS

Life Support Option	Applicability to Future Exploration Missions	Mass Impact for 2 EVA crew (lb)	Applicability to Asteroid Retrieval Mission
Short EVA Umbilical (28' Closed Loop)	No	--	Won't support mission due to short length Orion modifications would be required due to fan size
Long EVA Umbilical (100' Open Loop)	No	784	Could support asteroid mission Supplemental O2 tank required to support metabolic load Boost pump would be required for water cooling
EMU PLSS	In use on ISS	--	Suit integration effort would be significant Designed for hard upper torso vs. MACES soft upper torso
Exploration PLSS	Currently under development	585	Could support asteroid retrieval mission

Exploration–PLSS selected: LOWEST mass option;
Leverages recent technology development efforts; Benefit to Orion, ISS, and future Exploration Missions

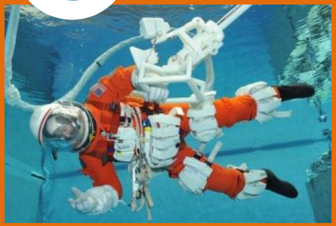


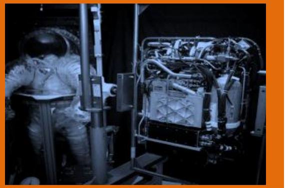


ARCM Space Suit and EVA System Architecture

PROPOSED ARCHITECTURE

ACES TO MACES

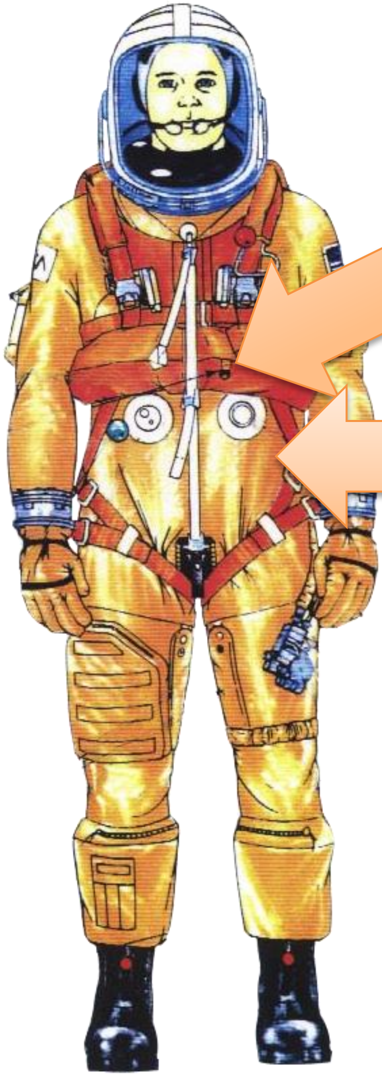




- The baseline suit for the Orion is the Modified ACES, a derivative of the shuttle ACES suit.
  - The ACES is derived from the original Launch/Entry Suit incorporated by NASA as part of the Crew Escape System following the Challenger Accident (1986).
  - The ACES is a full pressure suit with a nominal contingency operating pressure of 3.46 psid.
  - The ACES features an “open-loop” demand air system, meaning that expired air is vented out of the suit into the cabin atmosphere at ambient pressure.
- General physical characteristics of the standard ACES are unchanged for the MACES.
  - The following are identical between MACES and ACES
    - Pressure garment composition
    - helmet
    - gloves
    - boots
    - cooling
    - communications assemblies
    - Undergarments
  - Differences between MACES and ACES shown on the next page

