National Aeronautics and Space Administration

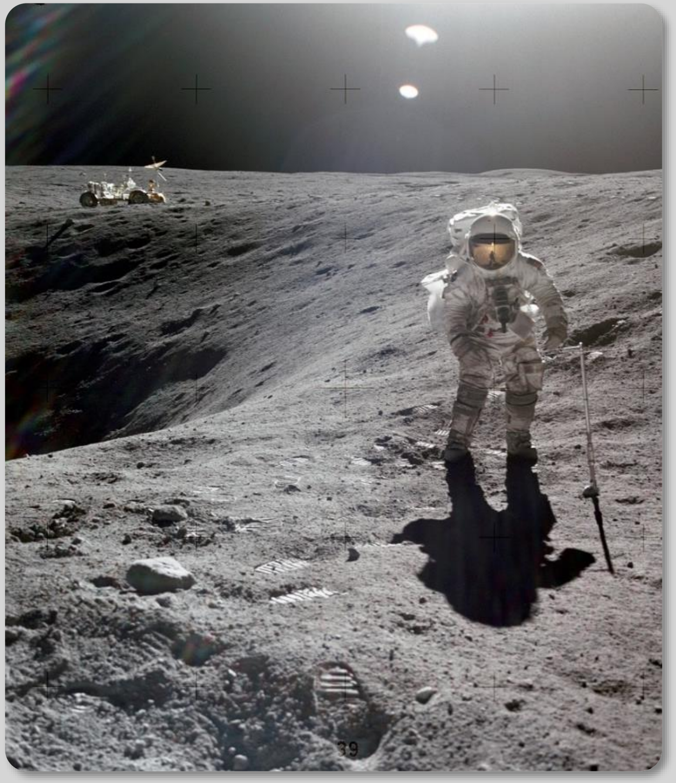
NASA Exploration EVA Integrated HITL Testing and Analogs

David Coan
EVA Operations & Engineering Specialist
NASA EVA Strategic Integration Office (XX)

Revision A
January 31, 2021

Agenda

- Exploration EVA System and Operations
- Exploration EVA Integrated HILT Testing
  - Joint EVA Testing Forum
- NASA Operational & Hardware Testing
- NASA Science Field Analogs
- NASA Mission Analogs
- References
- Questions
- Backup



Exploration EVA System & Operations

Lunar Surface Missions

xEVA System Concept of Operations

Returning to the Moon

Space Policy Directive – 1

December 11, 2017

"Beginning with missions beyond low-Earth orbit, the United States will lead the return of humans to the Moon for long-term exploration and utilization, followed by human missions to Mars and other destinations."

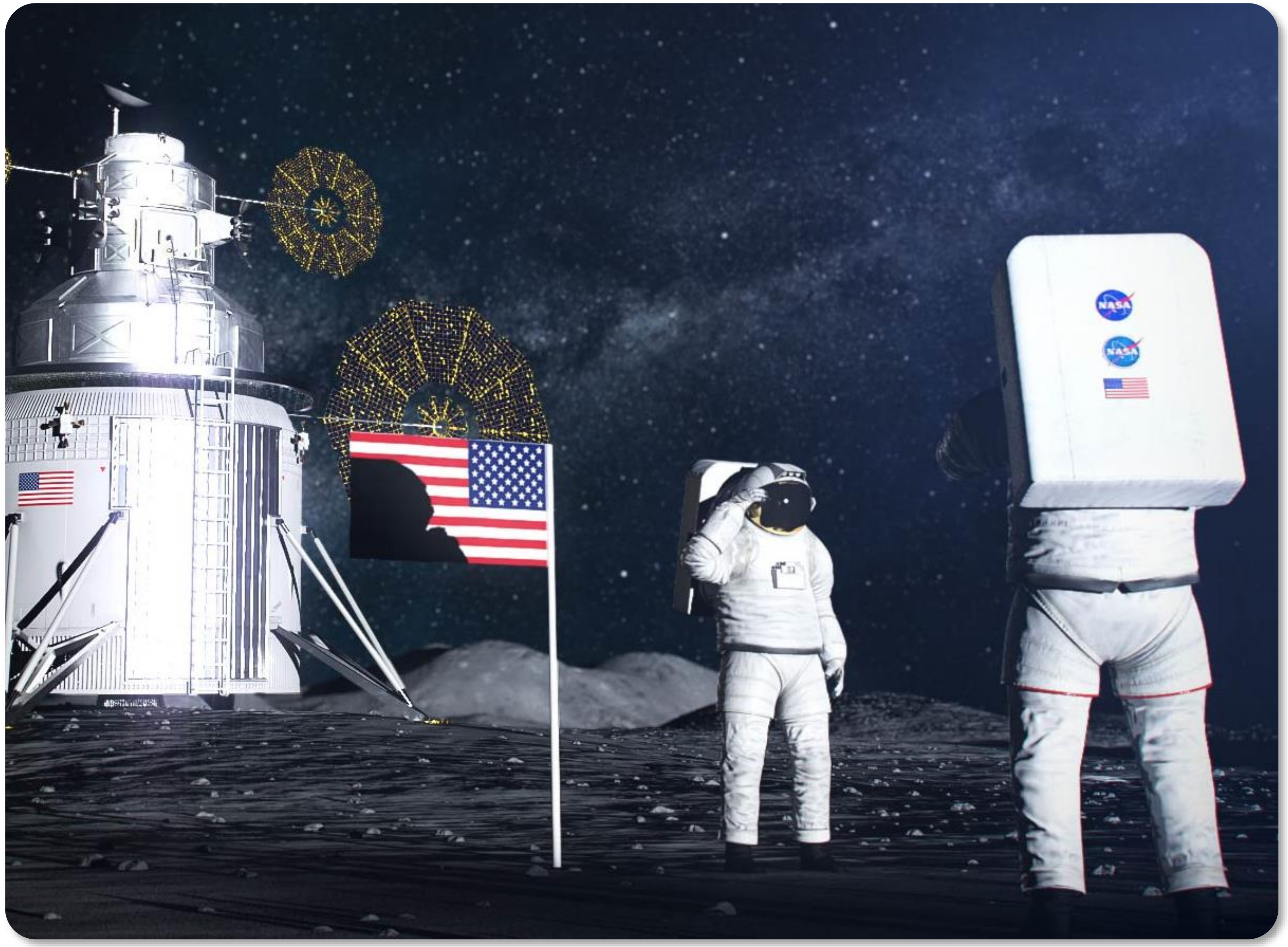
5th Meeting of the National Space Council

March 26, 2019

"Fifty years ago, "one small step for man" became "one giant leap for mankind." But now it's come the time for us to make the next "giant leap" and return American astronauts to the Moon, establish a permanent base there, and develop the technologies to take American astronauts to Mars and beyond."

"…it is the stated policy of this administration and the United States of America to return American astronauts to the Moon within the next five years."

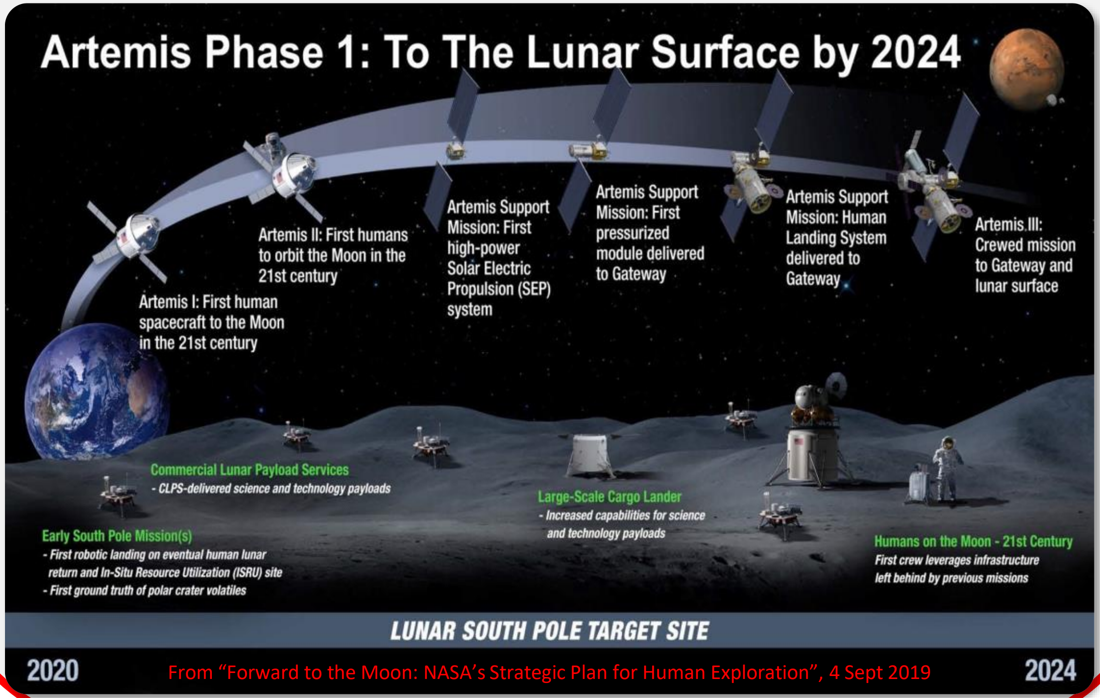
"And today, the National Space Council will recommend that when the first American astronauts return to the lunar surface, that they will take their first steps on the Moon's South Pole."



Artemis Architecture for EVA on Lunar Surface

Artemis Phase 1

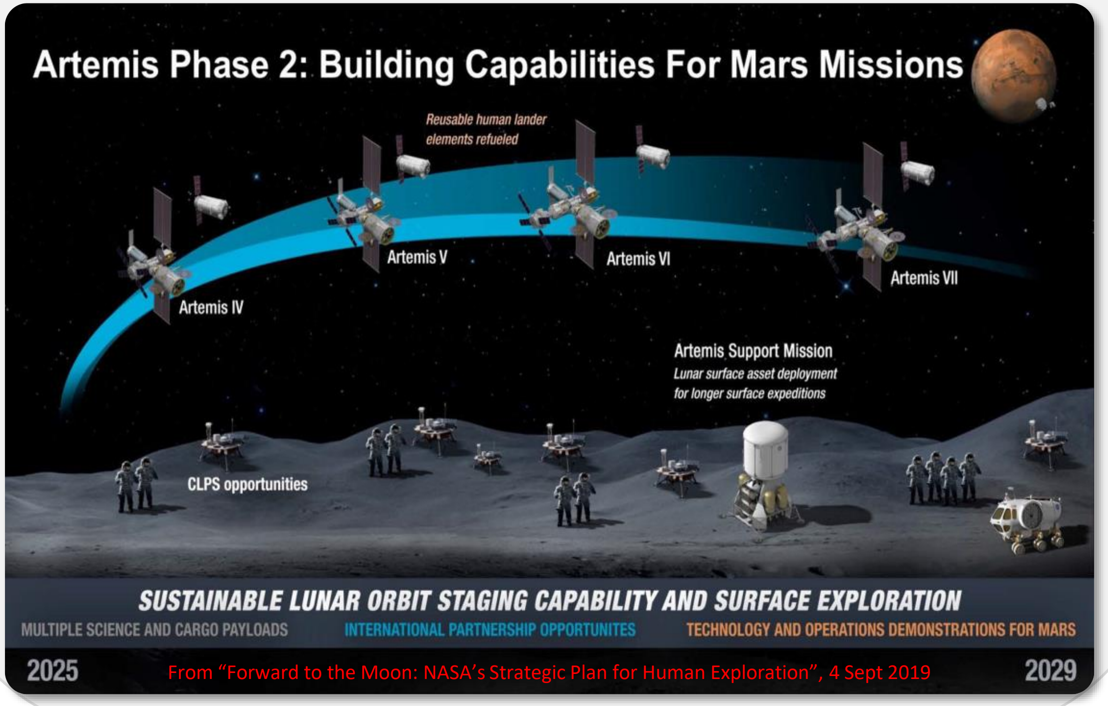
- "Artemis III" initial crewed mission during lunar daylight with two crewmembers landing on the surface
- Surface stay duration: 6.5 days (~156 hr)
- 2 – 5 surface EVAs
- Exploration excursions of up to a 2 km radius away from the lander (TBR)



From "Forward to the Moon: NASA's Strategic Plan for Human Exploration", 4 Sept 2019

Artemis Phase 2

- Includes both longer lunar daylight missions and mission extending through lunar night, with four (or more) crew landing on the surface
  - Longer extended missions during lunar daylight (~14 Earth days)
  - Sustainable long duration missions during lunar day & night (~42 Earth days to 6+ months)
- Exploration excursion distances from lander/habitat increased with use of unpressurized rovers and eventually pressurized rovers



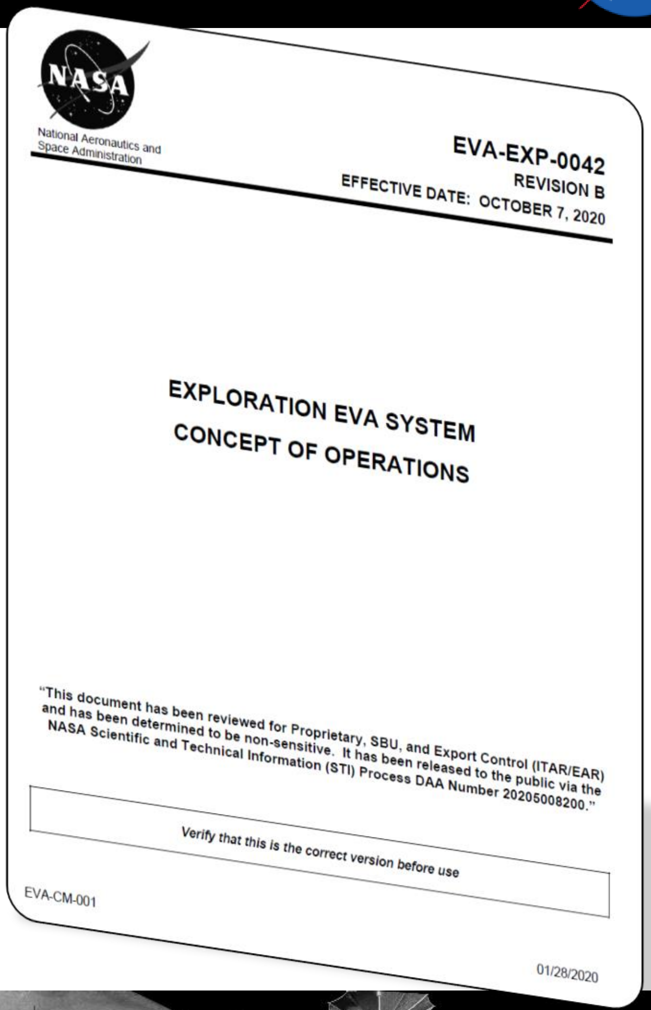
From "Forward to the Moon: NASA's Strategic Plan for Human Exploration", 4 Sept 2019

EVA-EXP-0042, The Exploration EVA System Concept of Operations

The *Exploration EVA System Concept of Operations* (EVA-EXP-0042) captures NASA's current Exploration mission architecture, concepts of operations, stakeholder expectations, and high level definition of the prospective capabilities and interfaces associated with performing an Extravehicular Activity (EVA) utilizing the Exploration EVA (xEVA) System and associated mission systems at all potential destinations.

EVA-EXP-0042 lays out the Artemis lunar surface con ops for EVA, including the science objectives driving the mission and the xEVA System capabilities needed to successfully complete the operations.

The current version of EVA-EXP-0042 can be found here: [Exploration EVA System Concept of Operations]


NASA
National Aeronautics and Space Administration

EVA-EXP-0042
REVISION B
EFFECTIVE DATE: OCTOBER 7, 2020

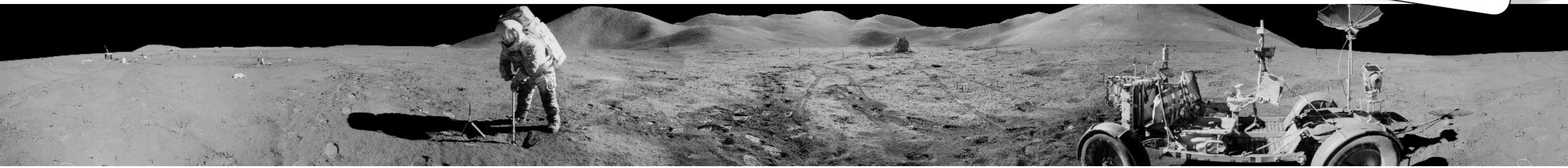
EXPLORATION EVA SYSTEM
CONCEPT OF OPERATIONS

"This document has been reviewed for Proprietary, SBU, and Export Control (ITAR/EAR) and has been determined to be non-sensitive. It has been released to the public via the NASA Scientific and Technical Information (STI) Process DAA Number 20205008200."

Verify that this is the correct version before use

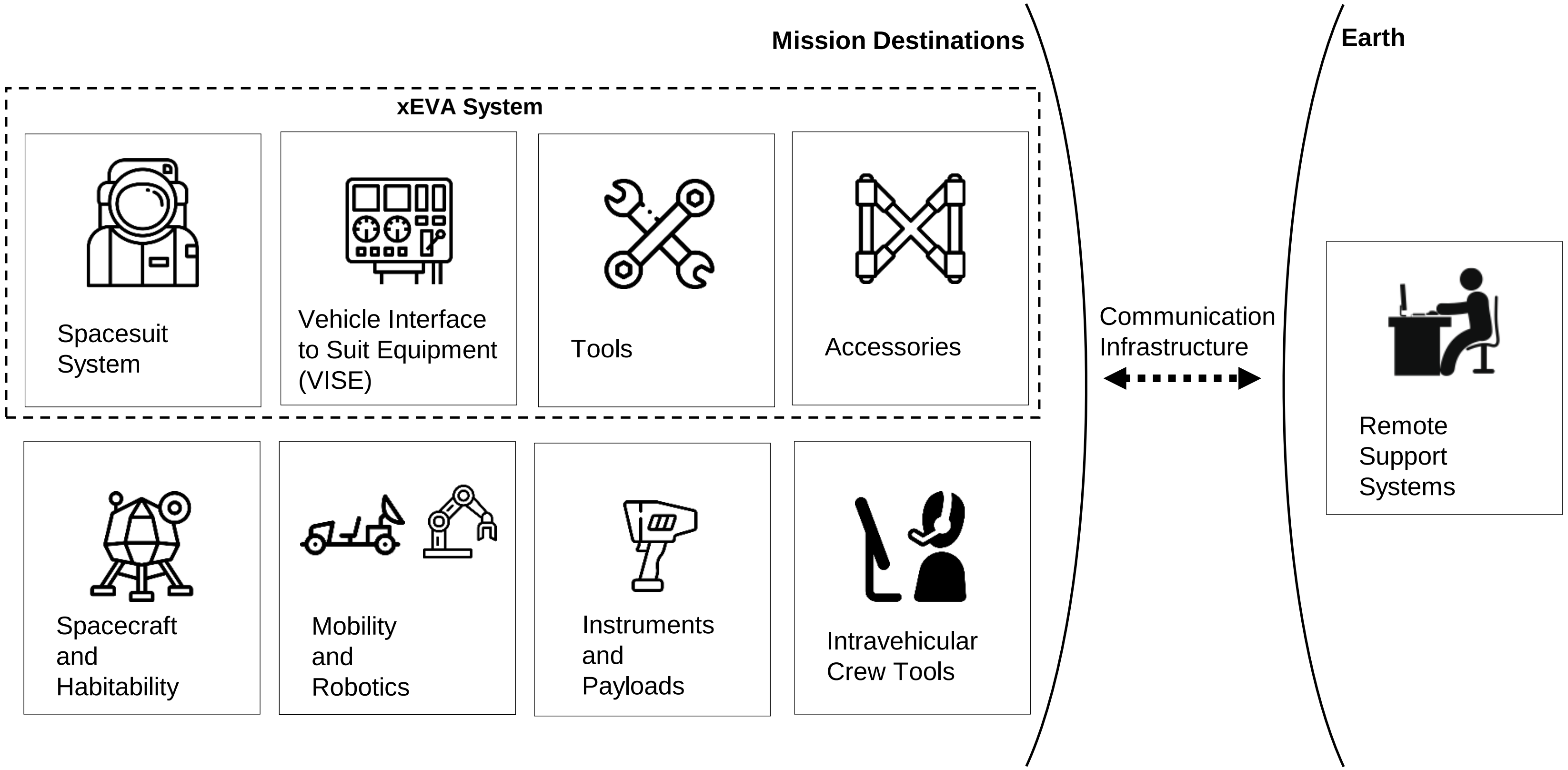
EVA-CM-001

01/28/2020



Mission Systems Utilized for Exploration EVA

Exploration operations will utilize the xEVA System in conjunction with other mission assets



xEVA System Capability Overview

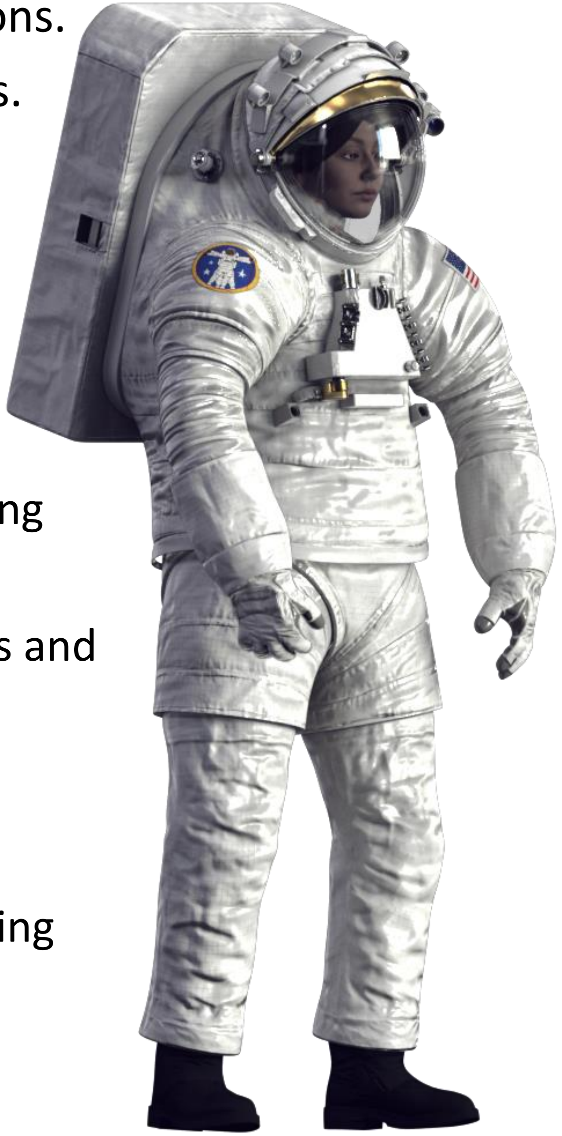
The Exploration EVA (xEVA) System allows crewmembers to conduct excursions outside a habitable vehicle in order to perform exploration, research, construction, servicing, and repair operations.

The xEVA System will enable and help accomplish the science goals for lunar surface missions.

The system includes the xEVA suit, the Exploration Servicing, Performance and Checkout Equipment (xSPCE), and the Flight Support Equipment (FSE).

A few key xEVA surface suit capabilities include, but are not limited to, as follows:

- Rear-entry spacesuit
- Suit pressures range from 0.4 psid to 8.2 psid, with a nominal EVA pressure of 4.3 psid
- Supports EVAs of up to 8 hours in duration (6±2 hours)
- Capability to operate for up to 2 hours of contiguous exposure in a shadowed area, including Permanently Shadowed Regions (PSRs)
- Translation via walking, crawling on hands and knees (short distances with slow controlled motions, scrambling (traversing sloped terrain while using one's hands), and climbing steps and ladders
- Walking up/down/across a slope of up to 20°
  [Note: Apollo 14 walked ~1.45 km from the lander]
- Ambulating on traverses of up to 2 km away from the lander (depending on terrain)
  [Note: Apollo 15 traversed on slopes of ~17°]
- Traversing across regolith and scree, down into and out of craters, volcanic terrains (including lava tubes), and shadowed regions (with the appropriate equipment and assets)
- Performing tasks while standing and non-neutral postures (e.g., kneeling)
- Ability to safely carry equipment, including pushing/pulling a carrier



Exploration Extravehicular Mobility Unit (xEMU)

The Exploration Extravehicular Mobility Unit (xEMU) is the dedicated EVA suit system design for use during lunar flight dynamic phases (if needed), microgravity EVAs, and lunar surface excursions.

