NBL xEVA Lunar DAVD Test Series 1 (2020)

Dive Helmet Test for DAVD Informatics and EVA Geology Tools

EVA-EXP-0079

04 August 2020

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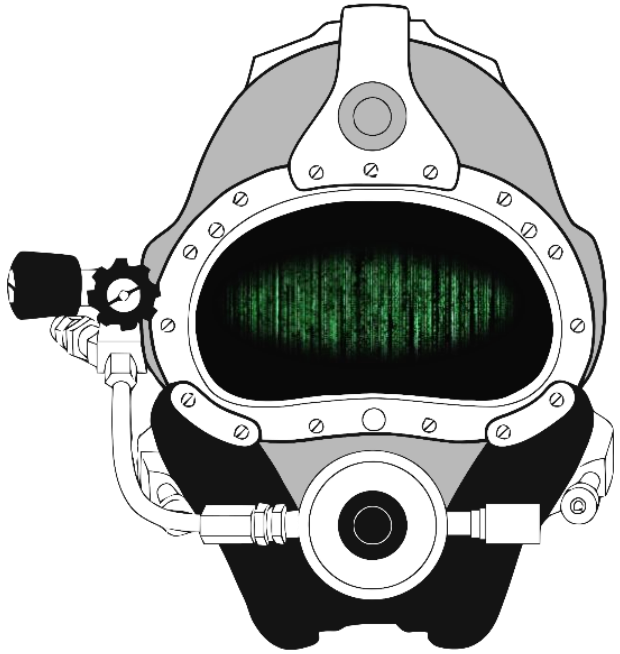
Photo credit: T. Graff



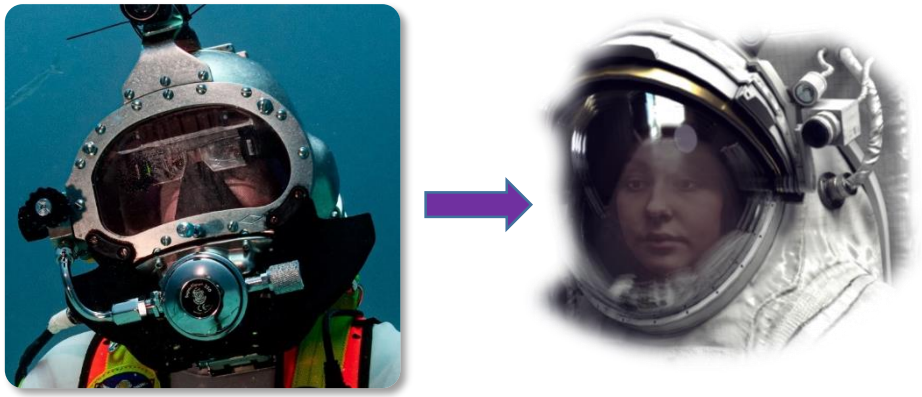
Goals, Objectives, and Equipment

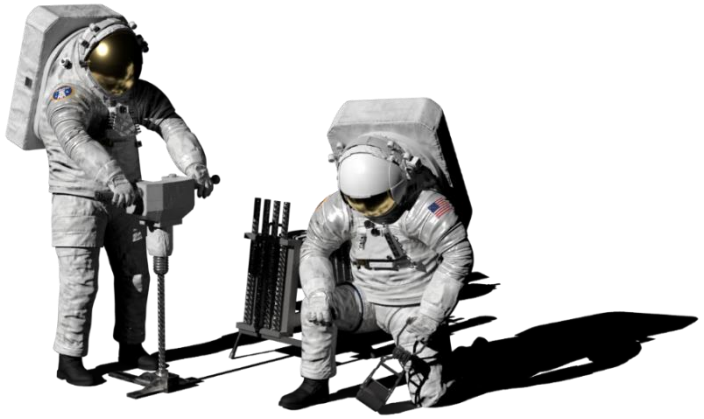
Goals of the NBL Lunar Dive Helmet Test for DAVD & Geology Tools