MODIFICATIONS TO SHUTTLE ACES

SHUTTLE ACES	MODIFIED ACES



Front view

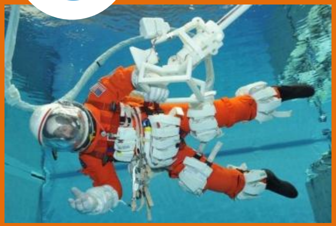
Back view

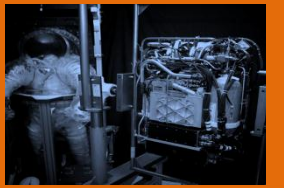
Primary Breathing System: Open Loop to Closed Loop addition allows operation with closed-loop ECLSS using Apollo-inspired equipment and solutions

Auxiliary Modifications: Retrofit from custom to MIL-STD life preserver unit (LPU) allows conformal seat integration

Secondary Breathing System: Emergency Oxygen System repackage and relocation (2 places) allows conformal seat integration

MACES EVA ENHANCEMENTS





- **To allow the MACES to conduct an EVA changes to the baseline Orion configuration are required:**
- EVA Gloves
  - Added in the course of validation testing
- Improved thermal protection for wider thermal range
  - Added in the course of validation testing
- EVA rated vision protection
  - Prototype created and tested to EMU specifications
- Tool attachment
  - Added in the course of validation testing
- Tether attachment
  - Added in the course of validation testing
- Body stabilization
  - Added in the course of validation testing
- Drink bag
  - Added in the course of validation testing

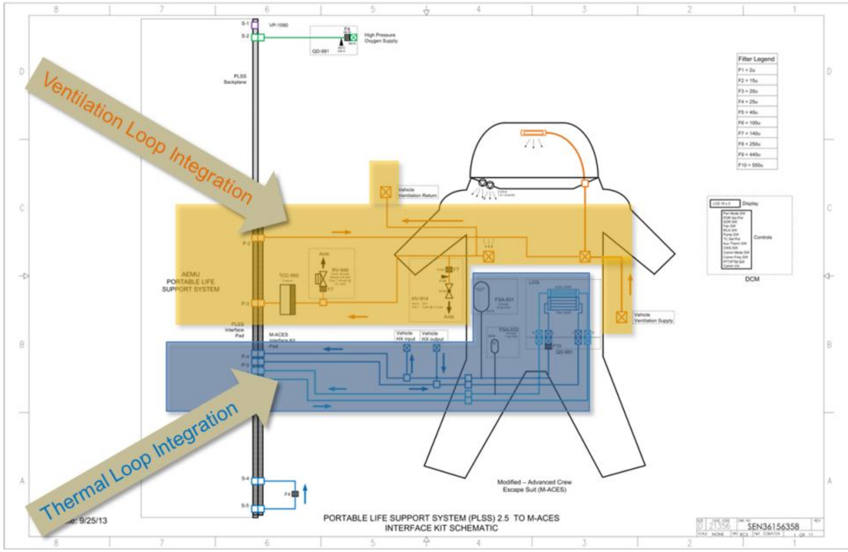
PLSS

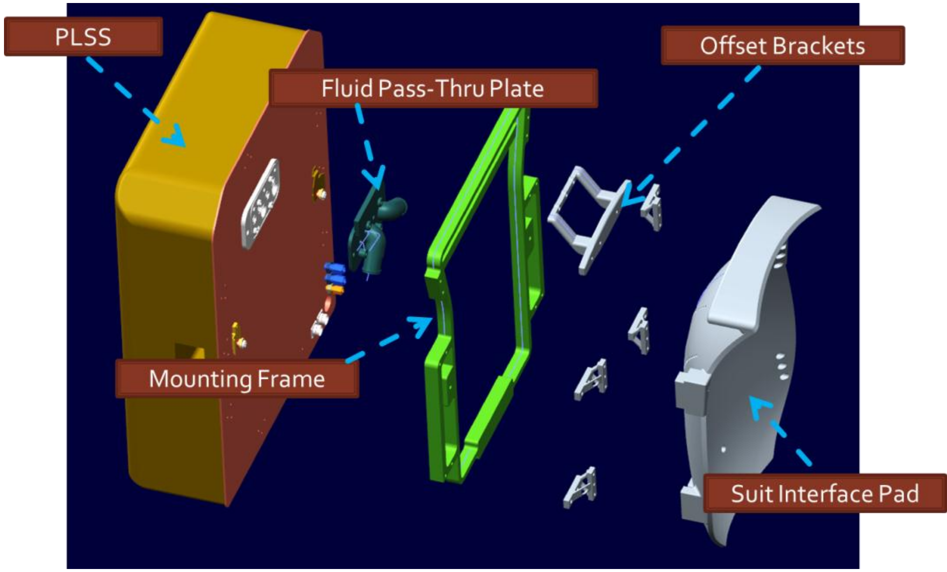
An Exploration PLSS is being developed as a suit agnostic life support system under the Advanced Exploration Systems (AES) Advanced EVA Systems Project and Office of Chief Technologist (OCT)