Reference the NASA Suit Up site: https://www.nasa.gov/suitup

Human Landing System (HLS)

Select EVA Key Attributes

- Capability to support up to 5 EVAs during the lunar surface stay
- Capability to support EVAs of up to 8 hours (6±2 hours) in duration each
- Appropriate volume to don, doff, and maintain the suits
- A minimum EVA hatch opening of 1.02 x 1.53 m (40x60 in)
- Allowance for performing incapacitated crewmember operations
- A cabin atmosphere that would allow for the shortest prebreathe and require the least amount of crew time (likely 8.2 psi and 34% O_2)
- Layered engineering defense protocols for lunar dust
- Volume and mass launch capacity for returning sample collected
- Margin to bring back EVA equipment from the lunar surface
- Total crew time in space, from Orion launch to landing, is expected to fall within 25-34 days, based on vehicle performance and launch opportunities

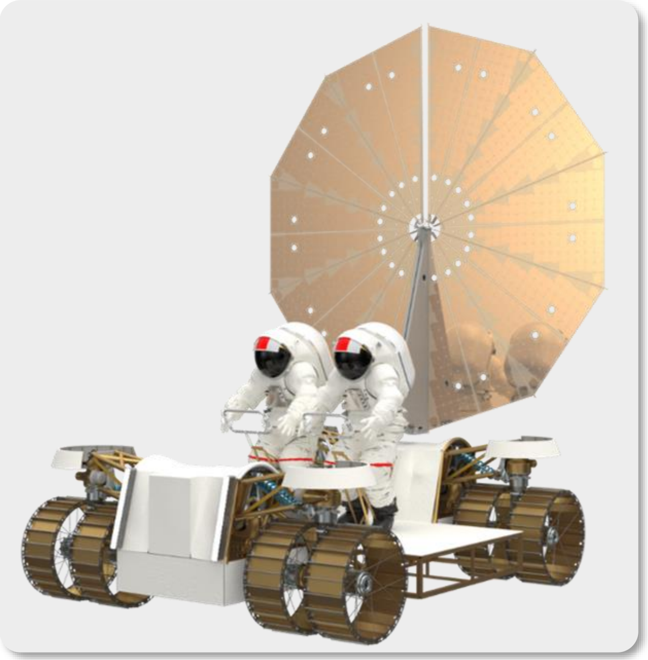
Extended Surface Mobility (Rovers)

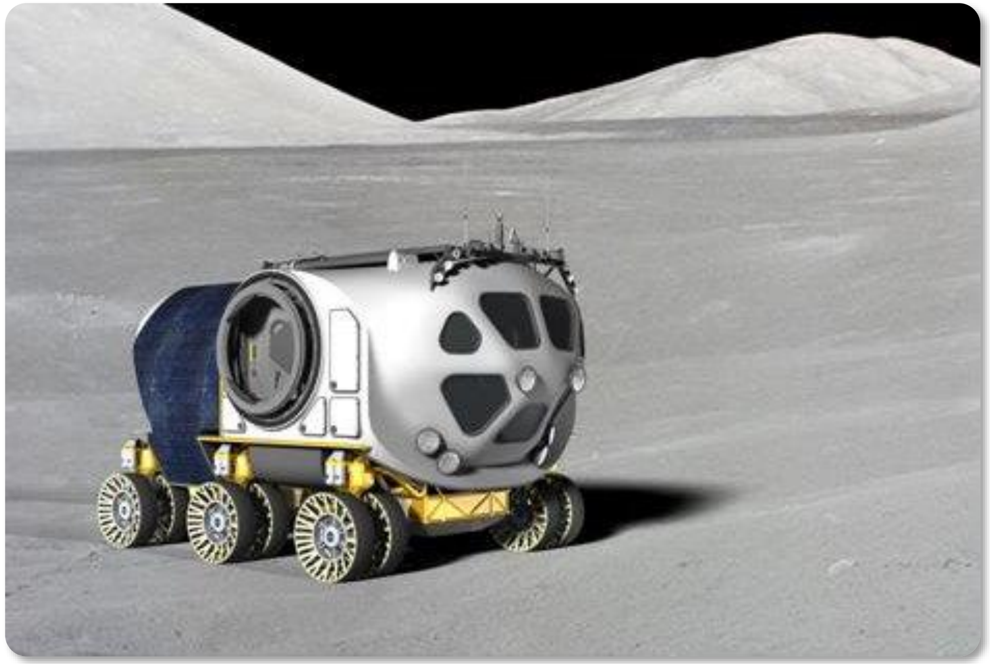
Lunar Terrain Vehicle (LTV)

- The LTV is an unpressurized rover (UPR) that allows for longer traverses within an EVA day, as long as the distance is balanced with suit consumables
- May be included in Phase 1 (TBD)
- Potential for the UPR to have some limited EVA consumables recharge capability (e.g., O_2)

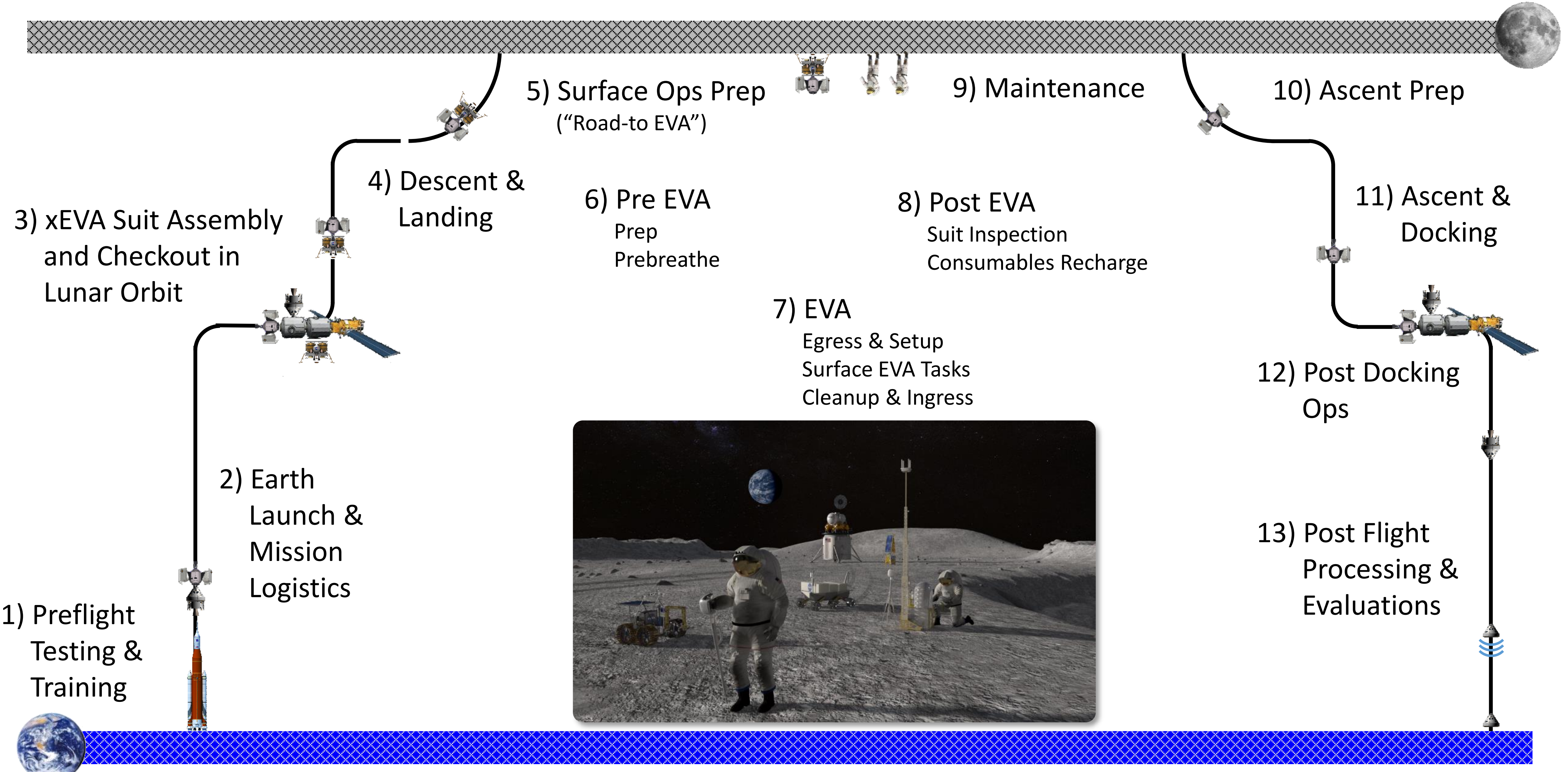
Habitable Mobility Platform (HMP)

- A single pressurized rover allows for multi-day excursions, with distance limited by a fully recharged suit walk back
- Dual pressurized rovers allow for multi-day excursions well beyond an suit walk back constraint, presuming one rover can rescue the other
- Included in Phase 2

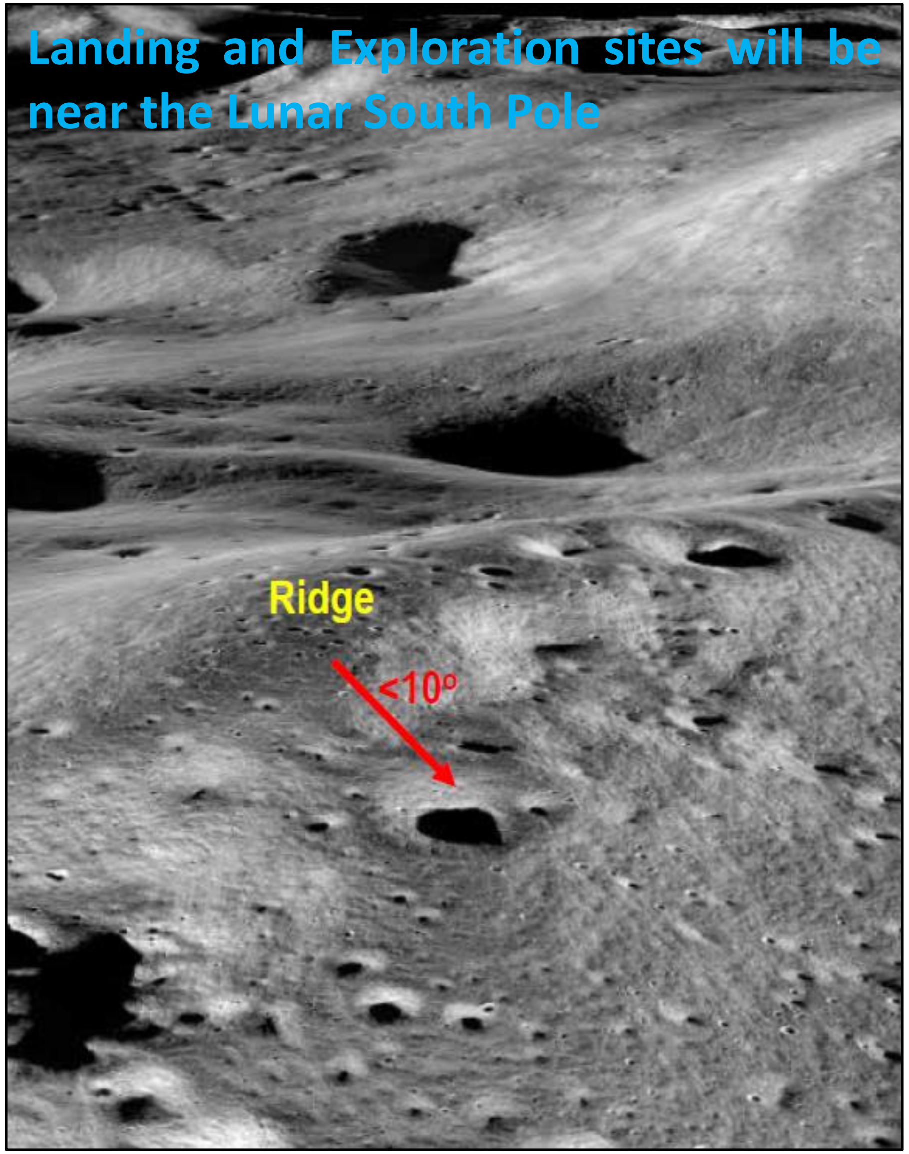


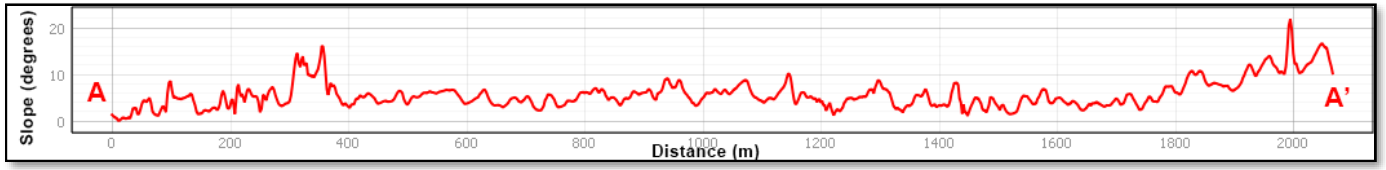


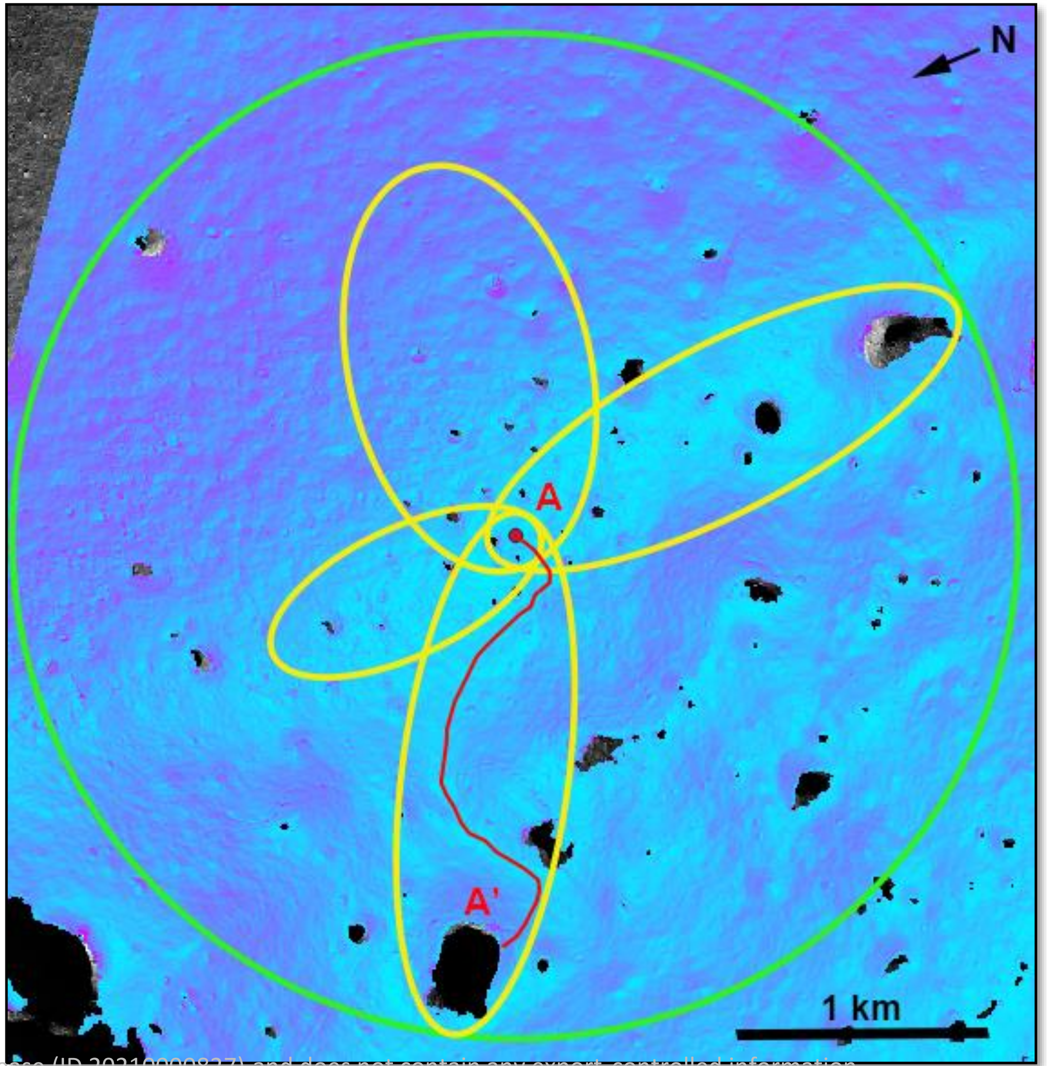
Phases of xEVA Operations



Environment for Notional Landing Site @ Connecting Ridge







Green circle represents a 2 km radius buffer surrounding the highest illuminated point on the ridge

Credit: Sarah Deitrick, Amy Jagge, Andrew Britton

Slope value (°)

0

40

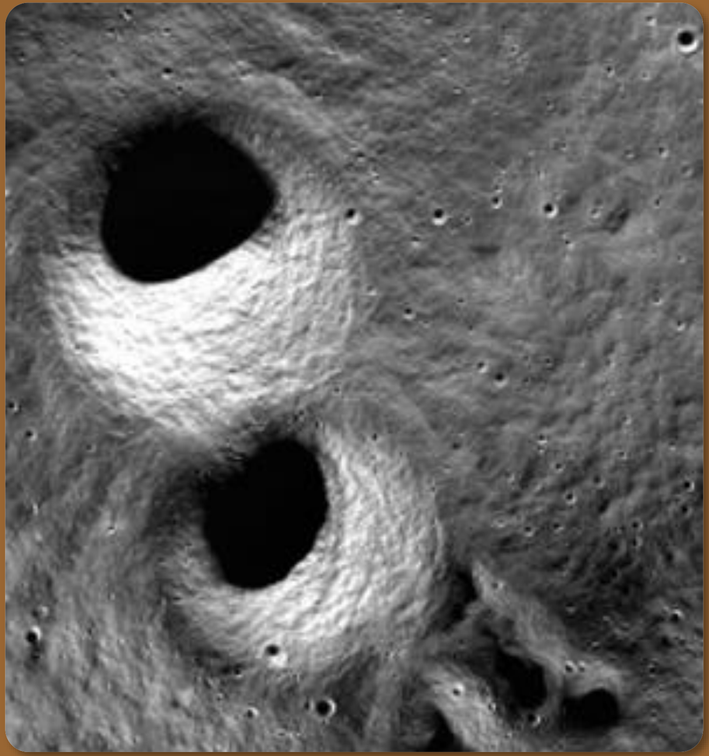
General Science Regions of Interest for Exploration

Craters

- Impact craters, pit craters
- Descend into, perform science tasks, ascend out (with appropriate equip)

Permanently Shadowed Regions

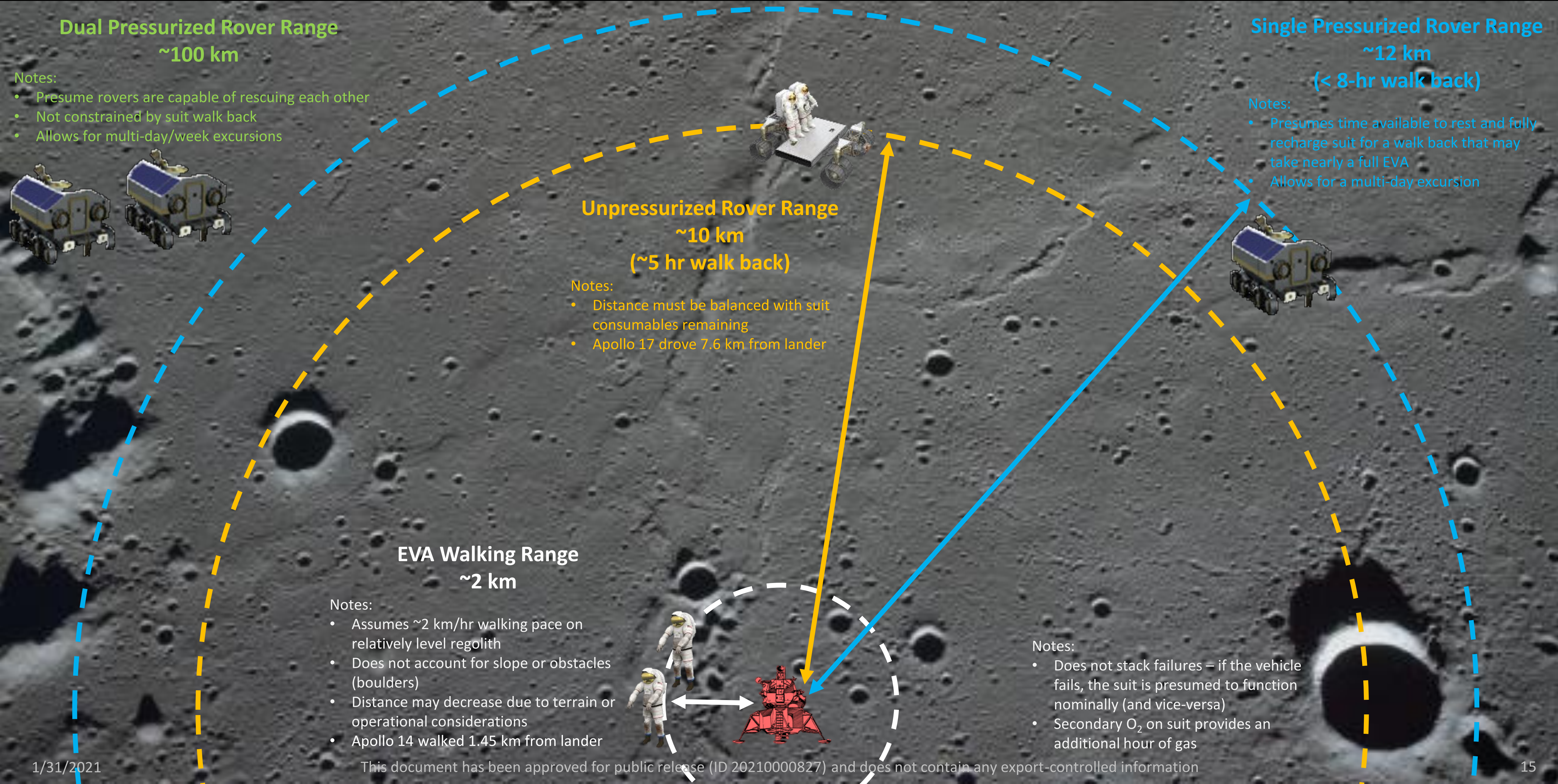
- Acquisition of ice water and volatiles samples
- Goal of 2 hours inside of shadowed regions



Volcanic Terrain

- Ingress into, perform science tasks, exit lava flows and tubes
- May require equipment ancillary to the xEVA suit

Lunar Excursion Ranges



Surface EVA Science Tasks

Observations

- Macro-scale (regional) context
- Micro-scale (local) context
- Verbal descriptions
- Imagery