The primary goal of this set of runs was to conduct engineering **checkout/acceptance test dives** with the **Diver Augmented Vision Display (DAVD)** and the **Coda Octopus Echoscope C-500 3D sonar** for use during **Exploration Extravehicular Activity (xEVA)** development testing and astronaut training, along with evaluating the current **Artemis Geology Tools**

NASA

- Conduct acceptance testing and evaluate DAVD as a capability testing platform for developing an EVA Informatics Heads-Up Display (HUD)
- Conduct acceptance testing of the CODA Echoscope C-500 3D sonar as a capability testing platform for developing EVA navigation on the lunar surface (e.g., with a LIDAR system)
- Test the current geology sampling tools and tool management equipment (Artemis Geology Tools)
- Utilize runs for Exploration EVA concept of operations testing for Artemis lunar missions
- Test dive the new weigh-out wetsuit and mockup PLSS





Navy

- Test DAVD Gen 1 system in production with CODA for Navy fleet divers
- Evaluate advances in system for the Gen 2

These dives will evaluated xEVA capabilities and test sampling procedures, and didn't assess any timeline

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

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**

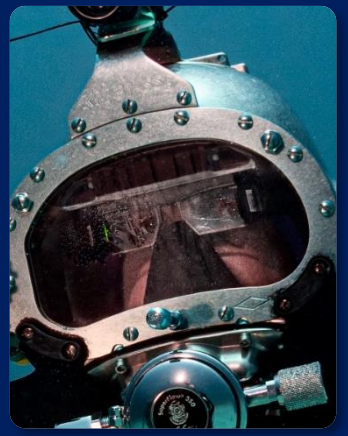
Robotic Operations
- Autonomous vs Crew Controlled
- Human-Robotic Interfaces

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**

Primary Goals/Objectives for Acceptance Testing in NBL

Following a “crawl, walk, run” approach, the primary goals/objectives for the test runs/dives involved acceptance testing of the equipment, and initial evaluation of potential ops and capabilities, including the following:

- Acceptance testing of the DAVD system in the NBL (simulating xEVA HUD)
- Acceptance testing of the Echoscope C-500 in the NBL (simulating potential area scanning system)
- Acceptance testing and initial evaluation with diver wearing the EVA tool management system
- Evaluation of the current geology sampling tools
- Initial operational use of new Surface Supplied Diving (SSD) and KM37/97 dive helmets in NBL by test subjects
- Initial test with the newly expanded lunar testing area in the NBL
- Acceptance testing and evaluation of the new weighout wetsuit and mockup PLSS in the NBL
- Initial look at utilizing NBL runs for Exploration EVA concept of operations testing for Artemis lunar missions
- Test dives for the Navy before they deploy DAVD to the USN fleet divers

Additional xEVA Test Objectives Linked to EVA Gaps

1. Evaluate the Diver Augmented Vision Device (DAVD) as an xEVA Informatics testing platform
2. Evaluate utilizing a dive helmet as an analog to a spacesuit for testing xEVA concepts of operations and equipment in the NBL
3. Evaluate EVA geology sampling tools for a lunar surface mission
4. Evaluate and determine tool & sample management and transportation

The test plan and details for the objectives are tracked on the NBL xEVA Lunar Test Series 1 wiki page

EVA Test Objective – Evaluate DAVD for xEVA Informatics

Evaluate the Diver Augmented Vision Device (DAVD) as an xEVA Informatics testing platform

Test Objective:61

Contents [hide]

Operational Relevance [edit source]

Provides information on a potential platform for future xInformatics testing.