- The first iteration of the packaged PLSS (PLSS 2.0) is assembled and testing is underway
- The first flight-like packaged PLSS (PLSS 2.5) initial design is in work
- Additional definition of PLSS driving requirements are needed to influence Exploration PLSS design
  - M-ACES interface has different flow and leakage requirements
  - ARCM mission has different environmental requirements

PLSS INTERFACE

- Interface Kit serves 3 vital purposes:
  - Secure pressure garment to PLSS structure
  - Suit-to-PLSS gas/fluids interfacing
  - Provide pre/post EVA gas/fluids servicing
- Kit-based solution preserves suit and life support designs
- First time a primarily LEA suit has been mated to a 'backpack' type life support system
- Unique Challenges
- MACES back curvature
- Need for support in all three (X,Y,Z) axis
- Limitation on MACES/PLSS front-to-back dimension

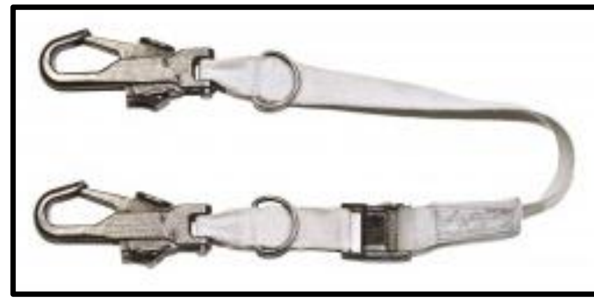




TOOLS

- EVA Tools and Equipment on the ARCM mission provide capability in three key areas:
  - The first is Suit-Tool interfaces:
    - Establish “Safe for EVA” capability with tether point adaptations to provide Safety Tethers connection of the Crew to the Vehicle
    - Provide loose restraint of hand tools to the suited Crew

EVA Safety Tether



Adjustable EVA Equipment Tether

Retractable Equipment Tether

TOOLS

- The second key function of EVA Tools and Equipment is Body Stabilization:
  - Rigidizable body restraint tethers with loads transmission for a fully-soft suit
  - Short Tethering for stabilization without pre-integrated rigidizable attachment points such as EVA Handrails

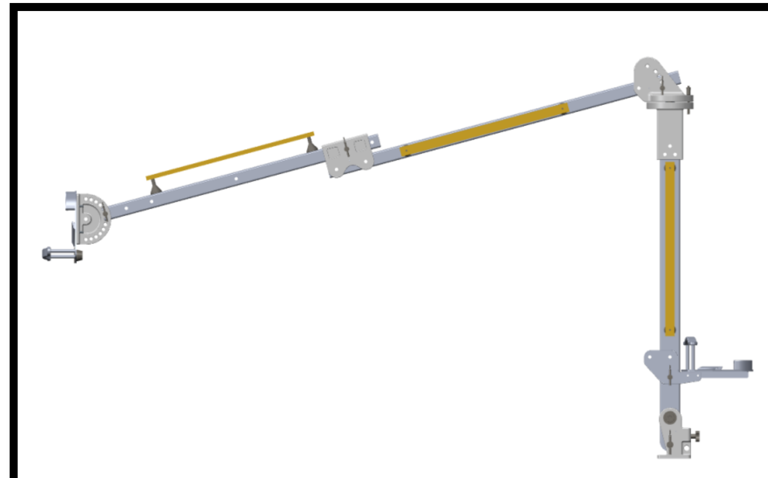
Body Restraint – "Rigidizable Tethering"