Data Collection

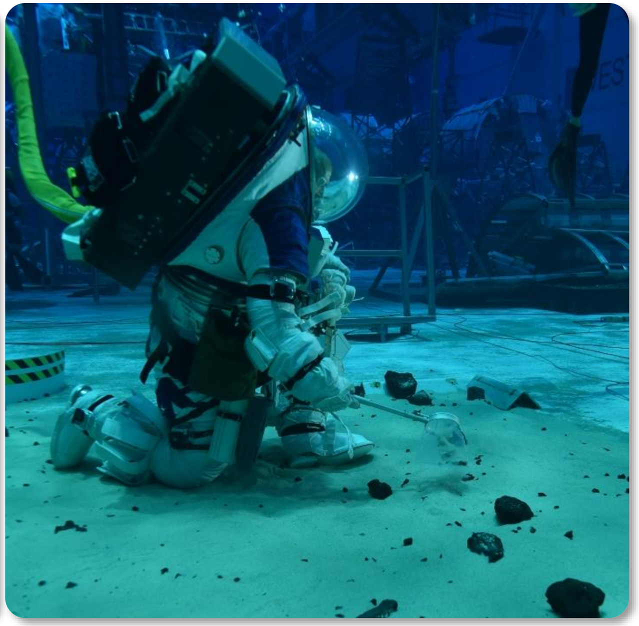
- Handheld (*in-situ*) instrument measurements
- Geotechnical measurements
- Science payload deployment

Rock Sample Acquisition

- **Float**: rocks that are loosely adhered to the surface [Tongs / Rake]
- **Chip**: piece of rock forcibly removed from a larger rock [Hammer / Chisel]
- **Core**: cylindrical samples of a rock [Core Drill and Bit]

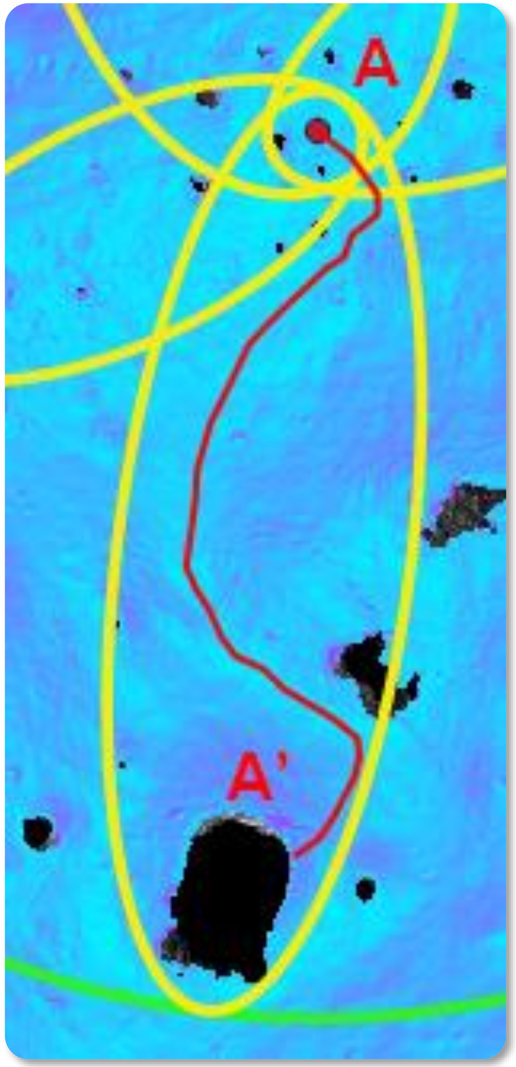
Regolith Sample Acquisition

- **Bulk**: representative loose surface material [Scoop]
- **Core**: cylindrical sample of regolith at depth [Drive Tube / Drill]
- **Surface**: undisturbed material from the top ~1mm surface [Surface Sampler]



Notional Design Reference EVA for xEVA Con Ops Development

	EV1	EV2
Egress & Setup	• Switch from vehicle power to suit battery power • Open hatch and egress • Descend to surface • Configure equipment transport system and tools on suit	• Switch from vehicle power to suit battery power • Open hatch and egress • Transfer any tools brought inside HLS to the surface • Descend to surface
Traverse to EB	• Walk downslope towards PSR at located A’ • Radial traverse distance is ~1 km, slopes range up to ~16°	• Walk downslope towards PSR at located A’ • Radial traverse distance is ~1 km, slopes range up to ~16°
Sampling from EB Deploy Instrument	• Conduct context observations, with imagery and verbal descriptions • Acquire sample as directed by MCC Science Team	• Set up sampling tools from transport system • Deploy geophysics instrument
Traverse to Crater	• Walk downslope towards PSR at located A’, begin descent into crater • Radial traverse distance is ~1.5 km, slopes range up to ~12°	• Walk downslope towards PSR at located A’, begin descent into crater • Radial traverse distance is ~1.5 km, slopes range up to ~12°
Sampling in Crater Deploy Station	• Conduct context observations and plan route into PSR • Deploy environment monitoring station	• Conduct context observations, with imagery and verbal descriptions • Acquire sample as directed by MCC Science Team • Ready tools for sampling in PSR [e.g., core drill]
Traverse into PSR	• Walk down into PSR at located A’ • Radial traverse distance is ~2 km, slopes range up to ~20° • Starts 2-hour thermal clock	• Walk down into PSR at located A’ • Radial traverse distance is ~2 km, slopes range up to ~20° • Starts 2-hour thermal clock
Sampling from PSR	• Conduct context observations, with imagery and verbal descriptions • Acquire sample as directed by MCC Science Team [e.g., core]	• Conduct context observations, with imagery and verbal descriptions • Acquire sample as directed by MCC Science Team [e.g., core]
Traverse to HLS	• Walk back upslope towards the HLS at located A • Radial traverse distance is ~2 km, slopes range up to ~20°	• Walk back upslope towards the HLS at located A • Radial traverse distance is ~2 km, slopes range up to ~20°
Maintenance	• Deploy comm antenna • Align antenna	• Route and mate power cables to comm antenna
Cleanup & Ingress	• Stow tools and equipment • Transfer science samples up to lander hatch • Conduct dust mitigation • Ascend to lander hatch and ingress • Attach servicing umbilcals • Close hatch and repress	• Stow tools and equipment • Conduct dust mitigation • Ascend to lander hatch • Transfer science samples up to lander hatch • Ingress lander and attach servicing umbilcals



Note: Details on EVA Timelines can be found in the “Preparation for Lunar Training and Execution”

NOTE: All EVAs are conceptual/notional only and are strictly for development of the xEVA system con ops, and not indicative of any actual flight plan or official mission profile

Exploration EVA Integrated HITL Testing

Joint EVA Testing Forum

Vision & Goals for NASA Integrated HITL Testing and Analogs

Integrated Operational Human-in-the-Loop Testing for Space Exploration

Develop and execute high-fidelity operational exploration analog missions that closely mimic the space environment of interest, thus developing and testing concepts that enable Exploration missions

Integrate tests and provide synergy across a broad portfolio of NASA-relevant exploration-focused work, including integrated operational tests

Enable the evolution of human space exploration through the integration of science, engineering, and operations

Advance the creation of the Tools, Techniques, Technologies, and Training needed to successfully execute missions to the Moon and Mars

Inform the design of the Exploration EVA System and xEVA Concept of Operations

Joint EVA Testing Forum: The Who, What, Where, Why, and How

The Joint EVA Testing Forum strives to facilitate development of the xEVA System and enable Exploration EVA

WHY

In the course of developing the systems and operations necessary for successful Artemis missions, a variety of enterprises and efforts are underway that are integral or related to the xEVA System.

The Joint EVA Testing Forum (JETF) serves to synchronize objectives and testing associated with Exploration EVA and the xEVA System.

With limited resources and hardware available for testing, the JETF will be a focal point to identify and track all testing requirements/requests and resources needed to execute those respective objectives.

The JETF provides EVA Office direction and priorities for testing related to the xEVA System and Concept of Operations.

The JETF ultimately strives to enable the evolution of human space exploration and successful execution of missions to the Moon and Mars through facilitating the development and evaluation of systems and operations associated with Exploration EVA, with a focus on the spacesuit, vehicle interfaces, tools, and accessories that comprise the xEVA System.

Joint EVA Testing Forum: The Who, What, Where, Why, and How

The JETF serves as the EVA Office mechanism to facilitate all xEVA-related testing and analog missions

WHO

The JETF channels EVA Office input and works in close integration with a multitude of groups and teams:

- EVA community groups
    - EVA Office
    - Engineering
    - Flight Operations
    - Science
    - Human Health & Performance
- Test facilities
- Exploration domains
- Artemis Program
- Human Landing System
- Surface Mobility
- Other NASA teams...

WHAT

The JETF acts as the active body regulating testing for the xEVA System and the xEVA Con Ops

Provides EVA Office direction and priorities

JETF focuses on tests associated with Exploration EVA:

- xEVA gaps and risks
- xEVA requirements
- Test objectives
- Test series and events (days/runs)
- Ground testing and training hardware
- Etc…

WHERE

Activities span a variety of test environments:

- Terrestrial gravity (1G)
- Tabletop
- Offloaded systems (ARGOS)
- Neutral Buoyancy Lab (NBL)
- Open water (NEEMO, NXT)
- Reduced gravity
- Relevant geological areas and field deployed tests (rock yard, D-RATS, etc.)
- eXtended Reality (XR, VR, HR, SHyRE)
- Etc…

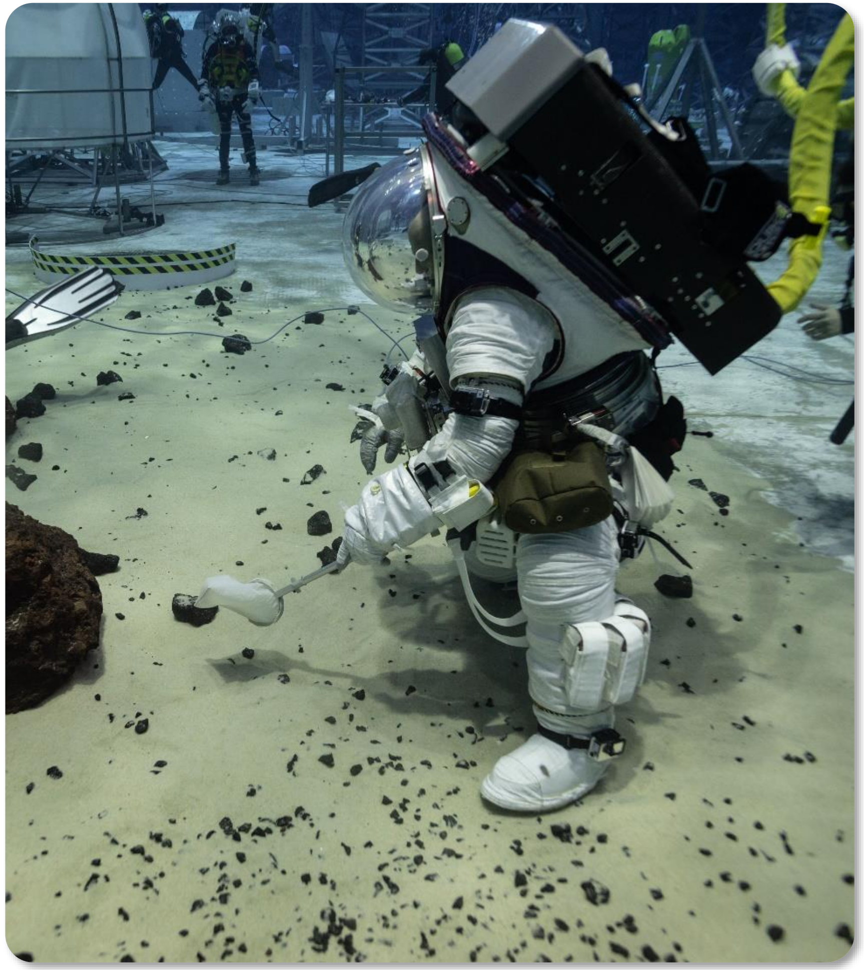
HOW

Tests involve a number of different types of outfitting for test subjects:

- Shirt-sleeve
- Mockup suits (Hollywood suit)
- Dive systems and helmets
- Atmospheric Diving Suits
- Spacesuits (Z2, xEMU)
- Vehicle mockups (HLS, Orion, LTV)
- Etc…

xEVA Ground Testing and Training Hardware

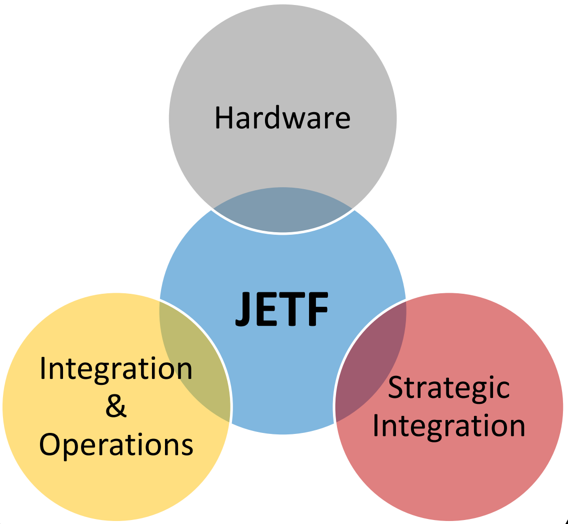
- The xEVA Ground Hardware aspect of the forum/working group will be a focal point to identify and track all testing requirements/requests and resources needed to execute those respective objectives
- The main objectives include:
  - Identify all required h/w requests & rationale (Suit, VISE, Tools)
    - Track their progress from delivery to completion
  - Prioritize requests and identify dependencies and risks
  - Highlight “pinch points” and “challenges” and raise risk to appropriate panel and/or board
- Integrate appropriate xEVA POCs for request for h/w and facility support
- Provide TBD interval status progress at the XX and ISS boards and panels as needed
- Specific hardware issues will still be worked through the responsible boards/panels
- Track ground testing hardware build plans for xEMU, VISE, and Tools



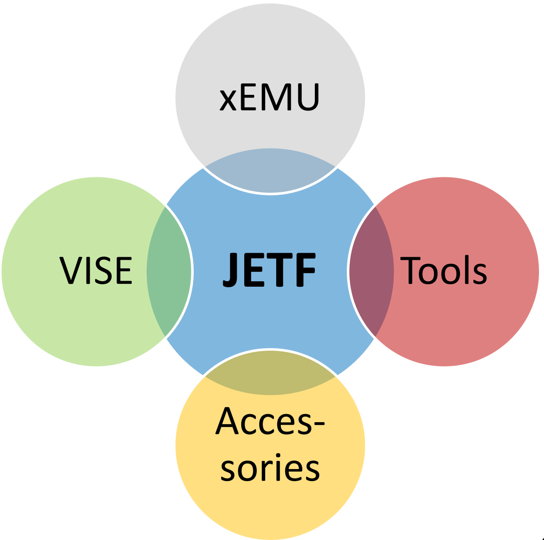
JETF Integrates Various EVA-Related Integrated HITL Testing Efforts

The JETF facilitates integrated HITL testing associated with Exploration EVA to ensure development milestones

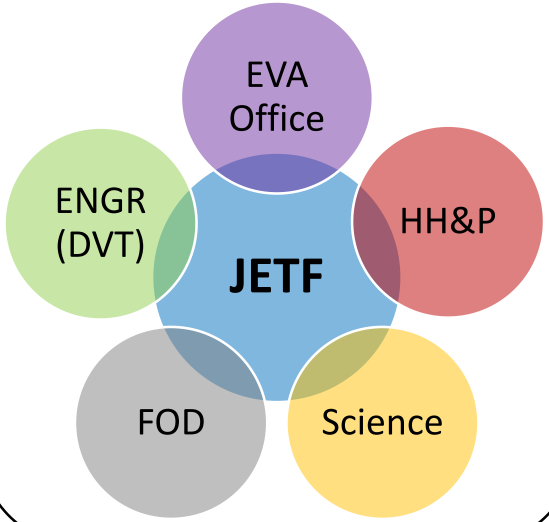
Linking Efforts within the EVA Office



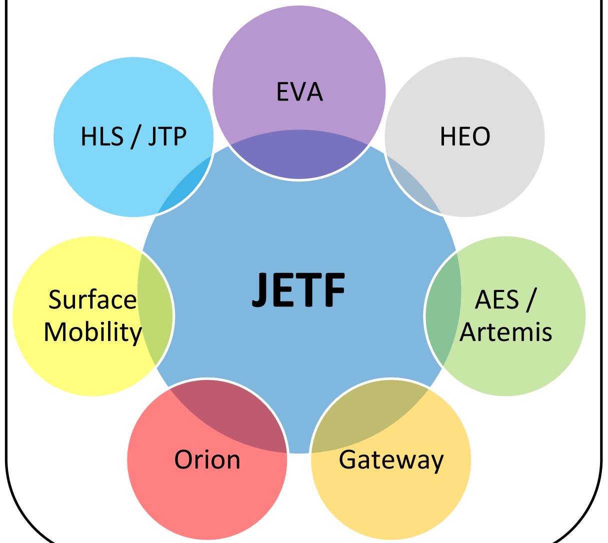
Aligning Testing of the xEVA System



Integrating the EVA Community and Testing Stakeholders



Crosscutting EVA-Related Testing with Exploration Domains



xEVA Requirements	EVA DVT
xEVA Con Ops	Operational Testing
xEVA Gaps/Risks	HH&P Testing

Ensuring Testing Process and Priorities

(Test Objectives → Test Series → Test Events)

Facilitating Ground Hardware Resources

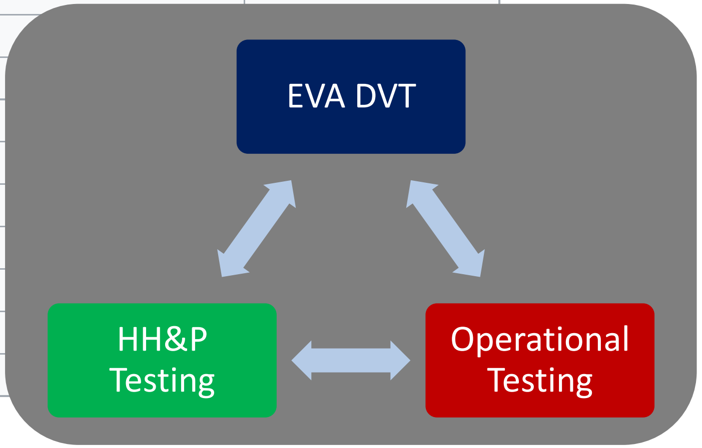
xEVA System Develop-ment Milestones

JETF Regulates xEVA System Integrated HITL Testing

The JETF acts as the EVA active body regulating integrated HITL testing for the xEVA System

Draft [edit | edit source]

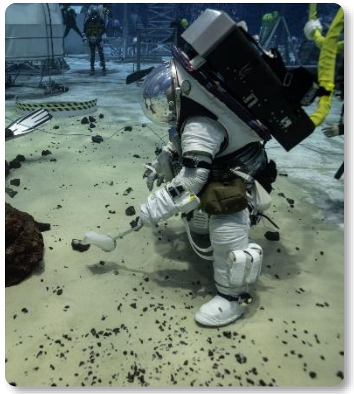
	Test series start date	Test series end date
Road to CDR Suited xEVA Tools Test Series 1	1 February 2021	30 June 2022
ARGOS MockPLSS & Gimbal Testing	9 February 2021	17 February 2021
Dynetics - HITL Medium Fi mockup evaluations	22 February 2021	26 February 2021
NBL xEVA Lunar DAVD Test Series 2	23 February 2021	26 February 2021
XEVA Microgravity Hatch and Airlock Ops Test Series 1		
Incapacitated Crew Rescue Conops		
SHyRE D1974 Flow Extended Series		
JARVIS Camera Operations Baseline Series		
APACHE PACES Shirt Sleeve VR Test Series 1		
JARVIS VR Camera Operations Baseline Series		
LTV, EVA, Lighting, and Navigation Simulation		
Contingency Crew Transfer		
Metabolic Rate Task Characterization Study		
NEEMO 24		



Proposed or Supported [edit | edit source]

	Test series status	Test series start date	Test series end date
Engineering Development Runs for Future ARGOS Studies	Supported	16 November 2020	2 December 2020
MKIII Mock-up Suit Mobility Evaluation	Proposed	25 January 2021	29 January 2021
2020 Surface Sampling Test Series	Proposed	1 April 2021	30 June 2021
NBL EMU Helmet-Mounted Display Ground Testing	Supported		
HLS Lo-Fi Mockup Evaluations	Supported		
DVT Fitchecks	Supported		

JETF facilitates and manages objectives and tests, which are sometimes redundant and competing, that require the use of the same limited ground hardware resources in order to meet the required system development and testing milestones




Analog Testing Development & Integration Themes (4-T's)

TOOLS

EVA Tools & Systems
- Handheld Tools for Building & Repair
- **Handheld Tools for Science**
- Power Tools
- **Tool Transport & Stowage Systems**
- Mobility & Compatibility Requirements
- Crew Rescue Systems

Instrumentation
- In-Situ Analytical Instruments
- Instrument Packages & Payloads

Sample Collection
- **Sample Acquisition & Handling**
- Contamination Mitigation
- **Transportation & Stowage**

TECHNIQUES

Exploration Operations
- **Procedure Development**
- **Communication Methods & Protocols**
- **Data Visualization & Management**
- Timeline Tracking & Scheduling

EVA Operations
- **EVA Concepts of Operations**
- **Advanced EVA Capabilities**

Science Operations
- Traverse Planning
- Science Decision Making Protocols
- **Sample Acquisition & Documentation**

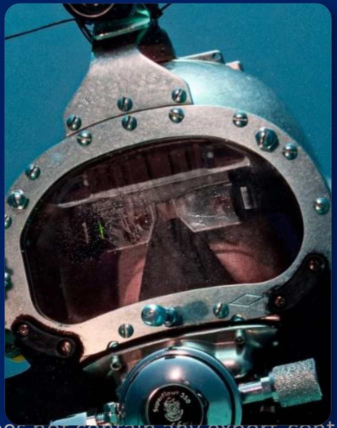
Robotic Operations
- Autonomous vs Crew Controlled
- Human-Robotic Interfaces

TECHNOLOGIES

Emerging Technologies
- **Informatics** & Intelligent Systems
- Virtual/Hybrid Reality Environments
- Medical & Human Performance
- EVA Support Systems & IV Workstation
- Advanced Spacesuit Developments

Technology Collaborations
- Commercial Connections
- University & Institute Collaborations
- **Other Government Agencies Links**
- International Partnerships

Innovations Incubator
- **Rapid Testing & Development**
- Idea Generation & Gap Recognition



TRAINING

Cross-Disciplinary Training
- **Involvement of Multiple Disciplines**
- **Sharing Between Diverse Skill Sets**
- Extensive Expertise & Experiences

Training Opportunities
- **Exploration Training**
- **Science Training**
- EVA & Space Suit Training
- **Tool & System Training**
- Student Opportunities

Astronaut Crew Training
- Expeditionary Opportunities
- Leadership Opportunities
- **Mission Realistic Environments**

Environments for Tests and Simulations

AQUATIC

Neutral Buoyancy Laboratory

Aquarius Reef Base (NEEMO)

ESA's Neutral Buoyancy Facility

TERRESTRIAL

Operational & Science Sites

Field Training Location

Extreme Environments

LABORATORY

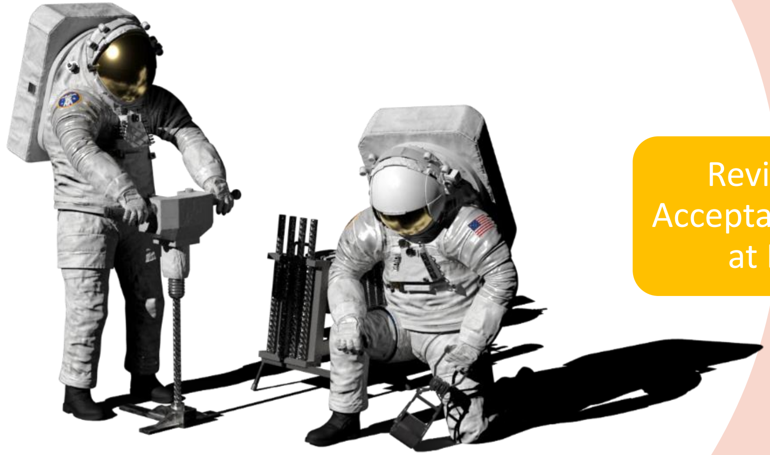
Active Response Gravity Offload System (ARGOS)