Related Test Events [edit source]

The following Category:Test events included this objective:

	Data parameters	Data products
2020/07/16 NBL KM37 + KM97 Test	Test Data Parameter: Video Test Data Parameter: Unstructured Feedback Test Data Parameter: Photography	List: • Talk:Test_Event:16#Test_Objective:61 • Video/Photos: \\JS-NBL-Video\NBL-Video\2020\2020-07\2020-07-16-LUNAR-1-6G-SCUBA
2020/07/17 NBL KM37 + KM97 Test	Test Data Parameter: Video Test Data Parameter: Unstructured Feedback Test Data Parameter: Photography	List: • Talk:Test_Event:17#Test_Objective:61 • Video/Photos: \\JS-NBL-Video\NBL-Video\2020\2020-07\2020-07-17-LUNAR-1-6G-SCUBA

Evaluate the Diver Augmented Vision Device (DAVD) as an xEVA Informatics testing platform

Moon-to-Mars Domain: EVA

Category: Exploration Informatics Subsystem,Facilities Assessment

Sponsors	• XX : EVA Office
Stakeholders	• XX : EVA Office
Related EVA Gaps:	• EVA Gap: xInformatics Capability for xEVA Suit
Related articles:	• Exploration EVA System Concept of Operations • NBL xEVA Lunar Test 1 • NBL xEVA Lunar Test Series 1 • NBL xEVA Lunar Test Series 3
Target test environments:	• NBL • NEEMO

Hardware

Required	• Diver Augmented Vision Device (DAVD)

PACES

All test objectives

EVA Test Objective – Evaluate SSD/Dive Helmet for xEVA Con Ops Tests

Evaluate utilizing a dive helmet as an analog to a spacesuit for testing xEVA concepts of operations and equipment in the NBL

Test Objective:53

Contents [hide]

Operational Relevance [edit source]

Utilizing dive helmets (e.g., KM97 and KM37) in the NBL will allow for quick and early evaluation of xEVA concepts of operations and equipment.

Testing the use of dive helmets with SME (with hard hat and spacesuit experience) will determine how applicable the helmets are for developing the Exploration EVA System Concept of Operations and Exploration EVA Tools & Equipment required for lunar surface missions. This will also allow for determination of whether the NBL can be effectively utilized for early NEEMO EVA training.

- Use of KM97 SSDS for Exploration EVA System Concept of Operations testing
- Eval new weigh-out (wetsuit with weight plates) for lunar test subjects
- Demo of Diver Augmented Vision Device (DAVD) and eval for Exploration EVA Informatics
- Eval of Artemis Geology Tools
- Use of NBL for NEEMO EVA training

Related Test Events [edit source]

The following Category:Test events included this objective:

	Data parameters	Data products
2020/07/16 NBL KM37 + KM97 Test	Test Data Parameter: Video Test Data Parameter: Unstructured Feedback Test Data Parameter: Photography	List: • Talk:Test_Event:16#Test_Objective:53 • Video/Photos: \\JS-NBL-Video\NBL-Video\2020\2020-07\2020-07-16-LUNAR-1-6G-SCUBA
	Test Data Parameter: Video Test Data Parameter:	List:

Evaluate utilizing a dive helmet as an analog to a spacesuit for testing xEVA concepts of operations and equipment in the NBL

Moon-to-Mars Domain: EVA

Category: Facilities Assessment

Sponsors
- XX : EVA Office

Stakeholders
- XX : EVA Office
- XI : ARES

Related EVA Gaps:
- EVA Gap: xInformatics Capability for xEVA Suit
- EVA Gap: Tool Transport on Surface EVAs
- EVA Gap: Defined Sample Types (Tool Design)
- EVA Gap: Sample Containment
- EVA Gap: Tools for Science Sampling on Surface EVAs

Related articles:
- Exploration EVA System Concept of Operations
- Diver Augmented Vision Device (DAVD)
- Artemis NBL Tests - Spring 2020
- Artemis NBL Tests - Spring 2020 Top Priority
- NBL xEVA Lunar Test 1

Target test environments:
- NBL

Hardware

Required
- KM97 dive helmet
- KM37 dive helmet
- Diver Augmented Vision Device

EVA Test Objective – Evaluate EVA Geology Sampling Tools

Evaluate EVA geology sampling tools for a lunar surface mission

Test Objective:29

Contents [hide]

Operational Relevance [edit source]

Geology tools will be critical for science mission success. The operational techniques will impact changes in the design of each tool. This objective provides test data for the design of the geology sampling tools for incorporation into the xEVA Tools CDR.