Body Restraint – "Waist Tethering"

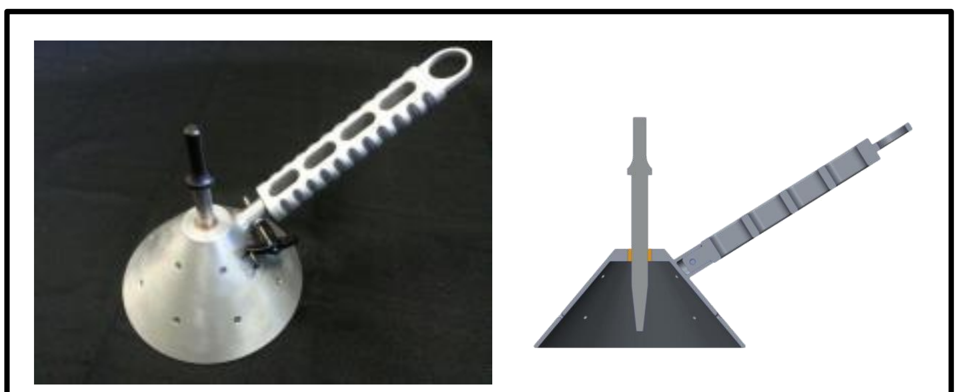
TOOLS

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

Crew-deployed translation paths – "Gap Spanner Boom"

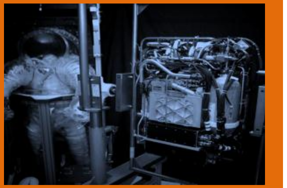


Crew-deployed translation paths – "Stabilization Boom"



EVA Geology–"Hammer Sampling Cup" for chip containment

EVA Geology–"Shallow Linear Core Tube"



ARCM Space Suit and EVA System Architecture

VALIDATION TESTING

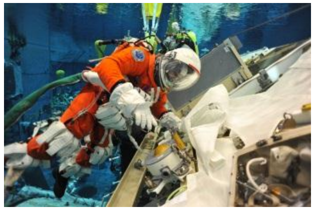
MACES TESTING

May | June | July | August | Sept | Oct – Jan | February | March | April | May

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)



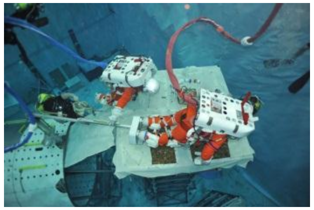
Task complexity increases while improvements are made to the suit including EMU gloves, drink bag, etc.

Need for improved stability and work envelope

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.