Virtual Reality & Hybrid Reality Laboratories

Mockups & International Space Station

The Process: The Circle of Life for Test Objectives Involving xEVA

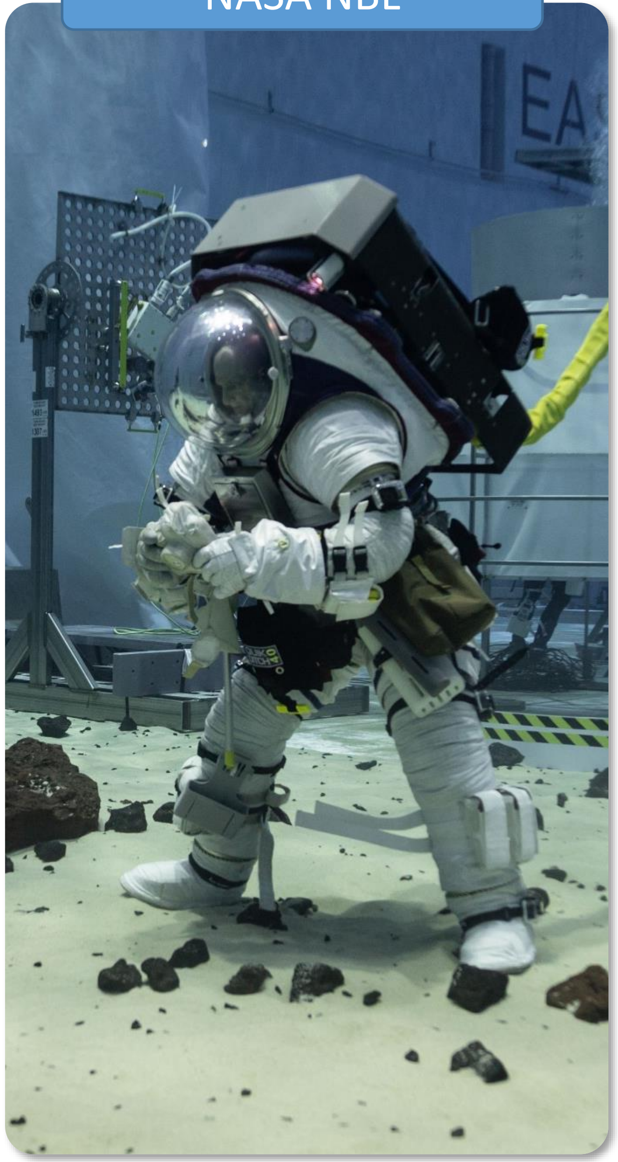
- EVA Gap/Risk
- Identification and Documentation of Gap
- Review and Acceptance of Gap at EEWG
- Creating Test Objectives Linked to Gaps
- Executing Test Series/Event
- Processing Results Post-Test
- Generation of Gap Closure Rationale
- Review of Gap Closure at EEWG



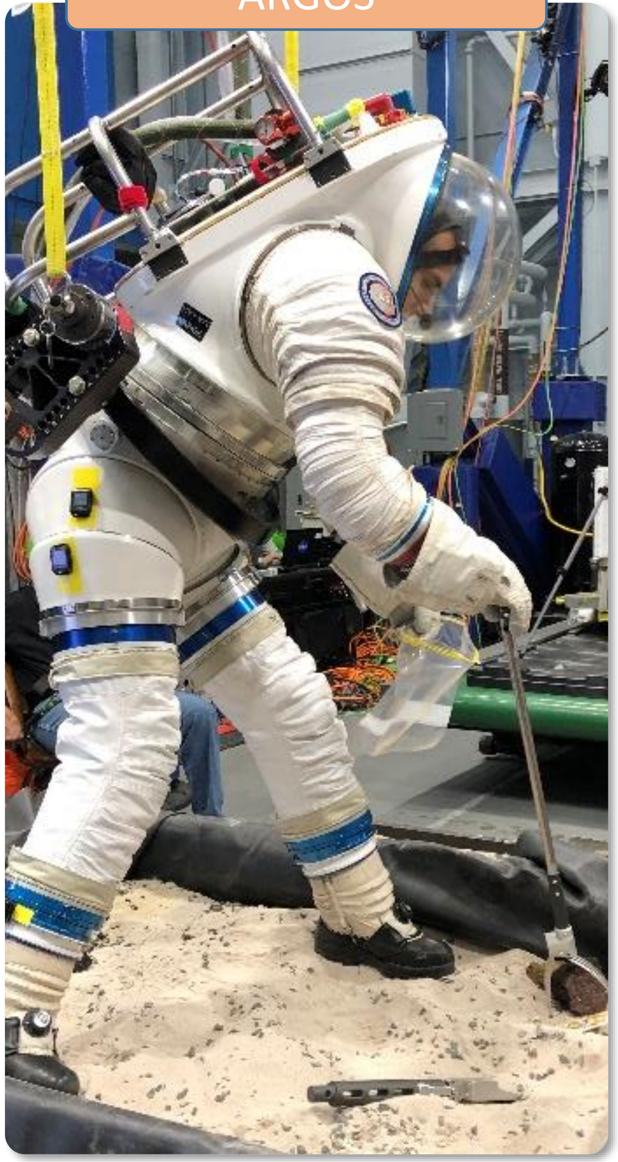
Examples of Some Recent xEVA-Related HITL Testing

JSC Rock Yard

NASA NBL



ARGOS



NEEMO

NASA Operational & Hardware Testing

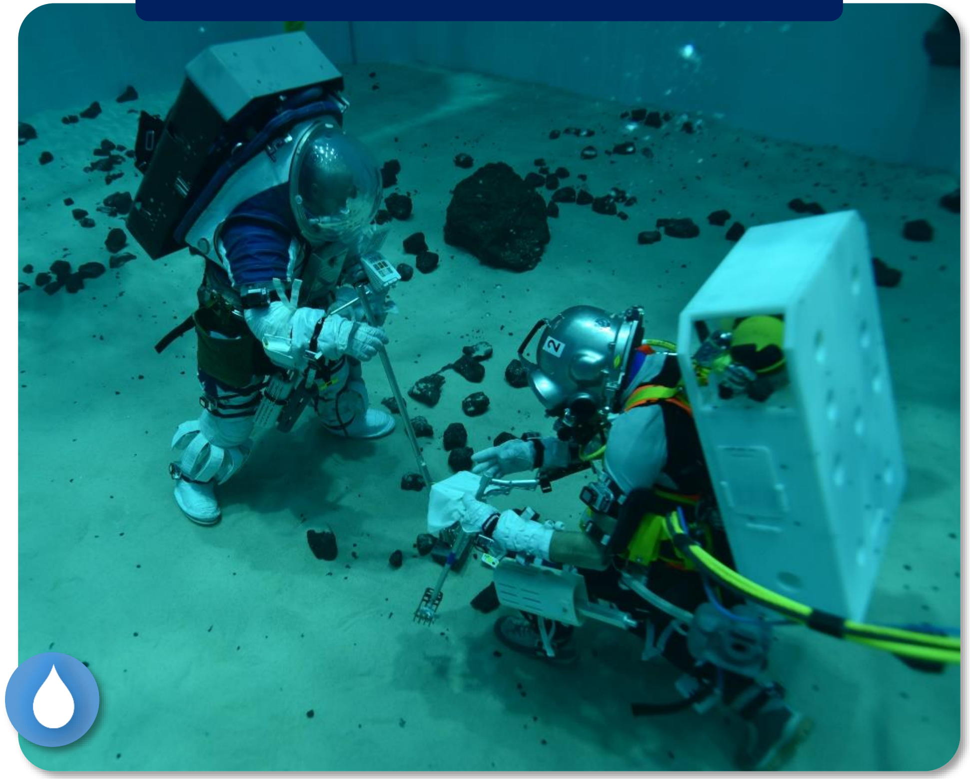
Integrated Human-in-the-Loop Testing for EVA and Exploration

Neutral Buoyancy Laboratory (NBL)

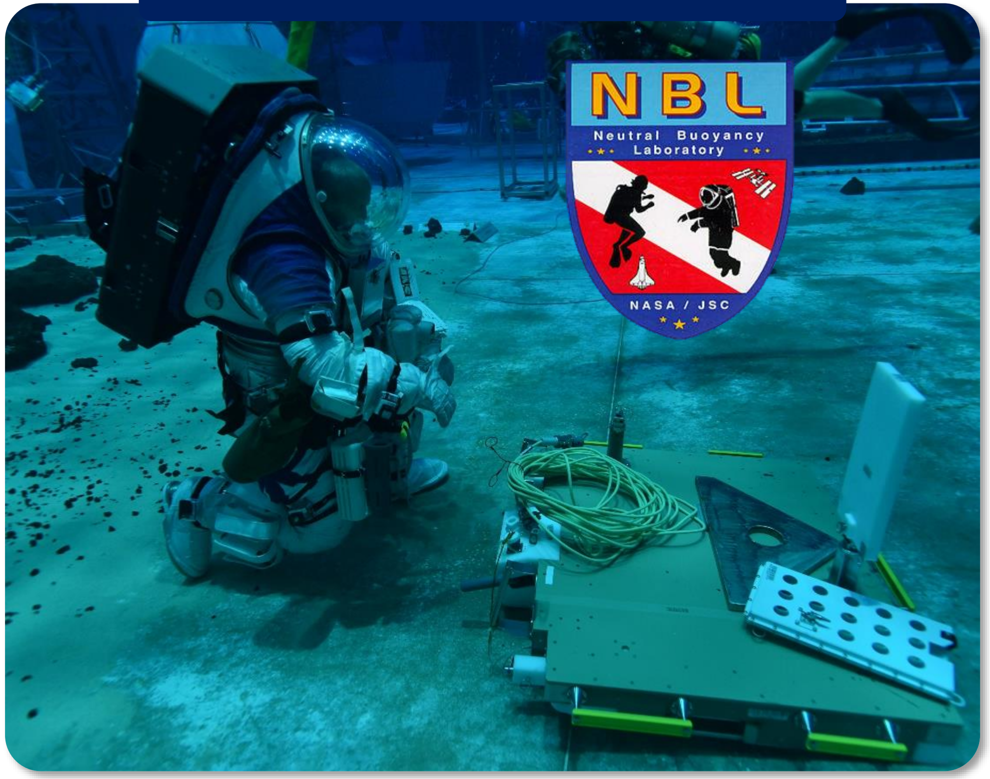
The NBL accomplishes simulation of a reduced gravity environment using underwater neutral buoyancy techniques.

- Allows for both micro-gravity and partial-gravity EVA testing and training
- Incorporates analog areas for geology tasks and capabilities for technology development (e.g., informatics)
- Evaluations are conducted with surface supplied diving helmets and high-fidelity pressurized spacesuits
- Incorporates xEVA equipment and con ops

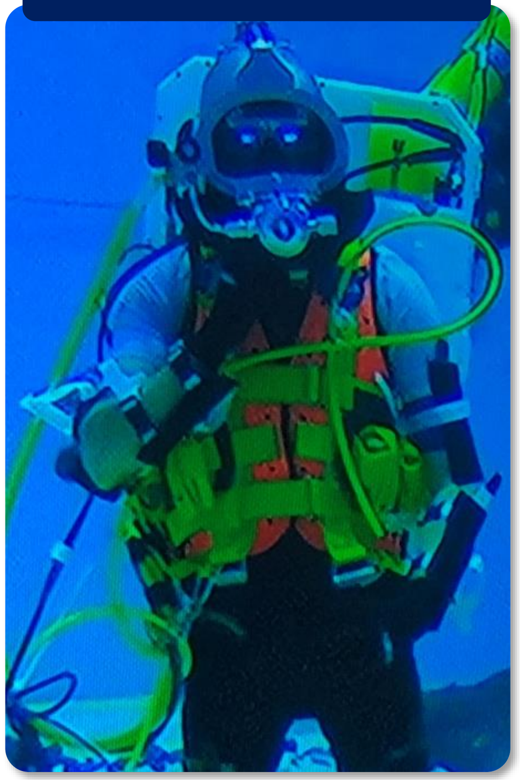
SCIENCE SAMPLING TASKS



ENGINEERING TASKS



TECH DEVELOPMENT

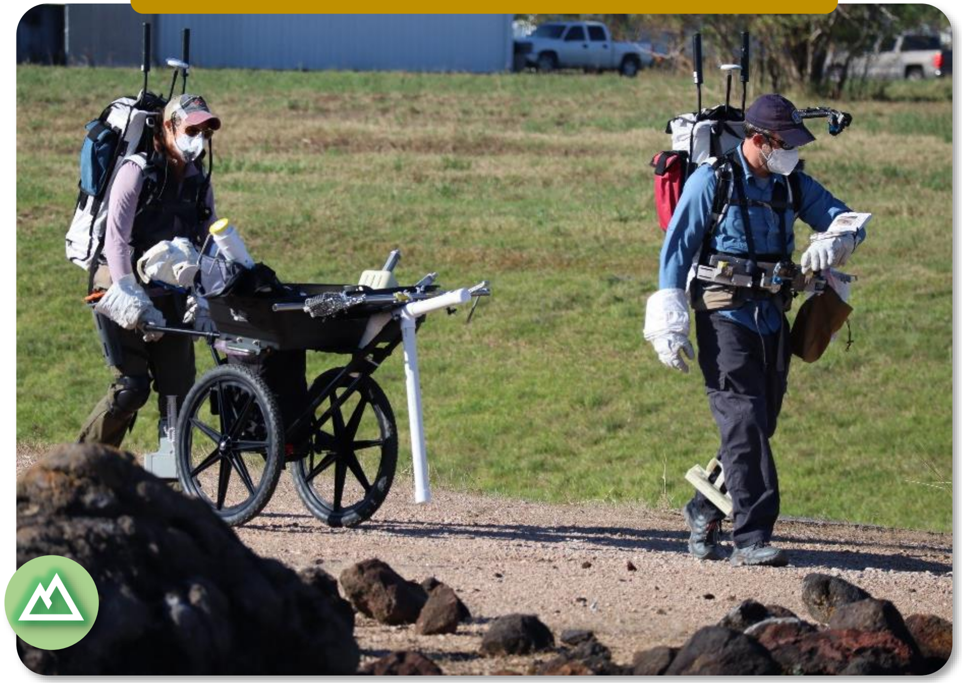


JSC Rock Yard

The JSC Rock Yard allows for smaller, leaner evaluations of science sampling tools, tool and sample management, and operations for conducting science during EVA excursions on lunar surface missions.

- High fidelity tool and hardware prototypes can be tested quickly
- Operational timelines and procedures can be exercised and evaluated
- Allows for the inclusion of informatics capabilities and technology development

TOOL & SAMPLE MANAGEMENT



ROCK SAMPLING TOOLS & TASKS

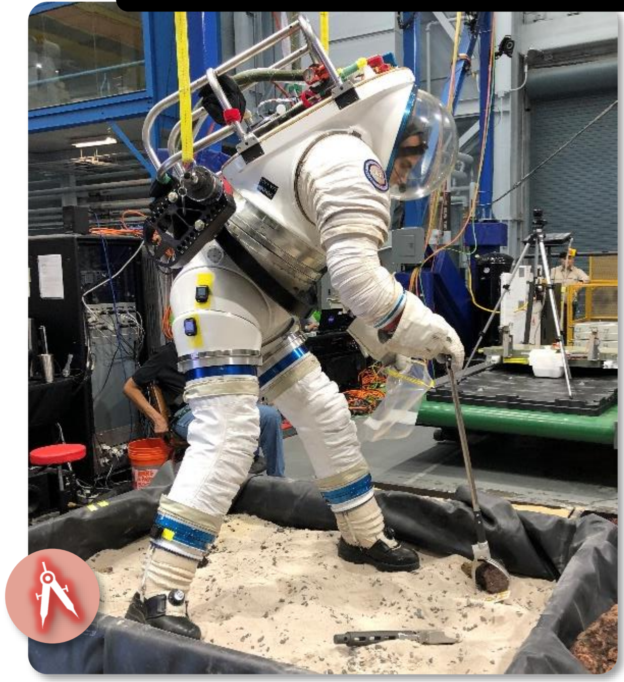
REGOLITH SAMPLING TOOLS

Active Response Gravity Offload System (ARGOS)

ARGOS is designed to simulate reduced gravity environments, such as Lunar, Martian, or microgravity, using a system similar to an overhead bridge crane with an inline load cell to continuously offload of a portion of a human or robotic payload's weight during all dynamic motions.

- High fidelity tool and hardware prototypes can be tested efficiently
- Supports high-fidelity pressurized spacesuits

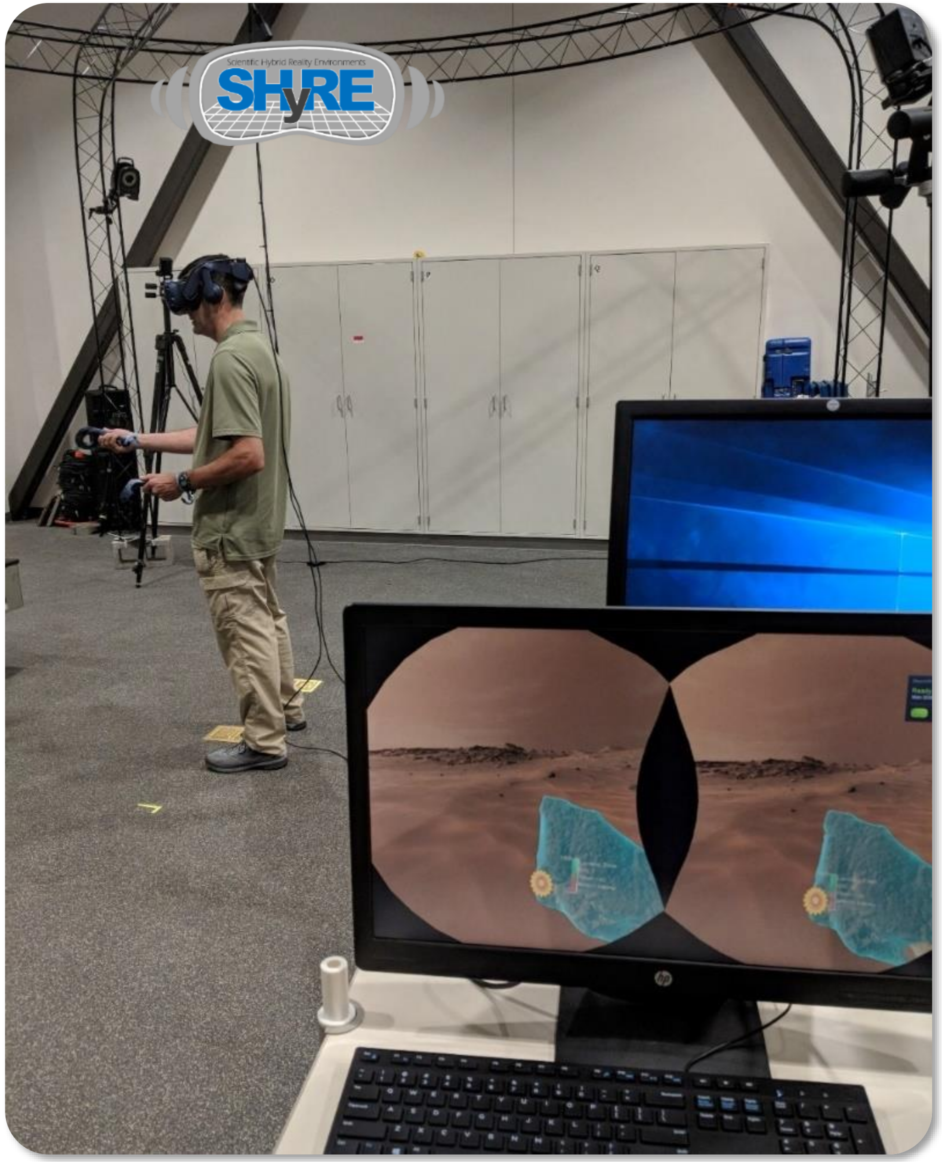
ROCK SAMPLING TOOLS & TASKS



REGOLITH SAMPLING

ENGINEERING TASKS

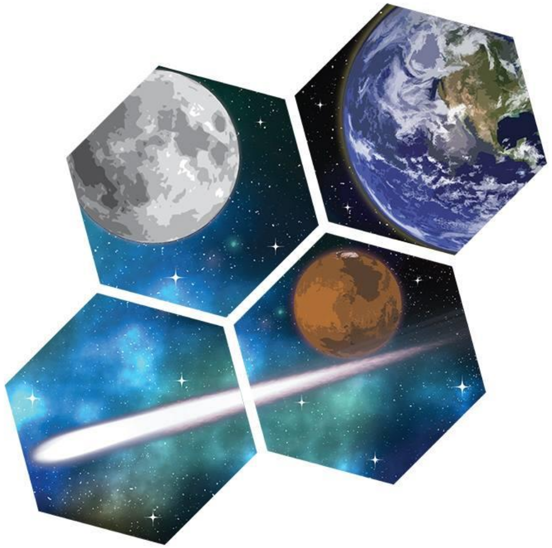
- Developing a high scientific fidelity hybrid reality (HR) model of real-world geological sites of interest, including embedded data and applicable tool usage
- Builds off of several years of RIS^{4}E *in situ* data collection in addition to data collected at the December 1974 flow, Kilauea Volcano, HI
- Testing environment that will be utilized for:
  - Ops con development for science-driven EVAs
  - Instrument deployment procedures
  - EVA Support System and IV Workstation capabilities for science
  - Crew training platform



Parabolic Flight (Reduced Gravity Aircraft)

Specialized aircraft allow for the parabolic flight profiles. These profiles enable brief moments of varying degrees of "reduced gravity" for ~25 seconds, from microgravity to lunar or Martian partial-gravity levels.