Related Test Events [edit source]

The following Category:Test events included this objective:

	Data parameters	Data products
2020/07/08 JSC Rock Yard Shirt sleeve Test	Test Data Parameter: Video Test Data Parameter: Unstructured Feedback Test Data Parameter: Photography	List: • Unstructured Feedback: Talk:Test_Event:15#Test_Objective:29 • Images: 2020/07/08 JSC Rock Yard Shirt sleeve Test • Video
2020/07/09 Advanced Spacesuit Lab Z-2.0 Test	Test Data Parameter: Unstructured Feedback	List: • Unstructured Feedback: Talk:Test_Event:7#Test_Objective:29 • Video
2020/07/16 NBL KM37 + KM97 Test	Test Data Parameter: Video Test Data Parameter: Unstructured Feedback Test Data Parameter: Photography	List: • Talk:Test_Event:16#Test_Objective:29 • Video/Photos: \\JS-NBL-Video\NBL-Video\2020\2020-07\2020-07-16-LUNAR-1-6G-SCUBA
2020/07/17 NBL KM37 + KM97	Test Data Parameter: Video Test Data Parameter: Unstructured Feedback	List: • Talk:Test_Event:17#Test_Objective:29

Evaluate EVA geology sampling tools for a lunar surface mission

Moon-to-Mars Domain: EVA

Category: Tools

Sponsors	• XX : EVA Office
Stakeholders	• XX : EVA Office • EC7 : EVA Tools Engineering • XI : ARES • ER : Rovers • CX3 : FOD EVA
Related EVA Gaps:	• EVA Gap: Tool Transport on Surface EVAs • EVA Gap: Defined Sample Types (Tool Design) • EVA Gap: Sample Containment • EVA Gap: Tools for Science Sampling on Surface EVAs
Related articles:	• Exploration EVA System Concept of Operations • NEEMO 24 EVA • NEEMO 24 EVA Top Priority • Artemis NBL Tests - Spring 2020 • Artemis NBL Tests - Spring 2020 Top Priority • NBL xEVA Lunar Test 1 • NBL Artemis PACES Test Series 1
Target test environments:	• ARGOS • NBL • NEEMO
Target activity modules:	• Ambulatory Traverse (Lunar Surface) • Geology Sampling (Lunar Surface)

EVA Test Objective – Evaluate EVA Tool & Sample Management

Evaluate and determine tool & sample management and transportation

Test Objective:28

Contents [hide]

Operational Relevance [edit source]

Provides data for determining which tools should be mounted to suit and what sort of tool transport system is needed for lunar surface missions.

Where do samples go between EVAs?

What samples go back to Earth (if not all)? Trade between samples and equipment?

Related Test Events [edit source]

The following Category:Test events included this objective:

	Data parameters	Data products
2020/07/08 JSC Rock Yard Shirt sleeve Test	Test Data Parameter: Video Test Data Parameter: Unstructured Feedback Test Data Parameter: Photography	List: • Unstructured Feedback: Talk:Test_Event:15#Test_Objective:28 • Images: 2020/07/08 JSC Rock Yard Shirt sleeve Test • Video
2020/07/16 NBL KM37 + KM97 Test	Test Data Parameter: Video Test Data Parameter: Unstructured Feedback Test Data Parameter: Photography	List: • Talk:Test_Event:16#Test_Objective:28 • Video/Photos: \\JS-NBL-Video\NBL-Video\2020\2020-07\2020-07-16-LUNAR-1-6G-SCUBA
2020/07/17 NBL KM37 + KM97 Test	Test Data Parameter: Video Test Data Parameter: Unstructured Feedback Test Data Parameter:	List: • Talk:Test_Event:17#Test_Objective:28 • Video/Photos: \\JS-NBL-Video\NBL-Video\2020\2020-07\2020-07-17-LUNAR-1-6G-SCUBA

Evaluate and determine tool & sample management and transportation

Moon-to-Mars Domain: EVA

Category: Tools

Sponsors
- XX : EVA Office

Stakeholders
- XX : EVA Office
- CX3 : FOD EVA
- EC5 : EVA Suit Engineering
- EC7 : EVA Tools Engineering
- XI : ARES
- ER : Rovers