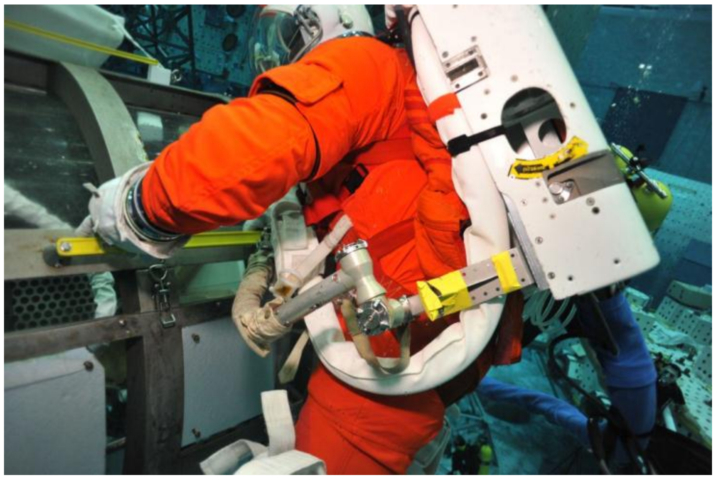
Hardware and Procedure Improvements

- 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

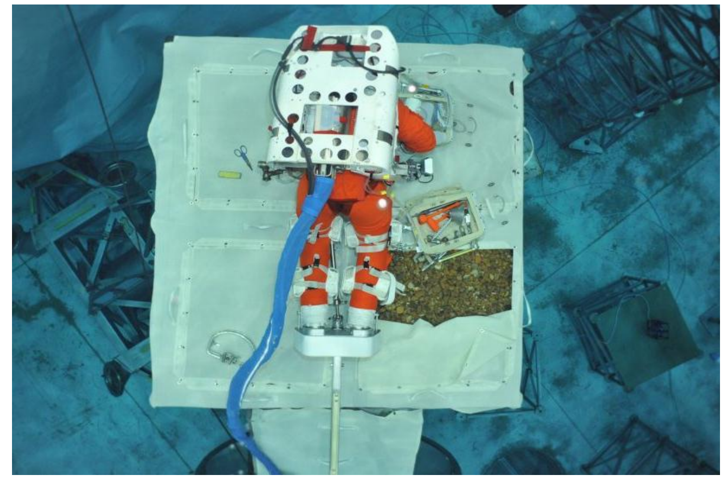
TOOL-SUIT INTERACTION TESTING

- The interaction of the EVA Tools & Equipment with the MACES has been tested in the NBL:

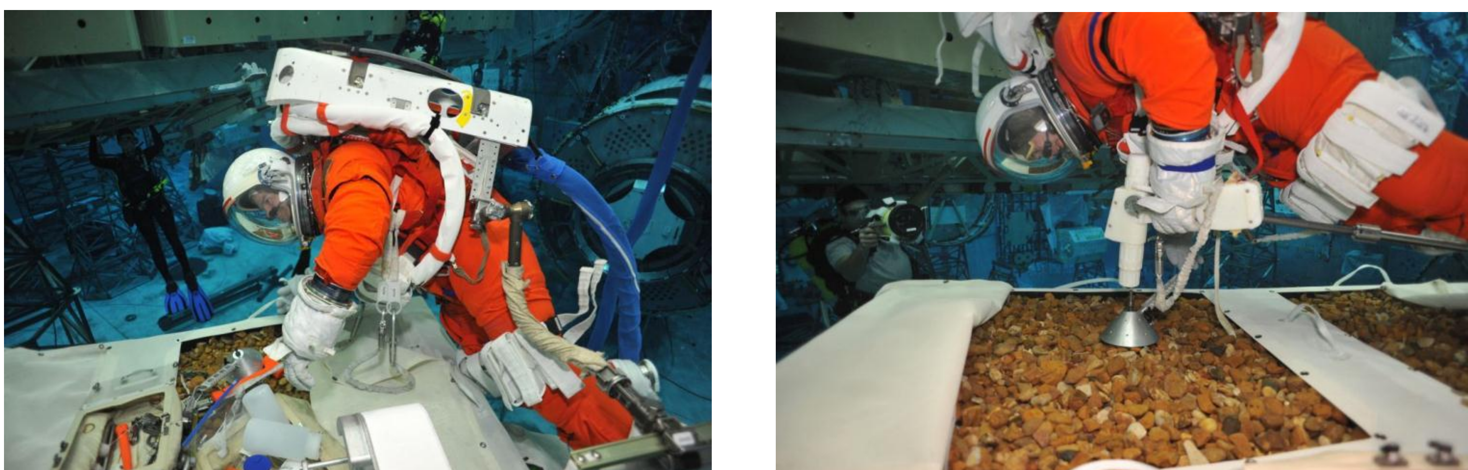
Body Stability



EVA Worksite



Microgravity Geology

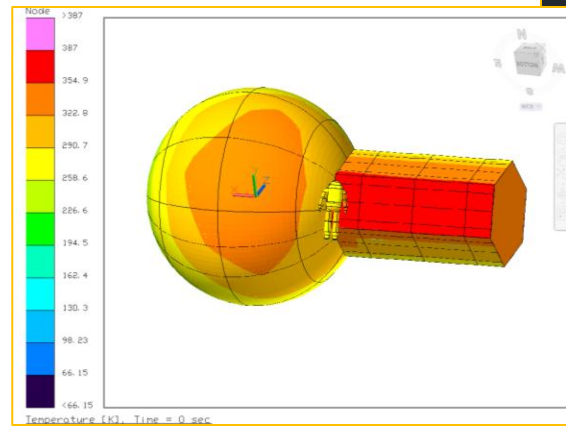


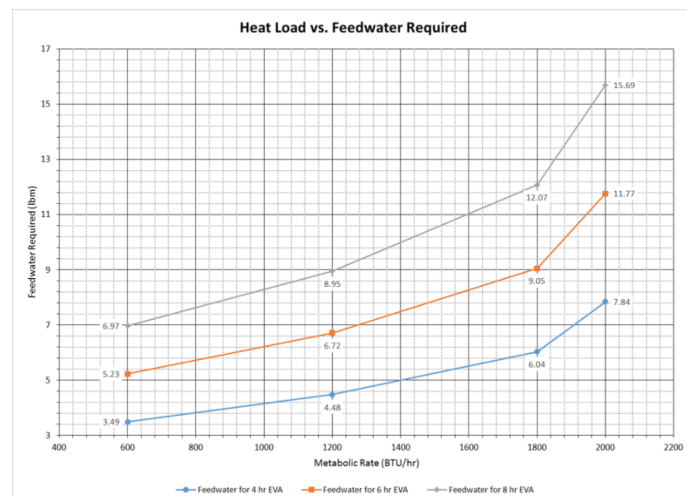
PLSS ONGOING ANALYSIS

- Several analysis tasks currently completed
  - Asteroid environment thermal definition
  - Integrated Thermal Control Assessment
  - Metabolic-rate based consumables estimation
  - Primary O2 tank sizing
  - Primary FSA sizing

- Analysis Underway
  - MSPV orifice sizing
  - CO2 washout estimation
  - Secondary O2 tank sizing
  - EVA-prep RCA saturation rate

- Initial Analysis Cycle complete January 2014

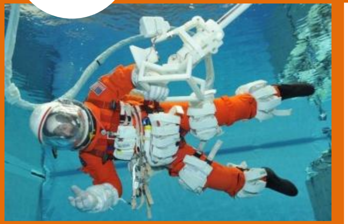


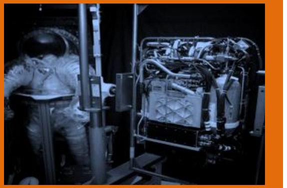


CONCLUSION

- The Asteroid Redirect Crewed Mission requires EVA capability.
- The proposed architecture was found to meet the mission constraints
  - MACES
  - Exploration PLSS
  - Enabling Tools
- Validation Testing will continue:
  - NBL testing will determine the right requirements to place on the suit.
  - The PLSS interface work will influence the PLSS as it continues to be develop.
- As the Asteroid Mission matures:
  - The suit/life support portion of the mission will adjust accordingly.
  - The EVA Tools can be iterated to accommodate EVA Suit optimization.

The goal of the EVA architecture for ARCM is to continue to build on the previously developed technologies and lessons learned, and accomplish the ARCM EVAs while providing a stepping stone to future missions and destinations.





ARCM Space Suit and EVA System Architecture

BACKUP

ACES TO MODIFIED ACES CHANGES