- Hardware design and development, utilizing high-fidelity pressurized spacesuits and tools
- Human factors testing
- Development of EVA techniques and training of crew



NASA Science Field Analogs

Solar System Exploration Research Virtual Institute (SSERVI)

Integration with Solar System Exploration Research Virtual Institute (SSERVI)-funded projects

- **RIS^{4}E**: Remote, In Situ and Synchrotron Studies for Science and Exploration
  - Focus: Remote sensing of airless bodies, field operations and metrics for human exploration, reactivity and toxicity of regoliths, synchrotron analyses of samples, volcanics and impact crater analog research
  - Investigates the effects of incorporating field portable instrumentation into science-driven EVA timelines

Multispectral Imaging & LiDAR for broad FOV

hXRF & XRD for in situ chemistry and mineralogy

- **GEODES**: Geophysical Exploration Of the Dynamics and Evolution of the Solar System

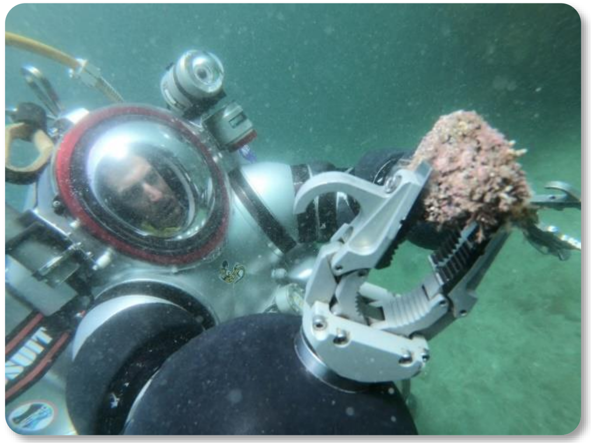
Other Science Field Campaigns and Geology Training

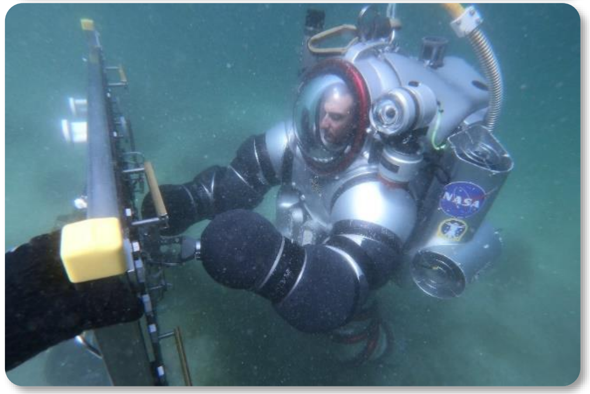
NASA Mission Analogs

NASA Extreme Environment Mission Operations (NEEMO)

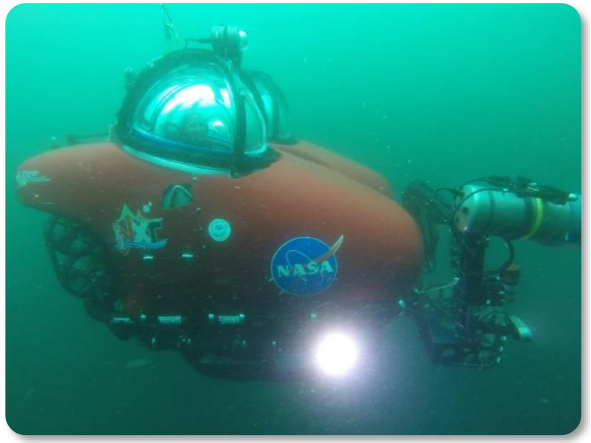
- NASA undersea high-fidelity spaceflight mission analog – focusing on exploration science and EVA techniques & tools, as well as maturing near term (ISS) flight hardware and ops concepts – that sends groups of astronauts, engineers and scientists to live, work and explore in a challenging environment
- Utilizes Aquarius Reef Base, the world's only undersea research station
- Located 5.4 miles (9 kilometers) off Key Largo in the Florida Keys National Marine Sanctuary, 62 feet (19 meters) below the surface
- Allows for evaluations of EVA end-to-end concepts of operations with crew that are in-situ in an extreme environment and provides for flight-like interactions between the crew and an MCC & Science Team
- Series of 23 space exploration simulations conducted since 2001

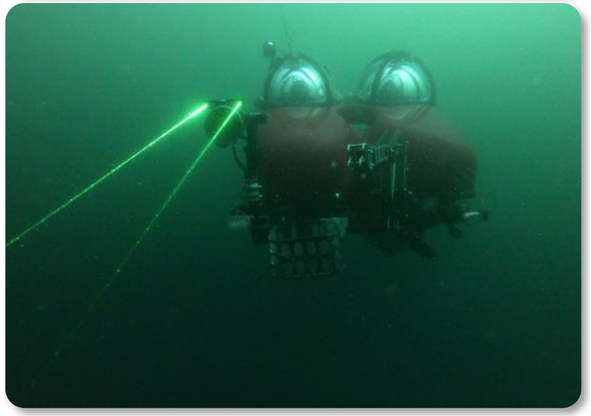
NEEMO Neoteric eXploration Technologies (NXT)





- Analog concept with operations that take place separately on both land and in water (“surf & turf”) – utilizes terrestrial geology training (“turf”) and then extends that experience into exploration techniques in a subsea operationally challenging environment (“surf”)
- Focuses on Exploration and EVA capability development (e.g. xEVA informatics), Exploration and EVA con ops development (including science operations with a suit and a rover), and some Exploration crew training
- Offers a high intensity, operationally challenging environment, with high workload, elevated stress, high bandwidth, time pressure, and unexpected external perturbations
- Utilizes Nuytco Research Exosuit Atmospheric Diving System/Suit (ADS), which provides an analogous restrictive suit that requires effort for positioning and working (much like in an EVA suit), and has a relatively large helmet volume at 1 ATM to evaluate off the shelf informatics hardware
- Deploys Nuytco Dual DeepWorker submersible as an analogous vehicle to a pressurized rover





Potential Follow-on to NASA Desert RATS Campaigns

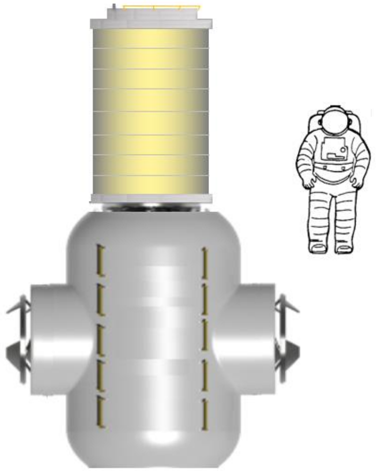
Desert Research and Technology Studies (RATS) missions were a planetary analog
- Took place at the Black Point Lava Flow near Flagstaff, AZ
- Provided environment analogous to Moon and/or Mars, with crew conducting geoscience operations
- Allowed immersion of whole team, both flight crew and flight controllers
- Geoscience data still utilized for research

Final Desert RATS mission took place in 2011

Possible follow-ons for any Lunar mission program

Integration with tests to evaluate future habitation concepts for exploration missions

Numerous components also being developed in other READy activities



Potential Follow-on to NASA RATS 2012 Simulation

Research & Technology Studies

- Mission tested techniques, tools, planning, and communication protocols
- Matured operational concepts and technologies through integrated demonstrations
- Exercised overall ‘MCC style’ coordination between hardware, procedures, crew operations, mission control operations, science team operations, and engineering team

RATS 2012 was an asteroid analog mission

- EVAs conducted in VR Lab and on ARGOS
- Vehicle/asteroid sim was tied to VR lab/EVA sim to allow vehicle and EV interaction

Possible surface-focused follow-ons for any Lunar mission program

References

References for EVA Testing & Analogs on nasa.gov/suitup

Suit Up

Related Topics

All Topics A-Z

Extravehicular Activity Reference Documents

In an effort to provide relevant and timely information to the Extravehicular Activity (EVA)/Space Suit community, we have created this repository to share pertinent reference materials supporting NASA's Exploration efforts pertaining to EVA.

Reference Documents

- Exploration EVA System Concept of Operations (October 2020)
- 2020 EVA Gap List
- Exploration EVA System Concept of Operations Summary for Artemis Ph 1 (EVA-EXP-0075)
- 2020 Crew Health & Performance EVA Roadmap
- Extravehicular Mobility Unit Data Book.pdf
- 2018: EVA Airlocks and Alternate Ingress/Egress Methods Document.pdf

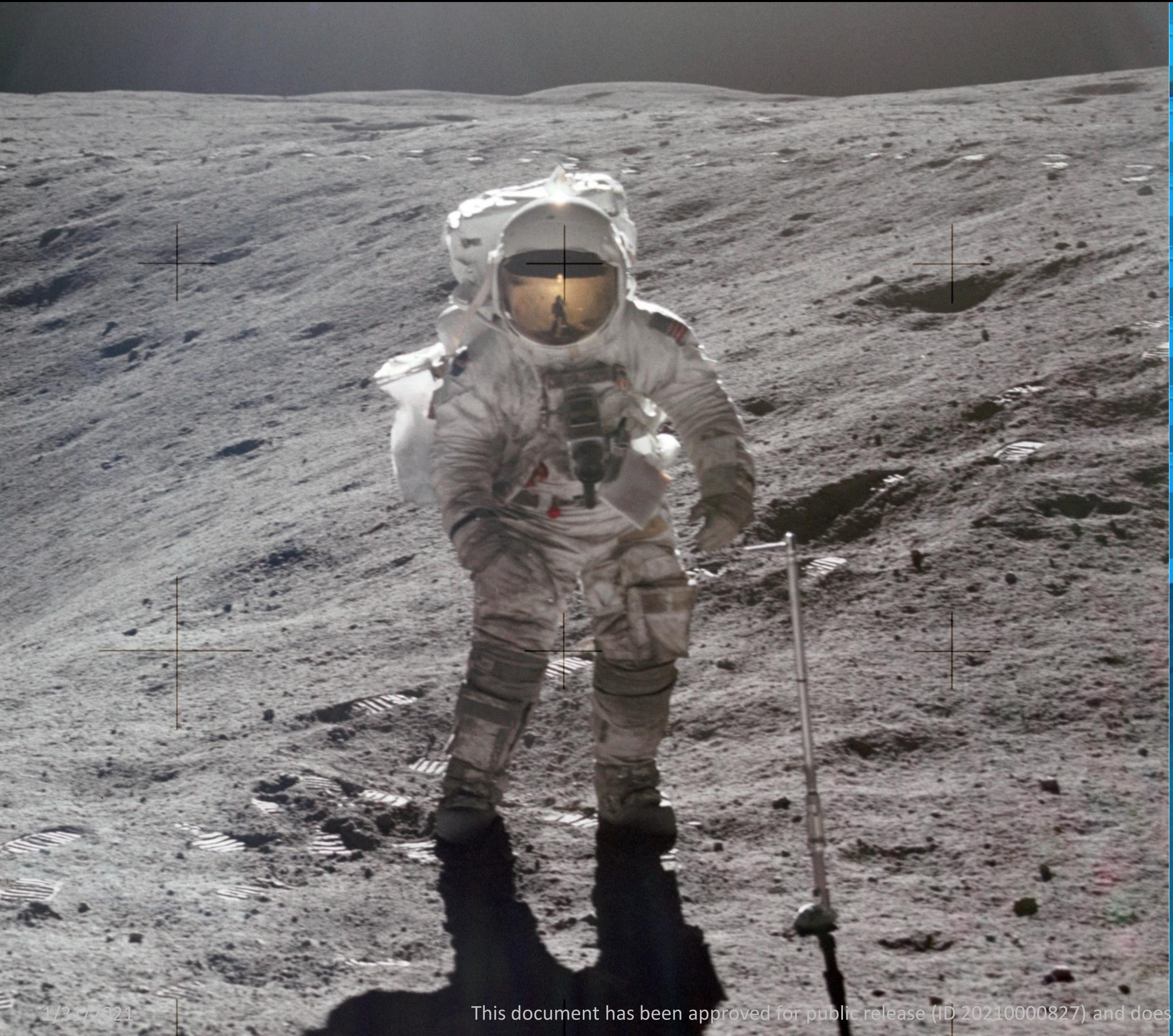
xEVA Testing & Analogs

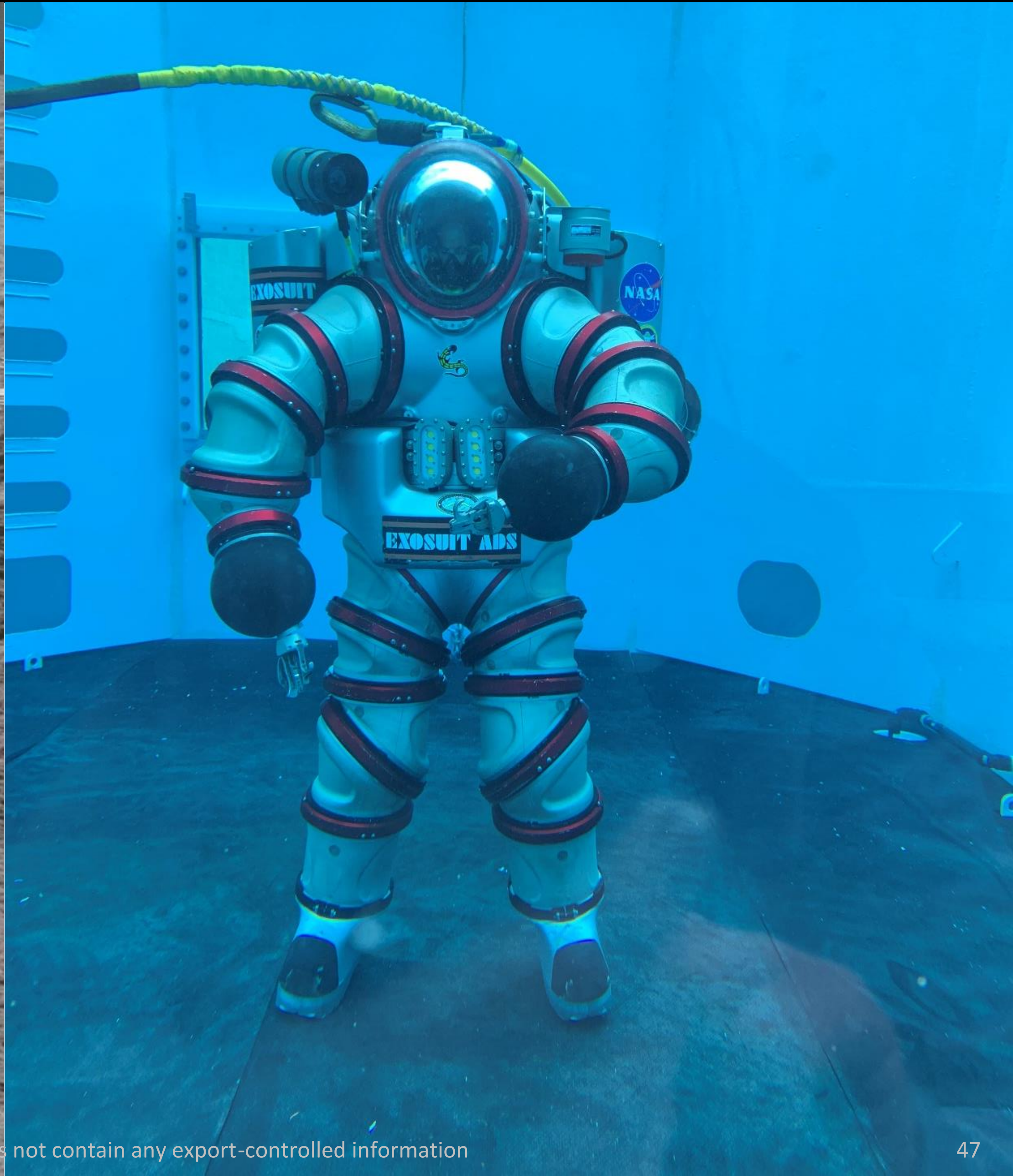
- NBL xEVA Lunar DAVD Test Series 1 (2020)
- NXT Feasibility Mission EVA & Science Operations Summary of Results (October 2019)
- NEEMO 23 EVA & Science Operations Summary of Results (September 2019)
- Relevant Environments for Analysis & Development: Enabling Human Space Exploration Through Integrated Operational Testing (2019)
- Integrated Extravehicular Activity Human Research & Testing Plan: 2019
- 2017: Integrated Extravehicular Activity Human Research Plan.pdf
- NEEMO 22 EVA Overview & Debrief (December 2017)
- NASA Exploration and Science Analogs (10-2017)
- Operational Field Testing for Human Space Exploration (11-2016)
- NEEMO 21 EVA Mission Debrief (November 2016)
- Operational Field Testing for Human Exploration a.k.a., NASA Analog Projects (09-2016)
- NEEMO 20 Exploration EVA Results (December 2015)

Thank you!

Questions?

Backup Materials and Additional Information





Draft Charter for the JETF

Purpose [edit | edit source]

This charter formally establishes the Joint Extravehicular Activity (EVA) Testing Forum (JETF). The JETF acts as the EVA active body regulating Human-in-the Loop (HITL) testing for the Exploration EVA (xEVA) System (spacesuit, vehicle interfaces, tools, accessories) and tests associated with the xEVA Concept of Operations (con ops). The JETF works in conjunction with the xEVA Systems Panel and the EVA Configuration Control Board (CCB) to govern testing associated with Exploration EVA, including development testing, operational testing (including analog tests/missions), and verification testing. The forum integrates, affords synergy, and provides EVA Office guidance, direction, and concurrence across a broad portfolio of Exploration-focused tests and test objectives. The forum aligns xEVA ground hardware build planning and test event support hardware needs, and it determines priorities for ground hardware resources and the tests in which those are included, all in order to ensure agency's human exploration development milestones affecting EVA are met.

The JETF integrates across a broad spectrum of Exploration EVA groups and efforts. Within the EVA Office, the JETF links the testing aspects of the EVA Hardware Office, the EVA Integration & Operations Office, and the EVA Strategic Integration Office. At an EVA community level, the JETF assimilates testing activities for the EVA Office, Engineering, Flight Operations, Human Health and Performance, and other groups directly associated with EVA, including the Exploration Extravehicular Mobility Unit (xEMU), Vehicle Interface to Suit Equipment (VISE), tools, and ancillary EVA accessories. At Agency and Exploration domain levels, the forum connects the EVA testing community with Human Exploration and Operations (HEO), Advanced Exploration Systems (AES), Artemis, Gateway, Orion, the Human Landing System (HLS), Surface Mobility, and other Exploration systems, and it integrates EVA-related testing activities with Exploration mission architecture and vehicles utilized to conduct EVA operations. The JETF also provides the link for xEVA testing with any other testing bodies as they formulate.

The JETF ultimately strives to enable the evolution of human space exploration and successful execution of missions to the Moon and Mars through facilitating the development and evaluation of systems and operations associated with Exploration EVA.

Scope [edit | edit source]

The JETF focuses on synchronizing all operational and development HITL testing related to the xEVA System. The forum serves as the EVA Office mechanism to facilitate community input and collaboration with all testing (including development tests and analog missions) connected to Exploration EVA, while providing transparency across those activities. It also promotes technology development for strategic phases of Exploration. The JETF shares amongst the membership the current exploration event activities requiring ground hardware occurring within the respective organizations.

The forum engages in review, approval, and tracking of all EVA-related test objectives on behalf of the EVA Office. The forum will discuss, track and integrate current NASA Exploration activities that directly affect facility and other ground EVA hardware needs. It will prioritize limited ground hardware resources as driven by test support events, and manage long term planning to ensure ground hardware is available for event support. The JETF will also serve as an EVA point of contact for requested actions that may be required from current or future exploration ground hardware planning.

Tests moderated by the JETF include development tests, operational/analog tests, verification tests, "mission-class" analogs, NASA facility tests/missions, and field-deployed tests/missions at external locations. These activities span a variety of test environments, including terrestrial gravity (1G), tabletop, offloaded, neutral buoyancy, and reduced gravity; and they involve a number of different types of outfitting for test subjects, including shirtsleeve, mockup suits, underwater dive systems, and full spacesuits.

The JETF channels EVA Office input and works in close integration with a multitude of groups and teams across the EVA community groups, Exploration domain groups, facilities, and other NASA teams (reference appendix). The groups, teams, projects, and facilities that interact with the JETF will grow and evolve as the dynamic world of Exploration brings new needs and new capabilities. The JETF integrates with the HLS Joint Testing Panel (JTP) for EVA-related evaluations, and the Neutral Buoyancy Laboratory (NBL) EVA Development and Verification Testing (EDVT) for tests associated with the xEVA System.

The JETF works in conjunction with the other EVA boards, panels, working groups, and Integrated Product Teams (IPT). Statuses and results will be presented at the pertinent EVA groups as applicable. Relevant and critical results that impact system design will be brought from the JETF to the xEVA System Panel, and disseminated to the necessary project groups.

Reference for READy

Paper on READy presented at the 2019 International Conference for Environmental Systems (ICES)

https://ttu-ir.tdl.org/handle/2346/84787

49th International Conference on Environmental Systems
7-11 July 2019, Boston, Massachusetts

ICES-2019-80

Relevant Environments for Analysis and Development (READy): Enabling Human Space Exploration Through Integrated Operational Testing

David A. Coan [1]
The Aerospace Corporation, at the NASA Johnson Space Center, Houston, TX 77058 USA

Trevor G. Graff [2]
Jacobs, at the NASA Johnson Space Center, Houston, TX 77058 USA

Kelsey E. Young [3]
NASA Goddard Space Flight Center, Greenbelt, MD, 20771, USA

Marcum L. Reagan [4]
NASA Johnson Space Center, Houston, TX 77058, USA

and

Bill Todd [5]
Universities Space Research Association, at the NASA Johnson Space Center, Houston, TX 77058, USA

NASA is currently developing a multi-phase human exploration plan to explore various destinations throughout the solar system. These campaigns are currently focused on missions to cislunar space, the Moon, and Mars. All future exploration missions include Extravehicular Activity (EVA) operations that will be comprised of both engineering-focused tasks for constructing and maintaining infrastructure, as well as science-driven operations for exploration of the natural environment. Integrated operational tests, also known as analogs, provide relevant data for informing concepts, fleshing out technical details, and evolving systems. Analogs close technology, capability, and science gaps; identify and develop the best systems, innovations, and operational approaches; identify things that are effective and ineffective in a mission environment; and inform the development of strategic architecture and concept of operations. These analogs further inform the Exploration EVA System Concept of Operations document by exploring the combination of operations, engineering, and science for future destinations in mission-like environments. Exploration and analog experts from NASA's Exploration Integration & Science Directorate (EISD), located at the Johnson Space Center (JSC), established the Relevant Environments for Analysis and Development (READy) Project in order to enable human space exploration through the integration and testing of technologies, systems, operations, and science. The READy team leads the development and execution of high-fidelity operational missions that closely mimic the space environment of interest. The READy Project facilitates exploration objectives through four themes 1) Tools, 2) Techniques, 3) Technologies, and 4) Training, and takes place in three general types of environments 1) Aquatic, 2) Terrestrial, and 3) Laboratory. READy fulfills key objectives that enable human exploration, while providing synergy and ensuring integration across a wide variety of activities. These efforts will ultimately lead to mission readiness and success, reduce risk, increase scientific return, and improve the affordability of NASA programs and missions. This paper outlines READy's strategy and implementation plan.

[1] Operations & Engineering Specialist, Extravehicular Activity Office, READy Management Team, Mail Code XX4
[2] Chief Scientist, Astromaterials Research & Exploration Sciences, READy Management Team, Mail Code XI3
[3] Research Scientist, Planetary Geodynamic Laboratory, READy Management Team, Mail Code 6980
[4] Project Manager, Exploration Mission Planning Office, READy Management Team, Mail Code XM1
[5] Project Specialist, Exploration Mission Planning Office, READy Management Team, Mail Code XM

Partners from NASA, Academia, Research, Industry, and DoD

NASA

JSC

ARC

KSC

JPL

GSFC

esa

CSA ASC

JAXA

And a multitude of others…

XI

XM

XX

CB

EC

ER

SK

FIU

Florida International University

AQUARIUS

REEF BASE

HONEYBEE ROBOTICS

NPS

NAVSEA

NAVAL SEA SYSTEMS COMMAND

CORAL RESTORATION FOUNDATION™

JOHNS HOPKINS UNIVERSITY

ihmc

FLORIDA INSTITUTE FOR HUMAN & MACHINE COGNITION

USF

UNIVERSITY OF SOUTH FLORIDA

EMBRY-RIDDLE AERONAUTICAL UNIVERSITY

TELEDYNE TECHNOLOGIES INCORPORATED

GT

NMT

AllTraq

UNCW

DRAPER

VEGA Telehealth

TELOREGEN

Micro Aerospace Solutions

IMaGeS Lab

SHARK MARINE TECHNOLOGIES INC.