Related EVA Gaps:
- EVA Gap: Defined Sample Types (Tool Design)
- EVA Gap: Tool Transport on Surface EVAs

Related articles:
- Exploration EVA System Concept of Operations
- NEEMO 24 EVA
- NEEMO 24 EVA Top Priority
- Artemis NBL Tests - Spring 2020
- Artemis NBL Tests - Spring 2020 Top Priority
- NBL xEVA Lunar Test 1

Target test environments:
- ARGOS
- NBL
- NEEMO
- JSC Rock Yard

PACES

All test objectives

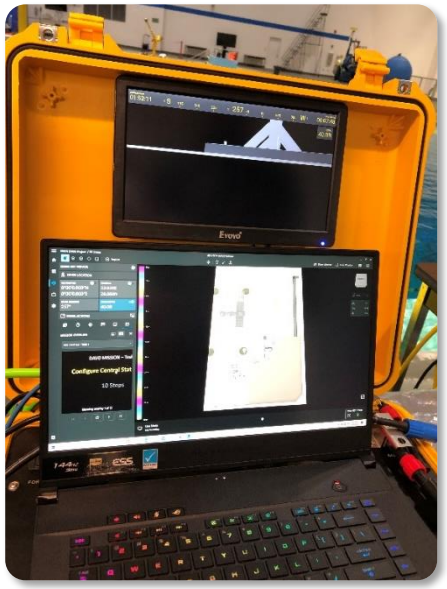
Diver Augmented Vision Display (DAVD) & Echoscope C500 3D Sonar

DAVD

- High-resolution see-through head-up display (HUD) embedded directly inside a diving helmet
- Allows a topside dive supervisor to relay visual mission data to the HUD via an Ethernet cable
- Divers can see augmented reality (AR) scenes, real-time images, videos, technical drawing, text style messaging, and step-by-step instructional sets
- Divers can also utilize real-time sonar imagery for navigation

Echoscope C-500

- Real-time 3D imaging sonar platform
- Analog for a LIDAR system on a lander



System Overview

Components:

- Topside control box
- Diver Processing pack (on diver)
- DAVD unit (inside helmet)
- Umbilical from topside to diver pack

TRR-2020-570

Return to TOC

15

NBL Surface Supplied Diving (SSD) with DAVD

System Overview Plan

Existing COTS Dive Equipment (Air SSDS)
TRR-2019-548

Existing NBL Surface Supplied Breathing Air

Existing NBL Video Interface

Existing KMACS-5 Comm. Interface

Computer for C-500 will be poolside. The Sonar will be independent of divers umbilical.

Control box for DAVD will be pool side. KM37 diver will be equipped with DAVD in helmet.