AEXA

University of Houston Clear Lake

voxer

xEVA System Capability Overview

The Exploration EVA (xEVA) System allows crewmembers to conduct excursions outside a habitable vehicle in order to perform exploration, research, construction, servicing, and repair operations

A few key xEVA surface suit capabilities include, but are not limited to, as follows:

General & Durations

- Rear-entry spacesuit
- Supports EVAs of up to 8 hours in duration (6±2 hours)
- Capability to operate for up to 2 hours of contiguous exposure in a shadowed area, including Permanently Shadowed Regions (PSRs)

Mobility

- Translation via walking, crawling/scrambling on hands and knees, and climbing ladders
- Walking up/down/across a slope of up to 20° and on traverses of up to 2 km away from the lander
- Traversing down into and out of impact craters, pit craters, lava tubes, fresh lava flows, splatter cones, and steep cliffs (with the appropriate equipment and assets)
- Perform tasks while standing and kneeling
- Capacity to carry some tools on the suit (attached directly or via a harness)

xEVA System Capability Overview

Audio Communications and Imagery

- Ability to record communication and video onboard the suit in case of loss of signal with the Mission Control Center (MCC)
- All audio, video, and integrated xEVA suit still imagery will be recorded with timestamp
- Hills, boulders, craters, and other natural obstacles may require the use of EVA-deployable comm repeaters
- Still photography is required and may be completed by the integrated xEVA suit info camera or supplemental equipment (e.g., a hand-held camera)

Visibility & Lighting

- Lights will support visual sight of suited astronaut boots, ground ahead, EV partner in a PSR, lander, and the EV worksite
- Primary lights are helmet-mounted, but may be supplemented by ancillary lights (e.g., flashlight) and/or lights on surface assets

Advanced Informatics

- For Phase 2, the xEVA suit will include an informatics system with a heads-up display type of capability that will allow for viewing of procedures, imagery, navigation data, suit data, possibly augmented reality cues, etc.

xEVA System Capability Overview

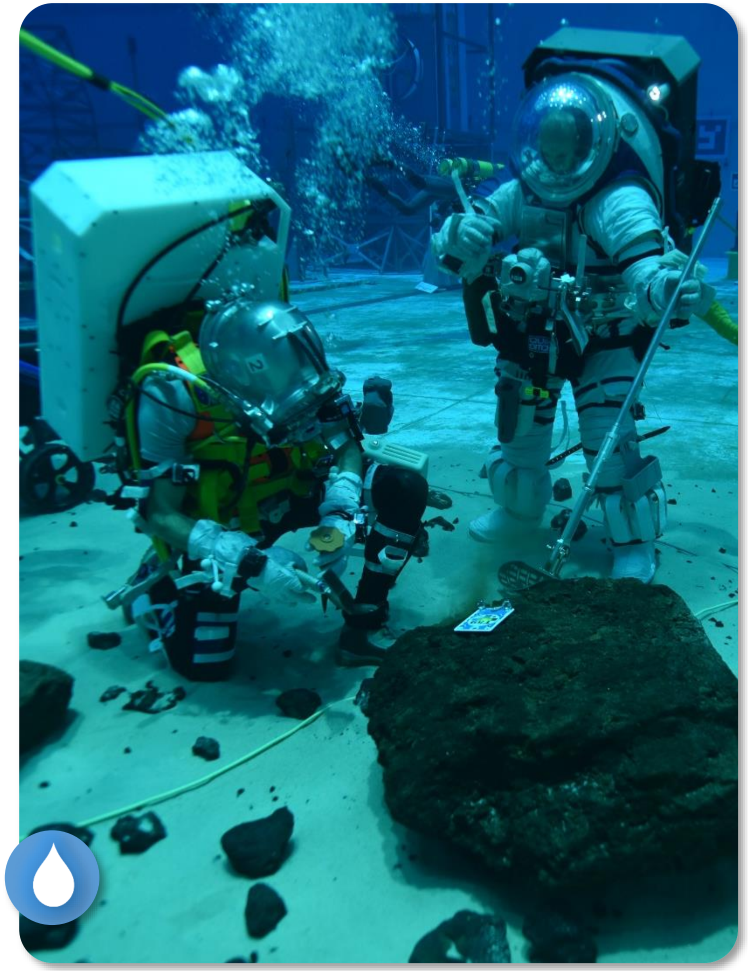
Tools

- Mobility/transportation
- Construction
- Geology
- Contingency

Other

- Operate within vehicles with the potential following nominal saturation atmosphere set points:
  - 14.7 psia with 21% O_2
  - 10.2 psia with 27% O_2
  - 8.2 psia and 34% O_2
- Crew able to “self-don/doff” suit (nominal ops efficiency and contingencies associated with incapacitated crew or failure to repress the vehicle cabin

Neutral Buoyancy Laboratory



NBL

- Currently utilized for ISS EVA training
- Beginning to mature the facility for Exploration EVA development and training
- Evaluations will start on scuba, then progress to surface supplied helmets, and eventually spacesuits
- Creating analog areas for geology tasks, with regolith and rock
- Includes lander mockups
- Incorporates xEVA equipment and con ops

NBF

- Tests have been done with the Lunar Evacuation System Assembly (LESA), a concept by ESA for rescuing an incapacitated EVA crewmember
- Evaluations have been conducted for various geology sampling tools and transportation equipment

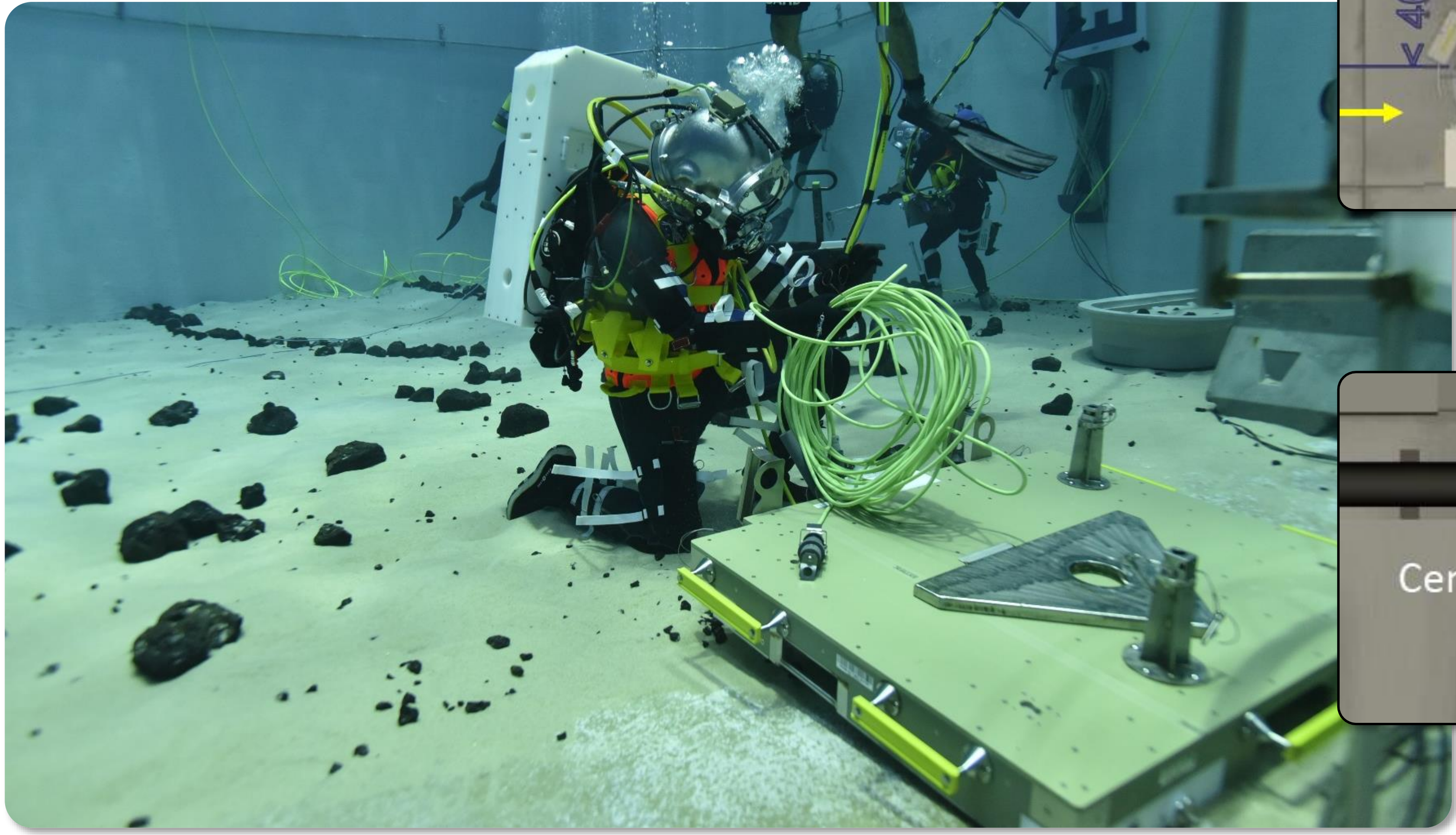
esa

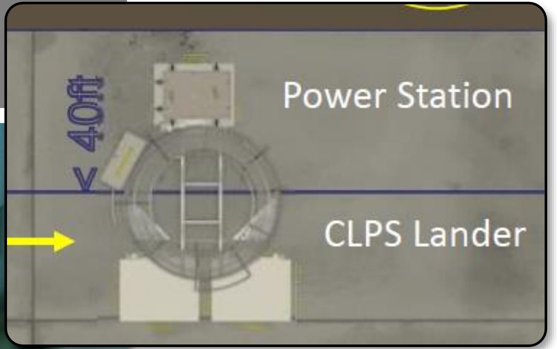
Neutral Buoyancy Facility

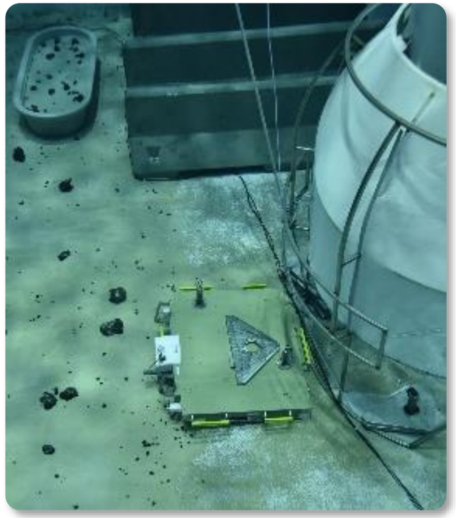
NBL: Surface EVA Engineering Tasks

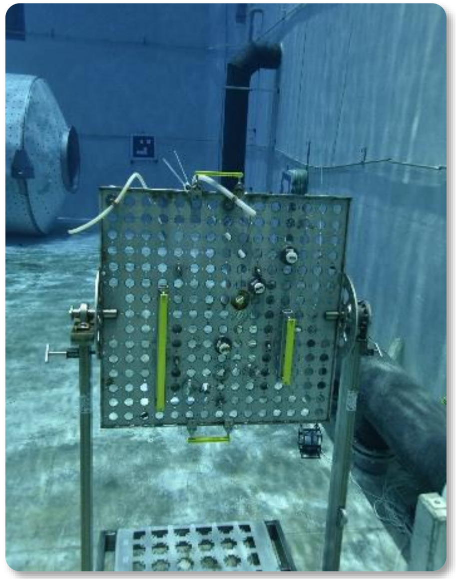
Construct Surface Infrastructure

- Route cable from Power Station to Central Station
- Mate and configure cable
- Configure jumper





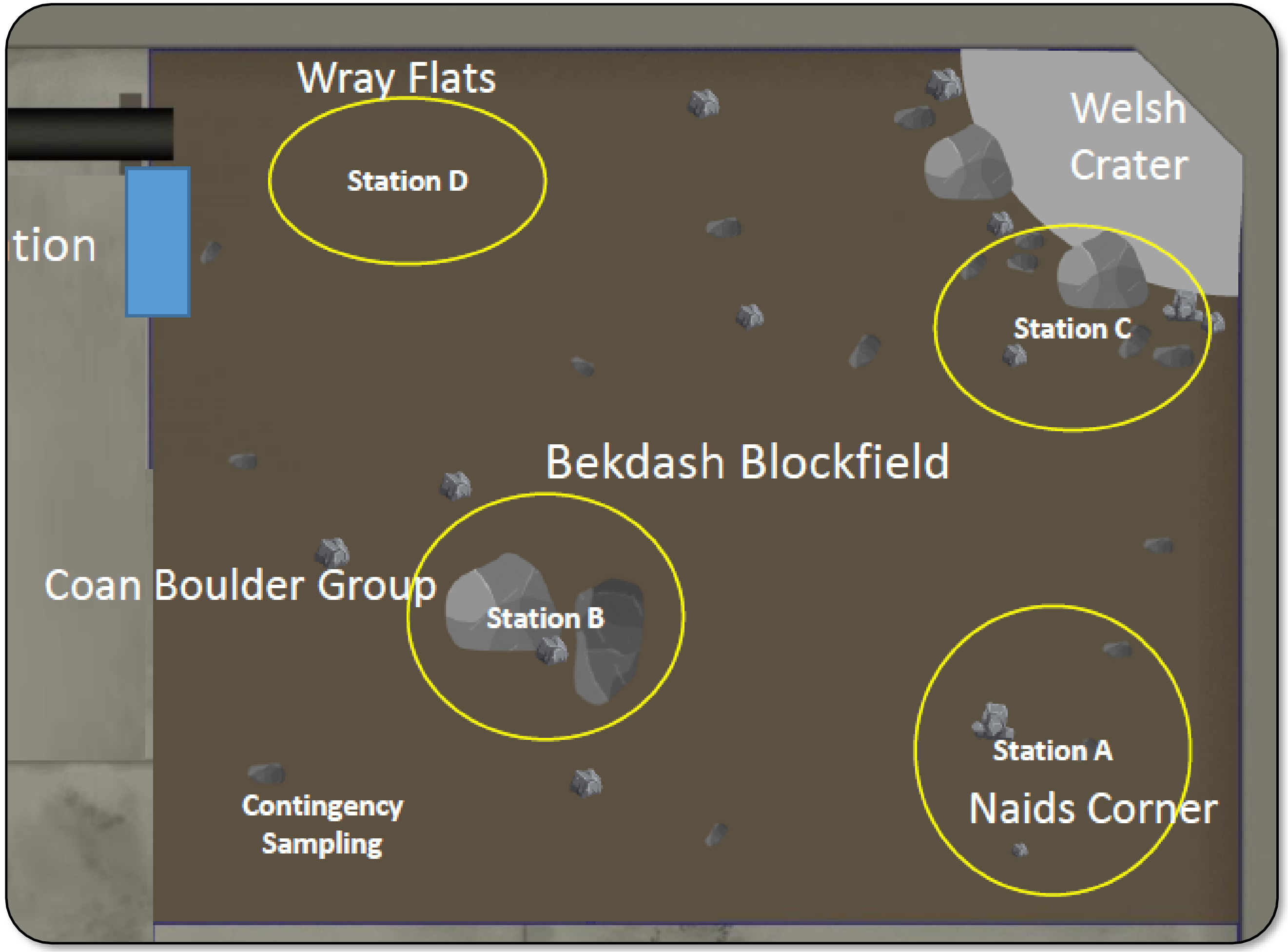


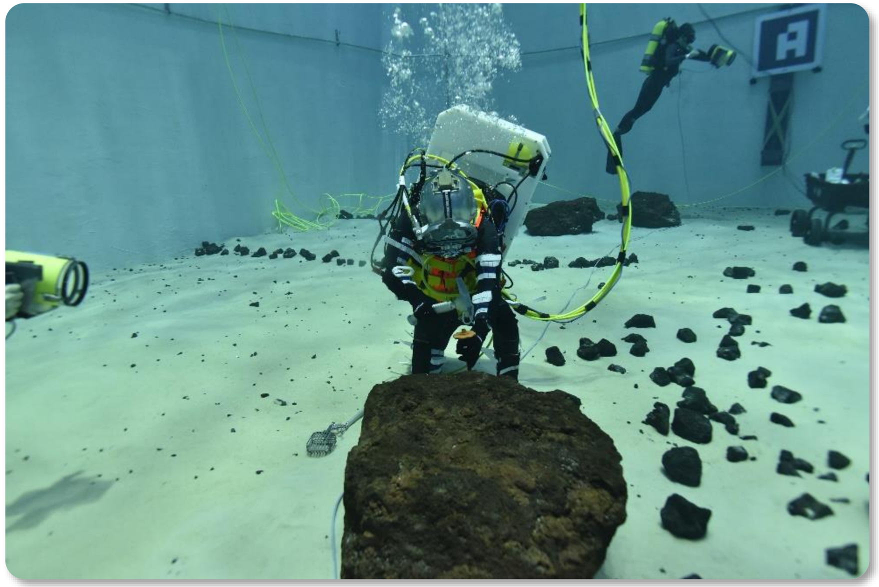


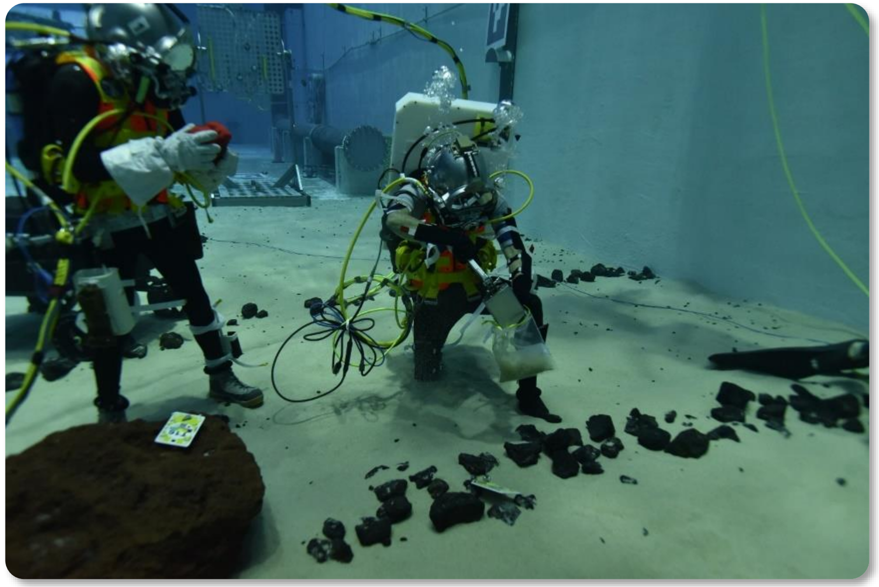
NBL: Surface EVA Science Tasks with Geology Tools

Rock Sample
- Float with Tongs and Rake
- Chip with Hammer and Chisel

Regolith Sample
- Bulk with Scoop
- Core with Drive Tube







NBL: Evaluating EVA Tool Management on Suit

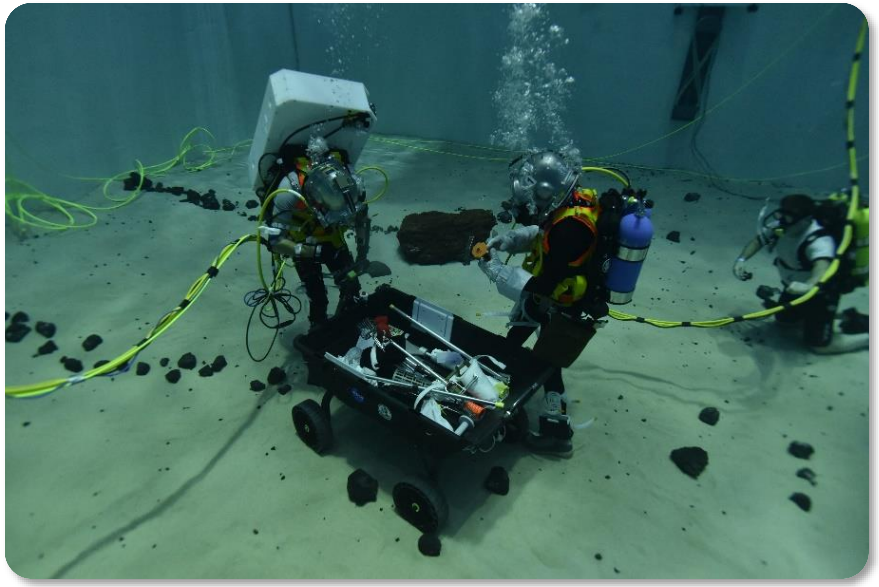
Suit-Mounted Geology Tools

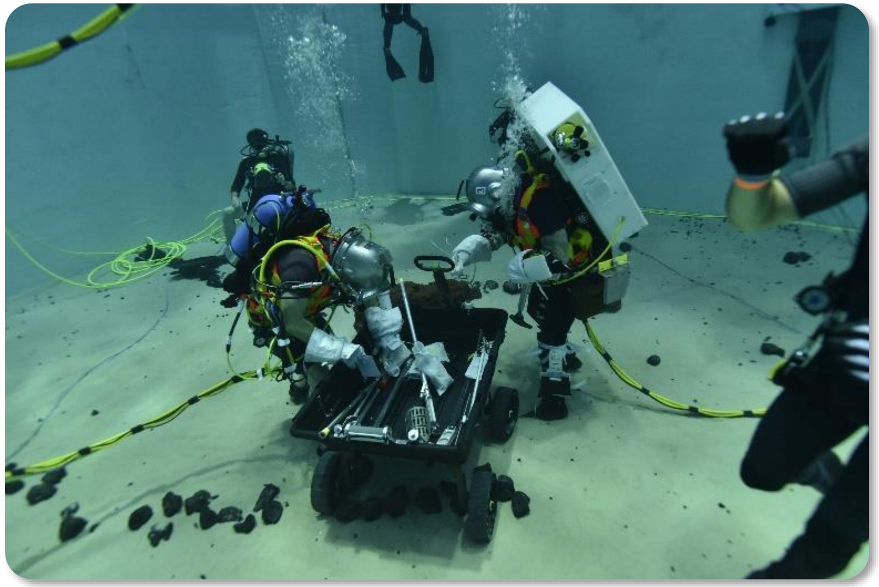
- Geology Hammer
- Scoops
- Point and Shoot Camera
- Sample Bag Dispensers
- Sample Bags
- Waist Pack
- Leg Holster for Hammer
- Leg Holster for Scoop and Chisel
- Utility Belt with Swing Arms

NBL: Evaluating EVA Tool Management with METS (Wheeled Carrier)

Geology Tools in METS

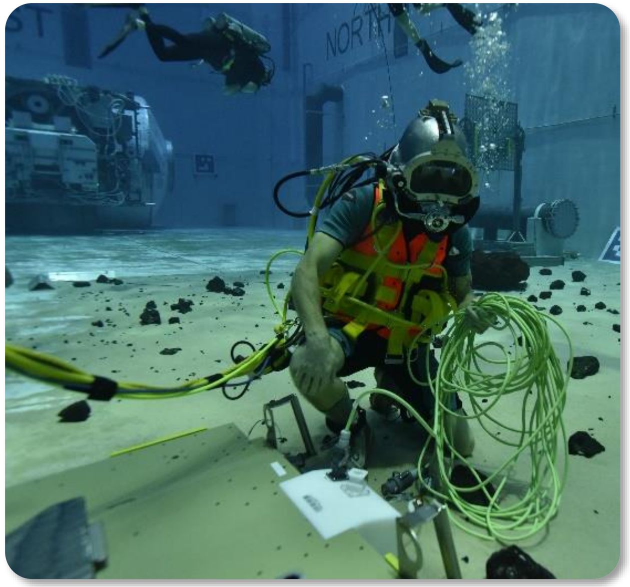
- Geology Hammer
- Tongs
- Scoops
- Rake
- Extension Handles
- Slide Hammer
- Drive Tube Kit
- Sample Bag Dispensers
- Sample Bags

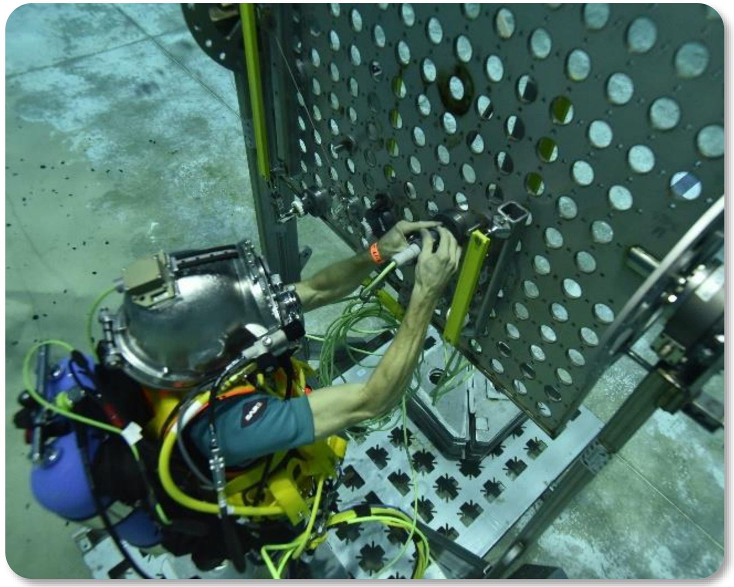


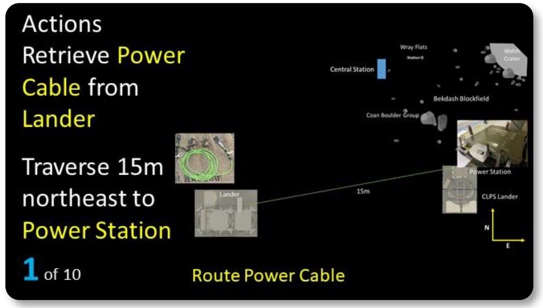


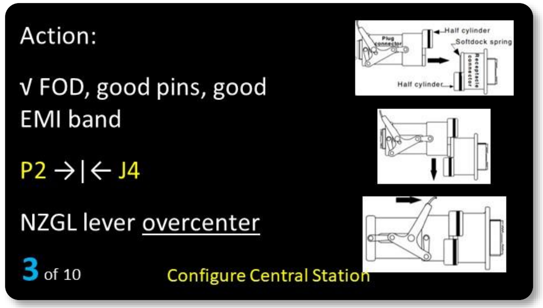
NBL: Evaluating Informatics for xEVA (Navy DAVD HUD)

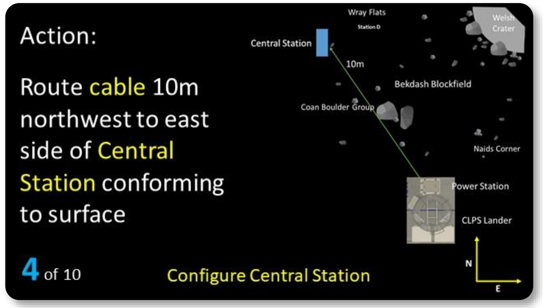
Retrieve power cable → Connect cable to Power Station → Route cable → Connect cable to Central Station

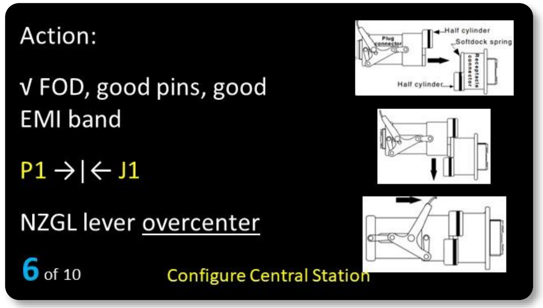












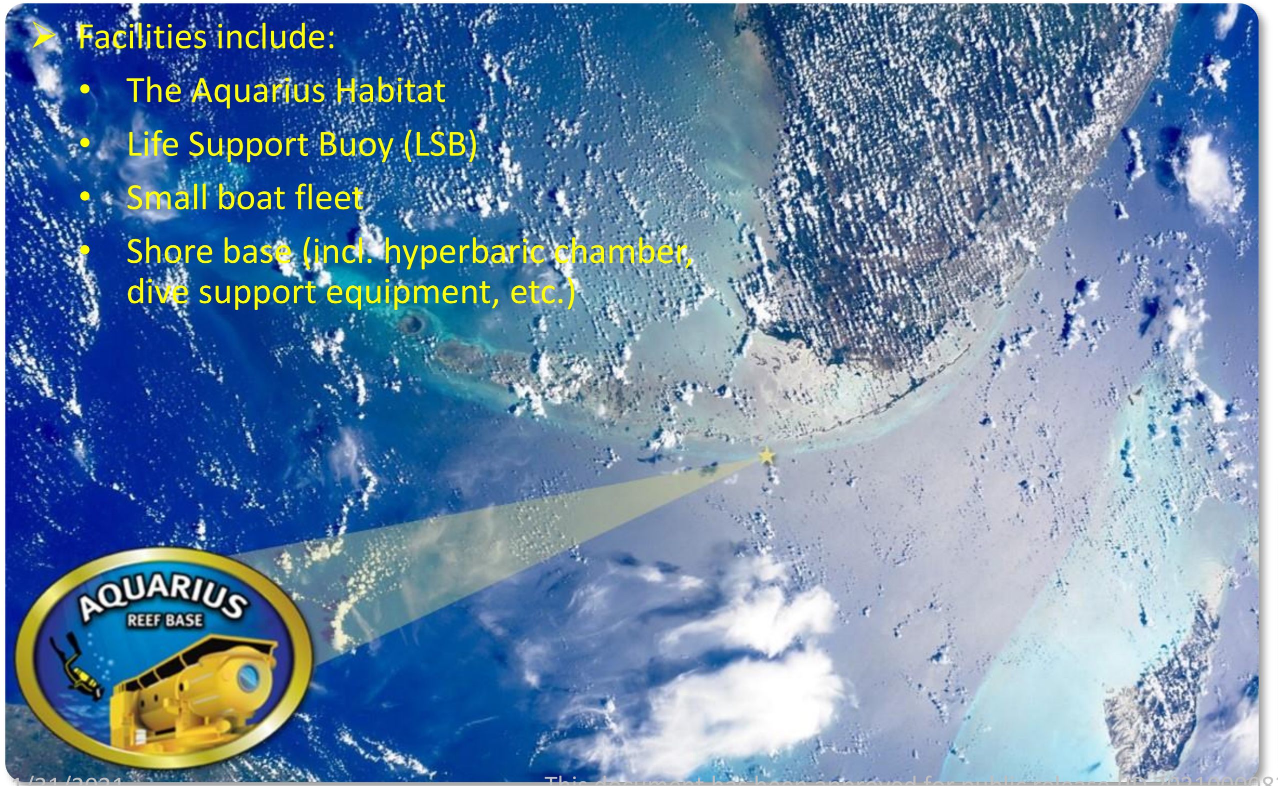
NEEMO: NASA Extreme Environment Mission Operations

- NASA undersea high-fidelity spaceflight mission analog – focusing on exploration science and EVA techniques & tools, as well as maturing near term (ISS) flight hardware and ops concepts – that sends groups of astronauts, engineers and scientists to live, work and explore in a challenging environment
- Allows for evaluations of EVA end-to-end concepts of operations with crew that are in-situ in a true extreme environment and provides for flight-like interactions between the crew and an MCC & Science Team
- Series of 23 space exploration simulations conducted since 2001

NEEMO: Facilities

- Aquarius Reef Base, the world's only undersea research station
- Located 5.4 miles (9 kilometers) off Key Largo in the Florida Keys National Marine Sanctuary
- 62 feet (19 meters) below the surface next to a deep coral reef named Conch Reef
- Operated by Florida International University

➤ Facilities include:
- The Aquarius Habitat
- Life Support Buoy (LSB)
- Small boat fleet
- Shore base (incl. hyperbaric chamber, dive support equipment, etc.)



Aquarius Habitat

ARB Shore Base

LSB

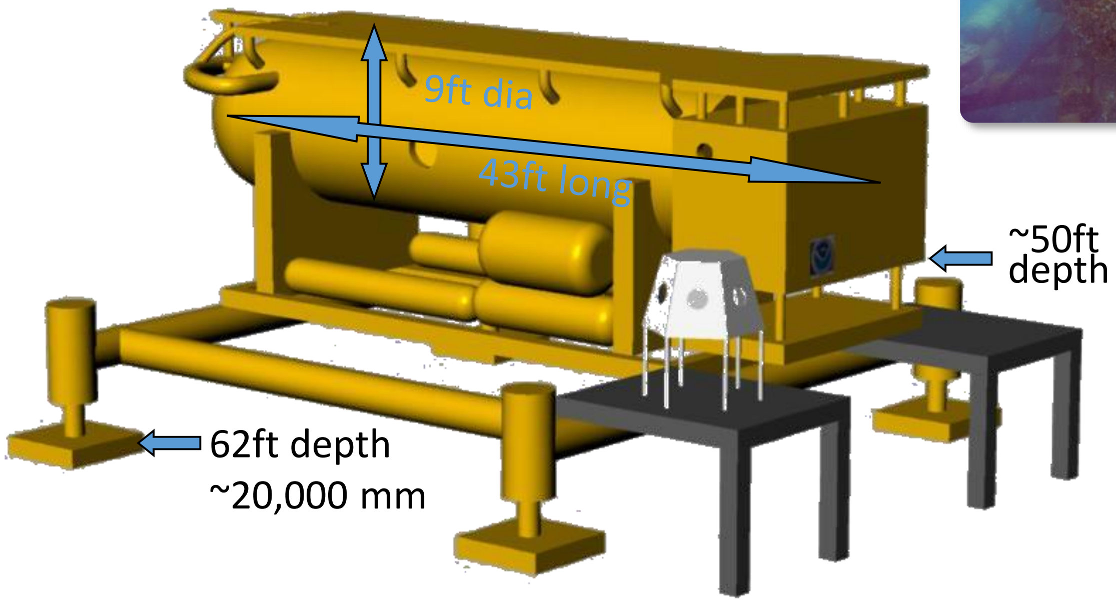

NEEMO MCC


Support Boats

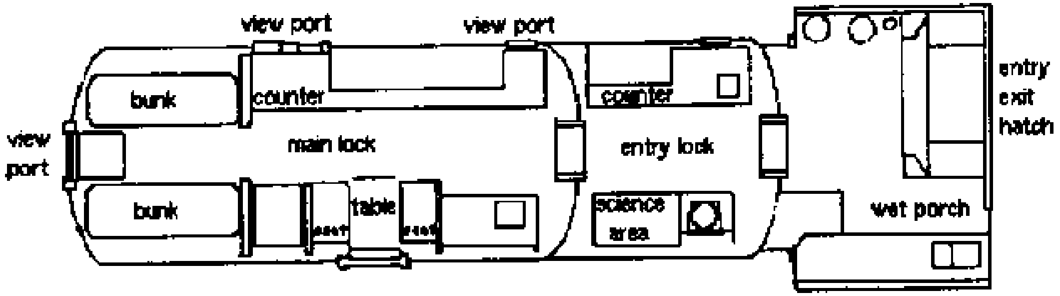

ARB Watchdesk

NEEMO: The “Spacecraft”: Aquarius Underwater Habitat



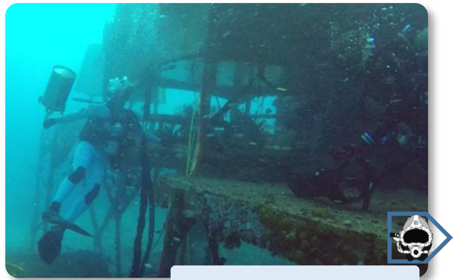



Model courtesy of Jim Maida and the GRAF Lab



Aquarius Underwater Habitat

Splashdown Photo



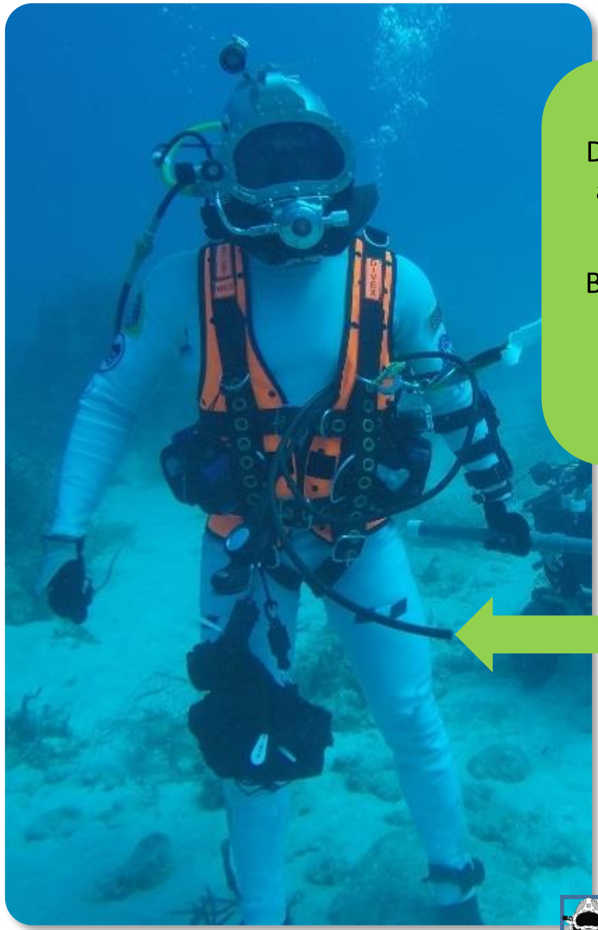
Wet Port Entrance

NEEMO: The “Spacesuit”: KM 37SS Helmet w/ Wetsuit & Harness

KM 37SS

37SS: Narrower FOV, Helmet movable

xEMU: Wider FOV, Helmet fixed



Dive helmet & system provide good analog to a spacesuit for concepts of operations evaluations

Both have different but comparable challenges for operations

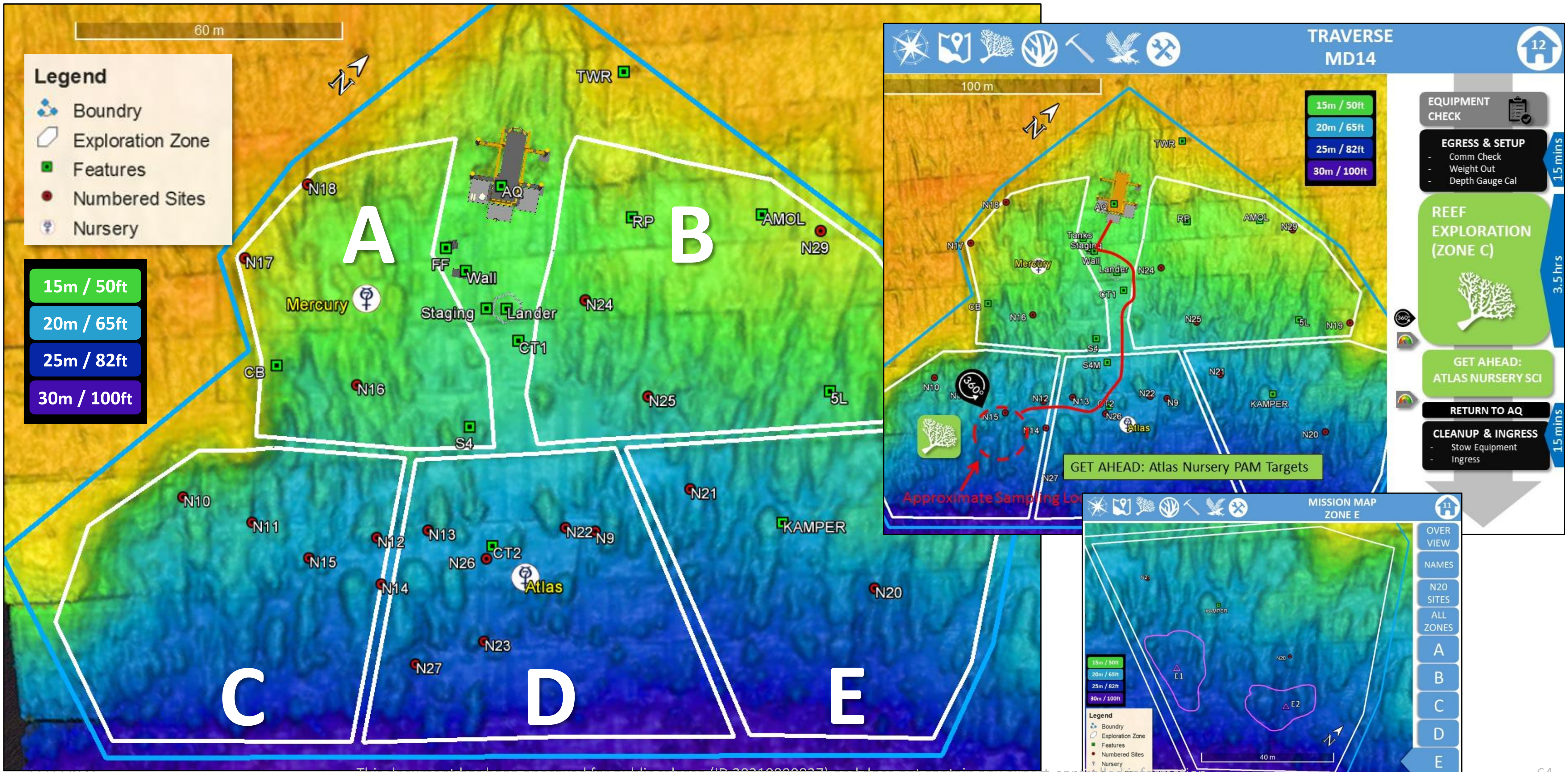
Will utilize EMU TMG

Wetsuit: Very flexible
xEMU: Pressurized, bulky

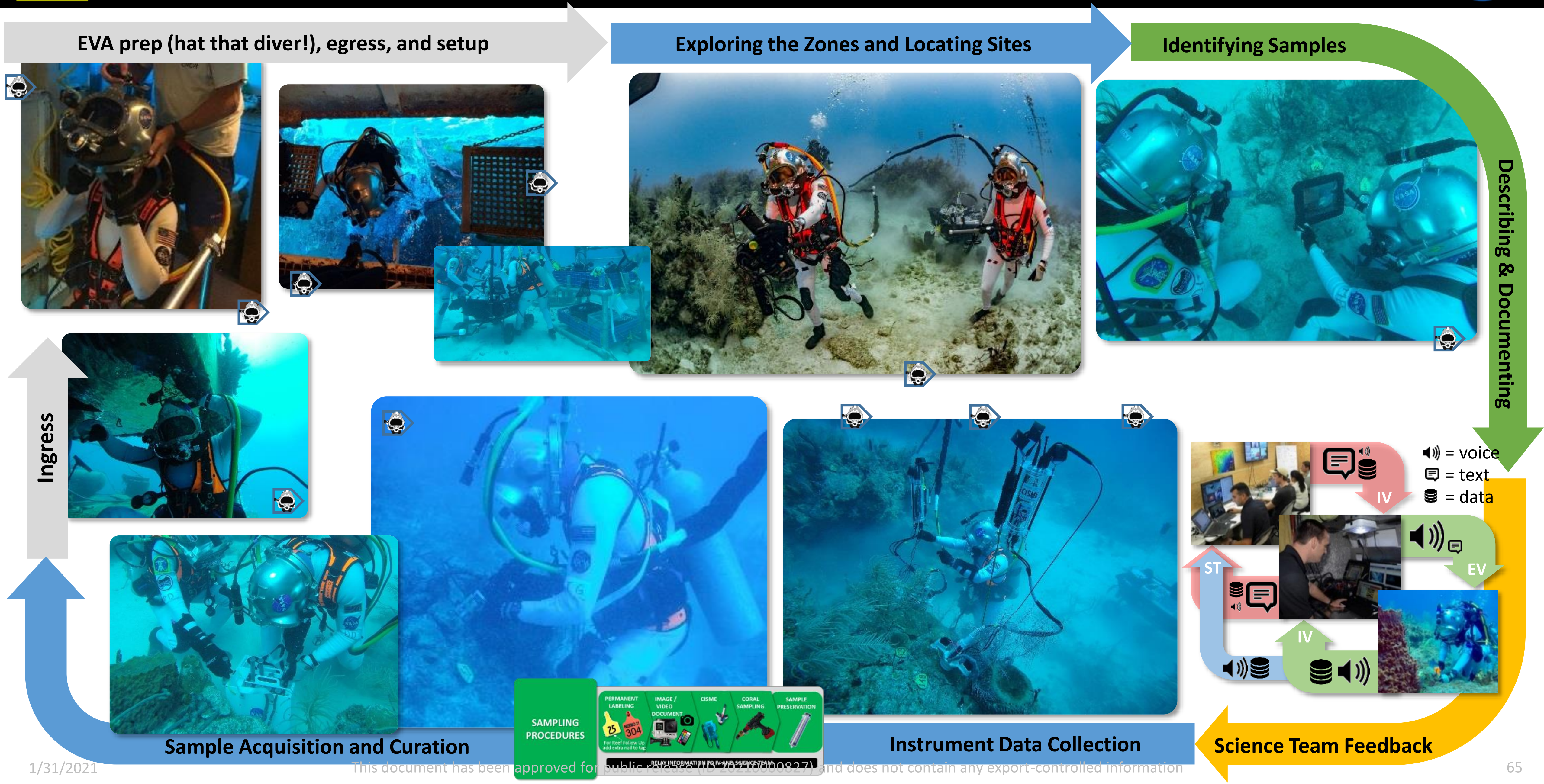
xEMU concept

TBD mEMU concept
(courtesy of *The Martian*)

NEEMO: Maps with Exploration Zones for EVA Excursions *(from NEEMO 22)*

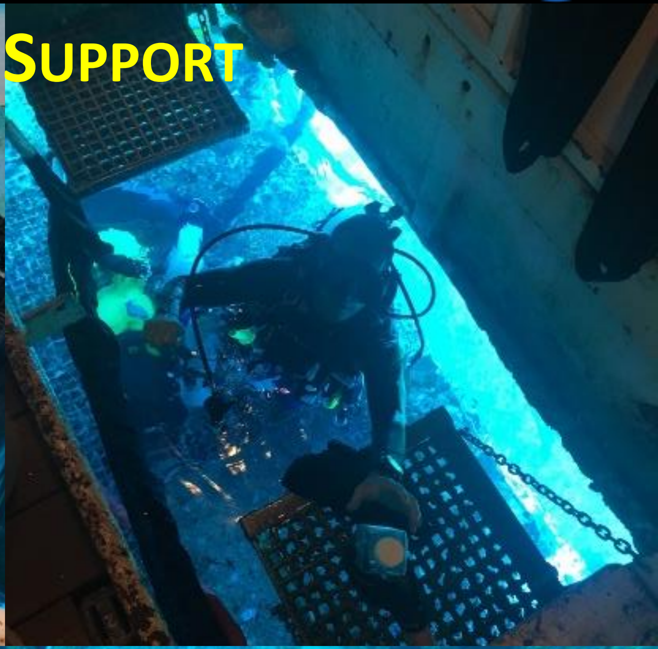


NEEMO: A Day in the Life of NEEMO EVA Operations



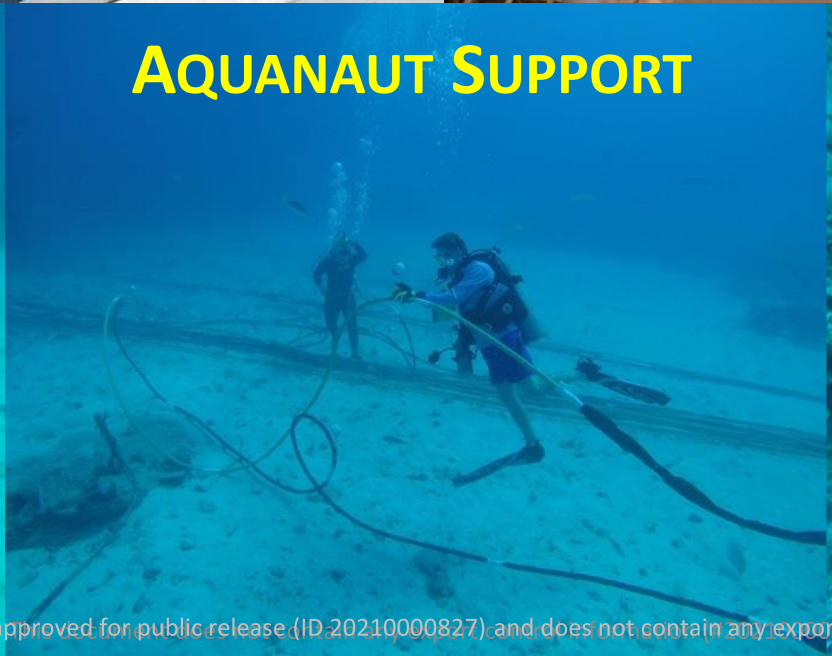
NEEMO: Topside Dive Support

POTTING & HAB SUPPORT


EVA SUPPORT

AQUANAUT SUPPORT




SCIENCE SUPPORT

NEEMO: Hab Tech Saturation Dive Support

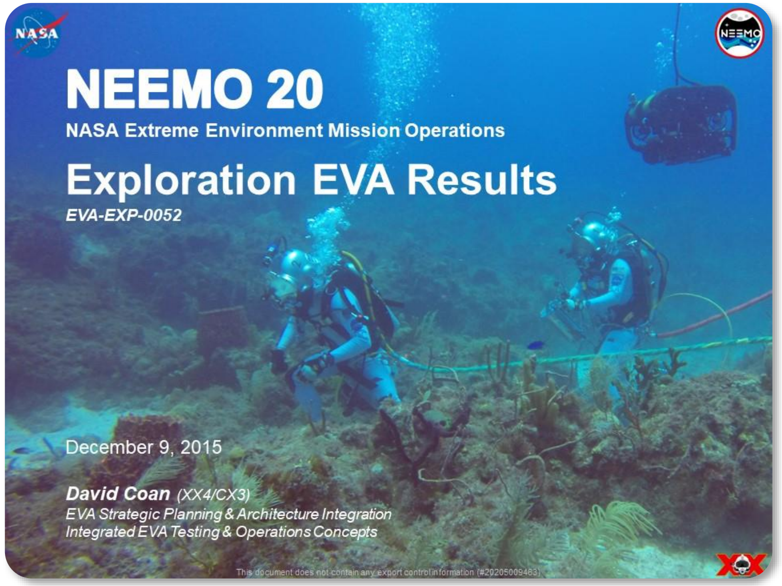
NEEMO: Missions & Crewmembers

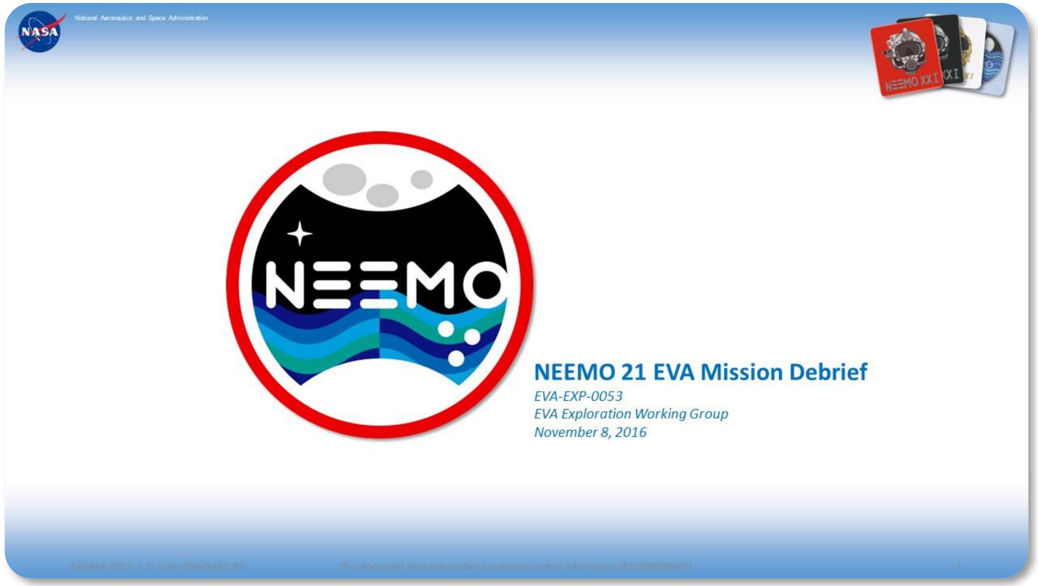
NEEMO 1 - 6 Days, Oct. 21-27, 2001	DT/B. Todd, CB/M. Lopez-Alegria, M. Gernhardt*, CSA/D. Williams*
NEEMO 2 - 9 Days, May 13-20, 2002	CB/M. Fincke, D. Tani, S. Williams, DT/M. Reagan
NEEMO 3 - 9 Days, July 15-21, 2002	CB/J. Williams, D. Olivas*, G. Chamitoff, SLSD/J. Dory
NEEMO 4 - 5 Days, Sept. 23-27, 2002	CB/S. Kelly*, R. Walheim, DA8/P. Hill, SLSD/J. Meir
NEEMO 5 - 14 Days, June 16-29, 2003	CB/P. Whitson, C. Anderson, G. Reisman, SLSD/E. Hwang
NEEMO 6 - 10 Days, July 12-21, 2004	CB/J. Herrington, D. Wheelock, N. Patrick*, EB/T. Ruttley
NEEMO 7 - 11 Days, Oct. 11-21, 2004	CSA/B. Thirsk, C. Coleman, M. Barratt, CMAS/C. Mckinley
NEEMO 8 - 3 Days, April 20-22, 2005	CB/M. Gernhardt*, S. Kelly*, D. Olivas*,, M. Schultz
NEEMO 9 – 18 days, April 3-20, 2006	CSA/D. Williams*, CB/N. Stott, R. Garan,, TATRC/T. Broderick*
NEEMO 10 – 7 days, July 22-28, 2006	JAXA/K. Wakata, CB/D. Feustel, K. Nyberg,, NOAA/K. Kohanowich
NEEMO 11 – 7 days, Sep. 16-22, 2006	CB/S. Magnus, T. Kopra, B. Behnken, T.J. Creamer
NEEMO 12 – 12 days, May 7-18, 2007	CB/H. Piper, J. Hernandez, SD/J. Schmidt, TATRC/T. Broderick*
NEEMO 13 – 10 days, Aug. 6-15, 2007	CB/N. Patrick*, R. Arnold, JAXA/S. Furukawa, Cx/C. Gerty
NEEMO 14 – 12 days, May 10-23,2010	CSA/C. Hadfield, CB/T. Marshburn, EAMD/A. Abercromby, S. Chappell
NEEMO 15 – 7 days, Oct. 20-26, 2011	CB/S. Walker, JAXA/T. Onishi, CSA/D. Saint-Jacques, NAC/ S. Squyres*
NEEMO 16 – 12 days, Jun 11-22, 2012	CB/D. Metcalf- Lindenburger, JAXA/K. Yui, ESA/T. Peake, NAC/S. Squyres*
NEEMO 17 – 7 days, Sept. 9-13, 2013	CB/J. Acaba, K. Rubins, JAXA/S. Noguchi, ESA/A. Mogensen*
NEEMO 18 – 9 days, July 21-29, 2014	JAXA/A. Hoshide, CB/M. Vande Hei, Jeanette Epps, ESA/Thomas Pesquet
NEEMO 19 – 7 days, Sept. 7-13, 2014	CB/R. Bresnik, ESA/A. Mogensen*, CSA/J. Hansen, ESA/H. Stevenin
NEEMO 20 – 14 days, Jul 20 – Aug 2, 2015	ESA/L. Parmitano, CB/S. Aunon, JAXA/N. Kanai, NASA/EVA/D. Coan
NEEMO 21 – 16 days (split), Jul 21-Aug 5, 2016	CB/R. Wiseman, M. McArthur, ESA/M. Maurer, IHMC/D. Kernagis, NMT/Marc O Griofa, NPS/N. du Toit
NEEMO 22 – 10 days, Jun 18-27, 2017	CB/K. Lindgren, ESA/P. Duque, NASA/ARES/T. Graff, IHMC/D. D'Agnostino
NEEMO 23 – 9 days, Jun 13-21, 2019	ESA/S. Cristoforetti, CB/J. Watkins, FAU/S. Pomponi, USF/C. D'Agnostino

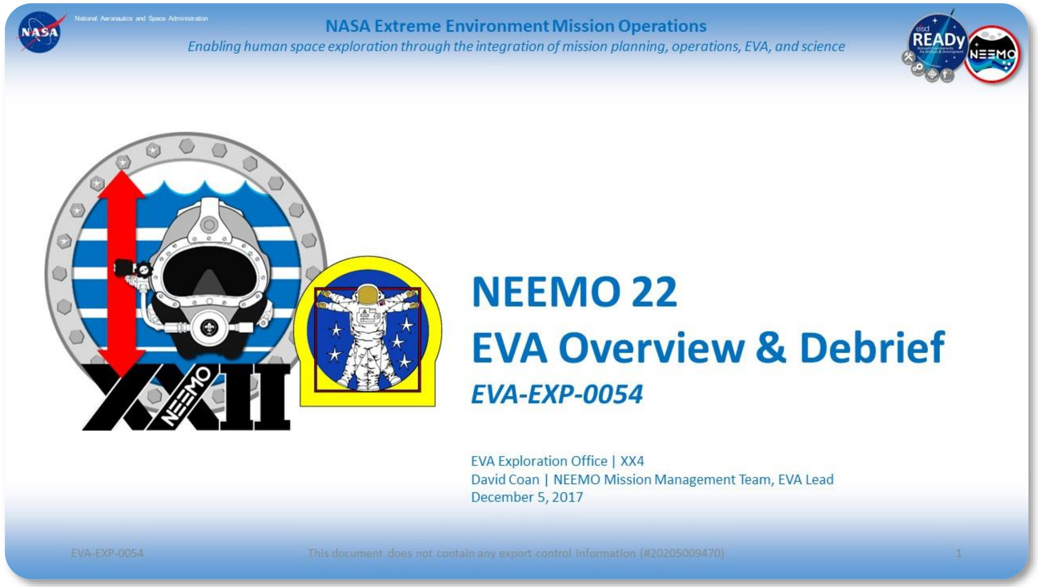
74 Crewmembers:
56 Astronauts (17 IP Astronauts)
20 Engineers, Scientists, Instructors, or MDs

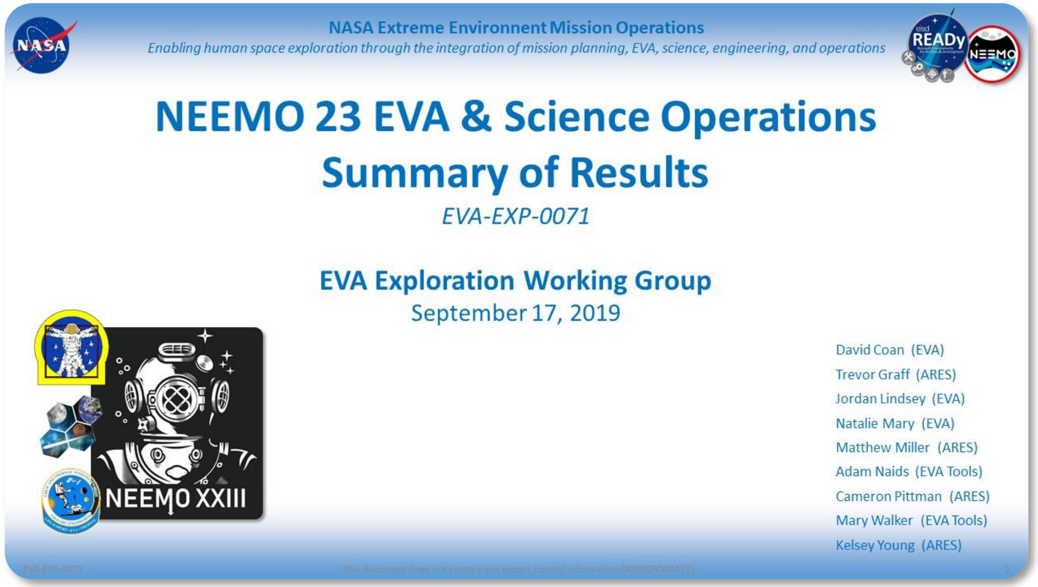
Key
* Repeater
Black – Experienced NASA Astronaut
Blue – Experienced Astronaut CDR upgrade
Green – IP Astronaut
RED – Rookie Astronaut
Gray – NASA (or Related) Engineer or Scientist
Orange –Engineer or Scientist External to NASA

NEEMO: Recent Relevant Missions for Planetary Surface Operations



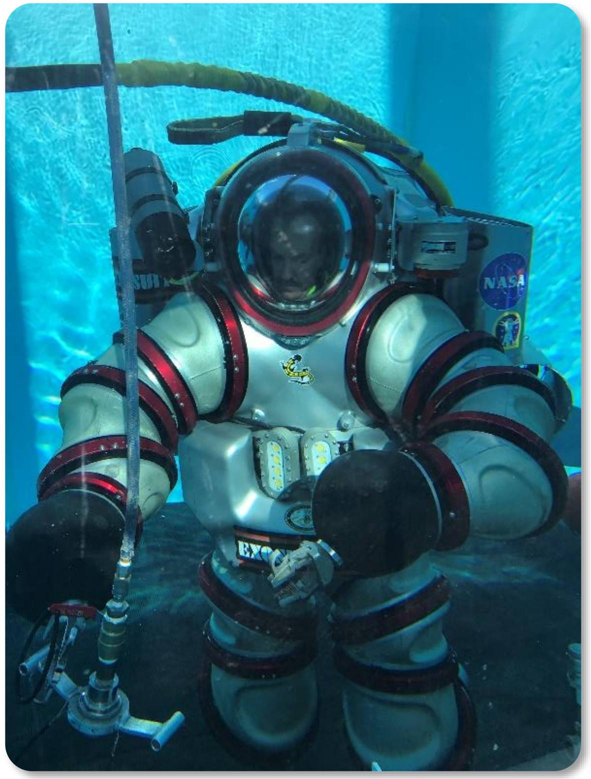


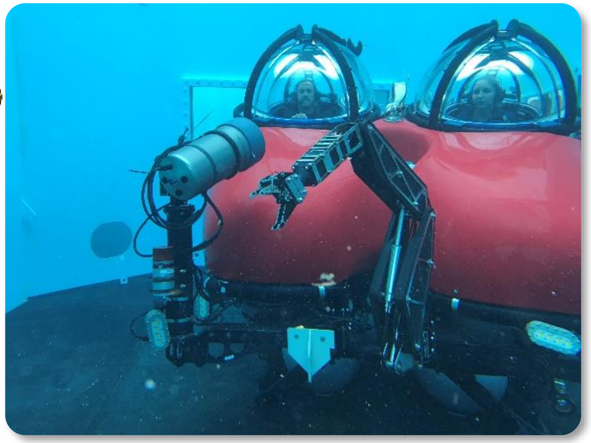




NEEMO Neoteric eXploration Technologies (NXT) Concept (pre-FaM)

- Concept currently in development for a potential add-on and possible follow-on for NEEMO
- Focuses on Exploration operations development and training, xEVA informatics, xEVA con ops, and integration of science operations
- Offers a high intensity operationally challenging environment, with high workload, elevated stress, high band-width, time pressure, and unexpected external perturbations
- Utilizes Nuytco Research Exosuit Atmospheric Diving System (ADS) and Dual DeepWorker submersible
- Exosuit provides a restrictive suit that requires effort for positioning and working somewhat analogous to an EVA suit, along with a relatively large helmet volume at 1 ATM to evaluate off-the-shelf informatics hardware





NXT: Nuytco Assets for NXT

EXOSUIT

- Atmospheric Diving System (ADS) that's an analogous restrictive suit
- Requires effort for positioning and working, as does an EVA suit
- Helmet volume at 1 ATM allows for evaluation of off-the-shelf informatics hardware (Lumus DK-52, similar to DAVD)
- Potential to continue collaboration with the U.S. Navy (e.g., DAVD & suits)
- Potential partnership with Nuytco for spacesuit develop (e.g., joints)

Dual Deepworker

- Two person submersible analogous to an excursion rover, with a Pilot and an Observer
- Pilot and Observer split flying, camera, manipulator, and observation duties
- Requires effort for positioning and working
- Utilized during NEEMO 15 & 16
- Feasibility evaluated by NASA READy MMT (Todd, Young, Coan, Graff, Reagan)
- Used for Science Operations

NXT: Feasibility Mission (FaM) Overview

Overview

- 10-day feasibility evaluation based out of USC Wrigley Marine Science Center on Catalina Island, CA
- Objectives focused on mission feasibility, crew experience and exploration training, science operations, and potential Exploration EVA capabilities
- Operations take place separately on both land and in water (“surf & turf”)
- Partners with NASA include ESA, JAXA, and Nuytco Research
- No commercial partners involved in FaM

Key Dates

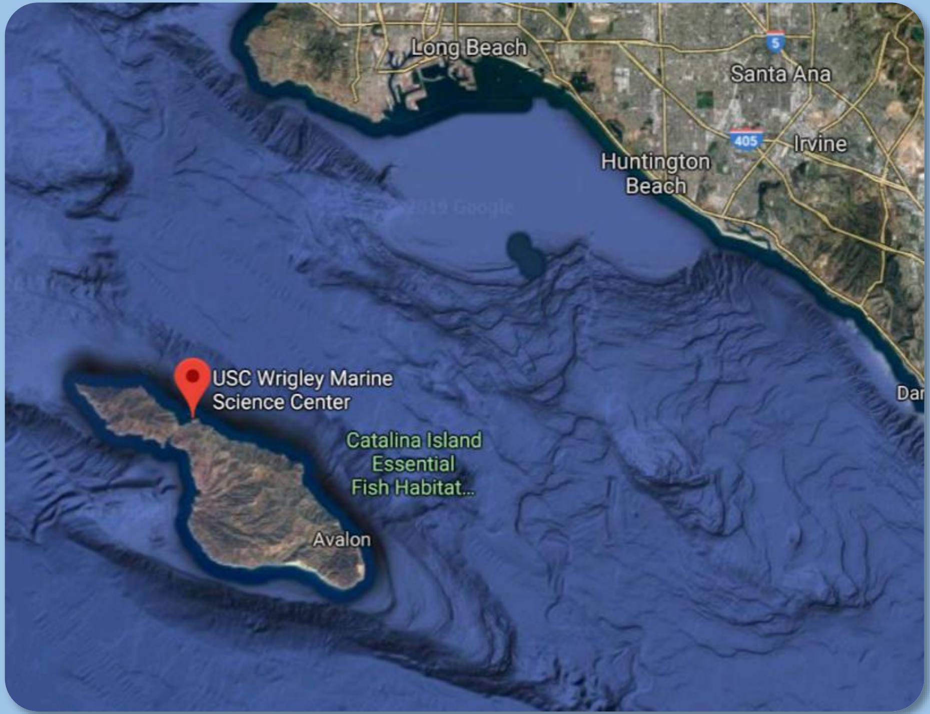
- Training Readiness Review (TrRR): August 6, 2019
- Feasibility Mission dates: August 19 – 28, 2019

Mission Management Team (MMT)

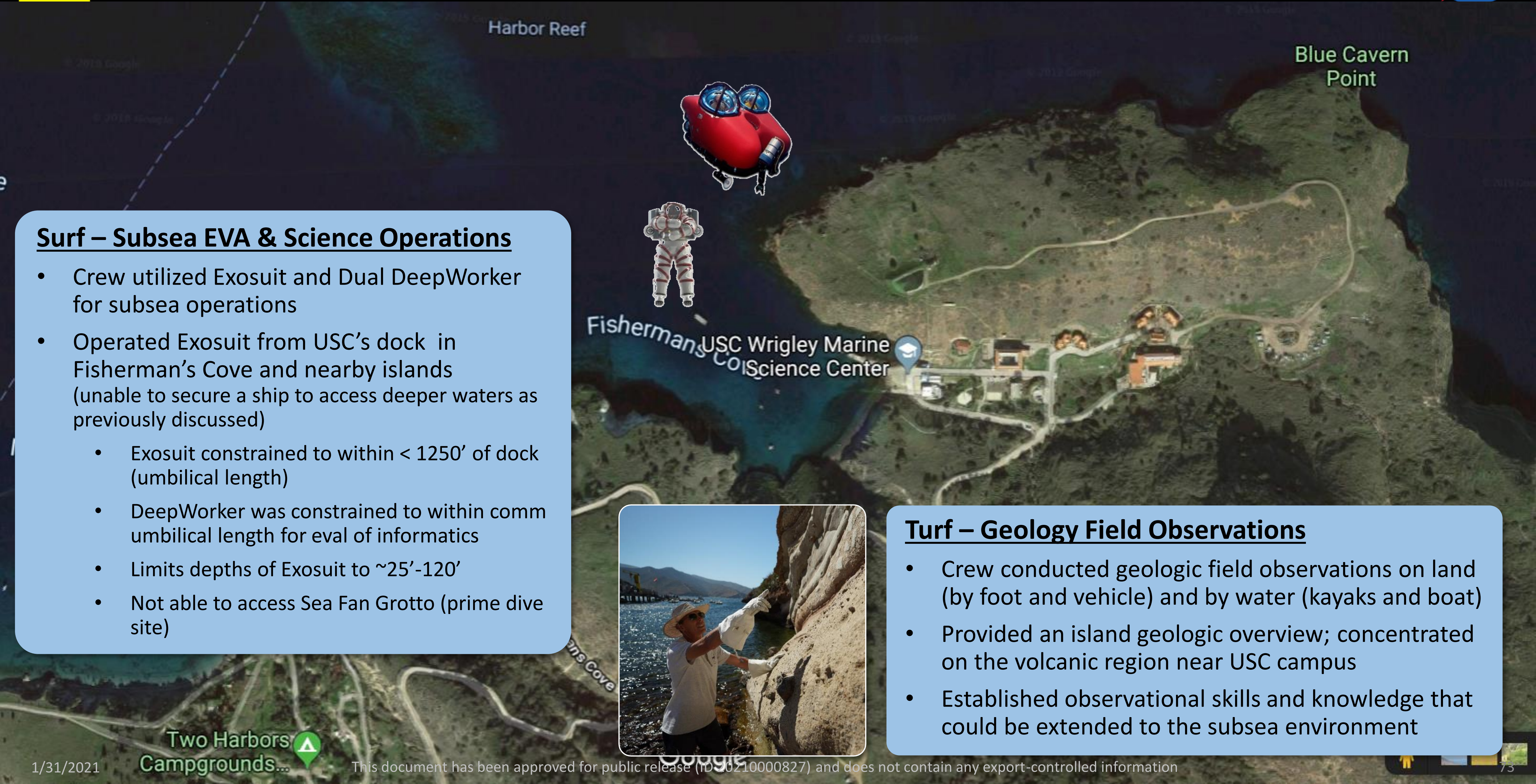
- David Coan (XX/EVA Lead)
- Trevor Graff (XI/Integration Lead)
- Jordan Lindsey (XX/EVA)
- Marc Reagan (XM/Mission Director)
- Bill Todd (XM/Project Specialist)
- Kelsey Young (XI/Science Lead)

Location

- Catalina Island, CA
- USC Wrigley Marine Science Center
  - Used as base of operations and for housing, with everything from maintenance facilities to working labs
  - Decompression chamber onsite at USC
- Local cove used for operations
- Allowed for “surf & turf” model



NXT: Field Location for FaM – USC Wrigley Marine Science Center, Catalina Island, CA



Surf – Subsea EVA & Science Operations

- Crew utilized Exosuit and Dual DeepWorker for subsea operations
- Operated Exosuit from USC's dock in Fisherman's Cove and nearby islands (unable to secure a ship to access deeper waters as previously discussed)
  - Exosuit constrained to within < 1250' of dock (umbilical length)
  - DeepWorker was constrained to within comm umbilical length for eval of informatics
  - Limits depths of Exosuit to ~25'-120'
  - Not able to access Sea Fan Grotto (prime dive site)

Turf – Geology Field Observations

- Crew conducted geologic field observations on land (by foot and vehicle) and by water (kayaks and boat)
- Provided an island geologic overview; concentrated on the volcanic region near USC campus
- Established observational skills and knowledge that could be extended to the subsea environment