1 Kirby Morgan 97, 1 Kirby Morgan 37 **(DAVD)**

TRR-2020-570

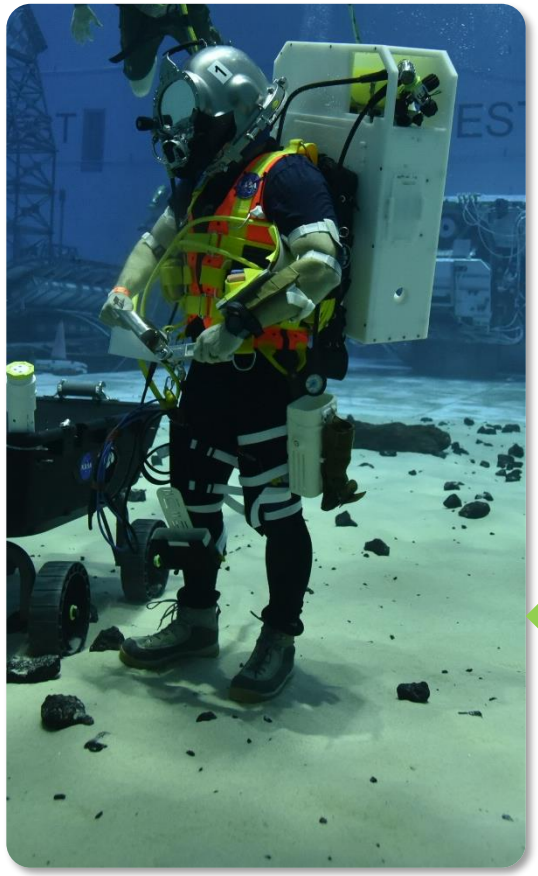
Return to TOC

The “Spacesuit”: SSD KM37/97 Helmet with Weighout Suit & Tools

SSD w/ KM37

KM37: Narrower FOV, Helmet movable

xEMU: Wider FOV, Helmet fixed



SSD w/ KM97 plus weighout suit & mPLSS

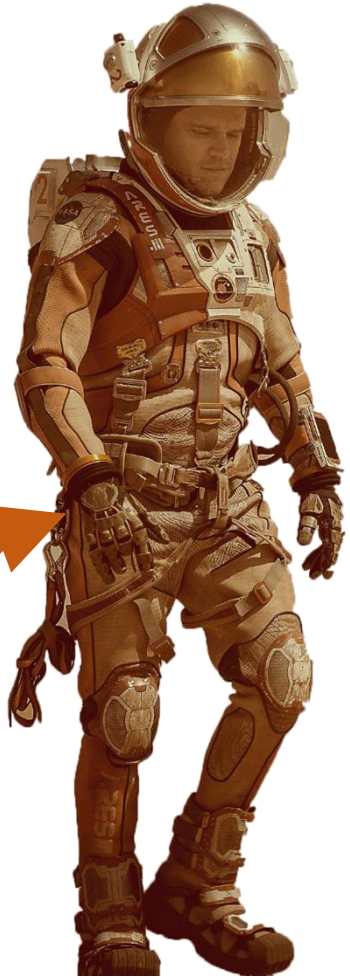
Dive helmet & system provide good analog to a spacesuit for concepts of operations evaluations

Both have different but comparable challenges for operations

EMU TMG with dive gloves simulates a pressurized glove

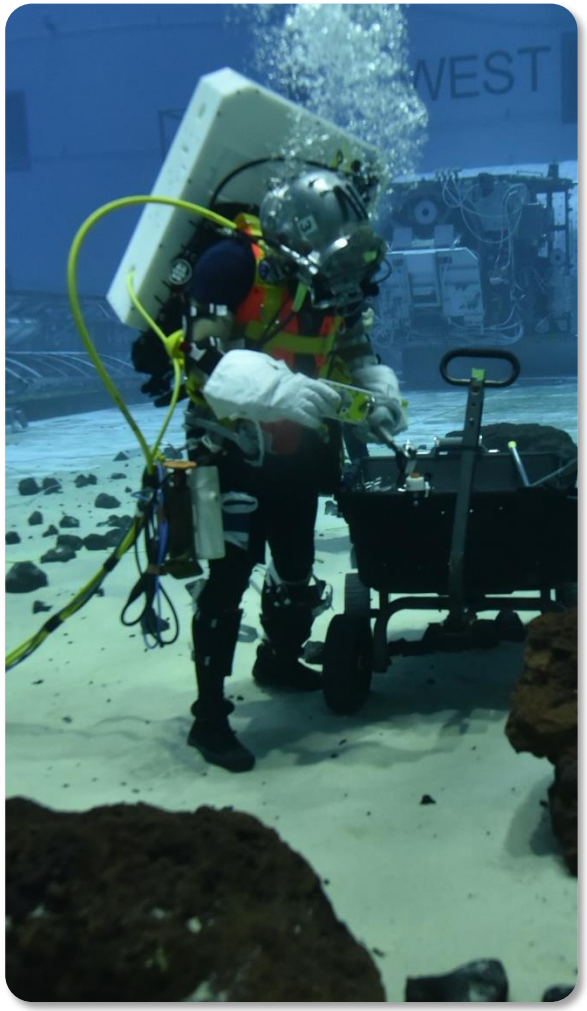
Wetsuit: Very flexible
xEMU: Pressurized, bulky

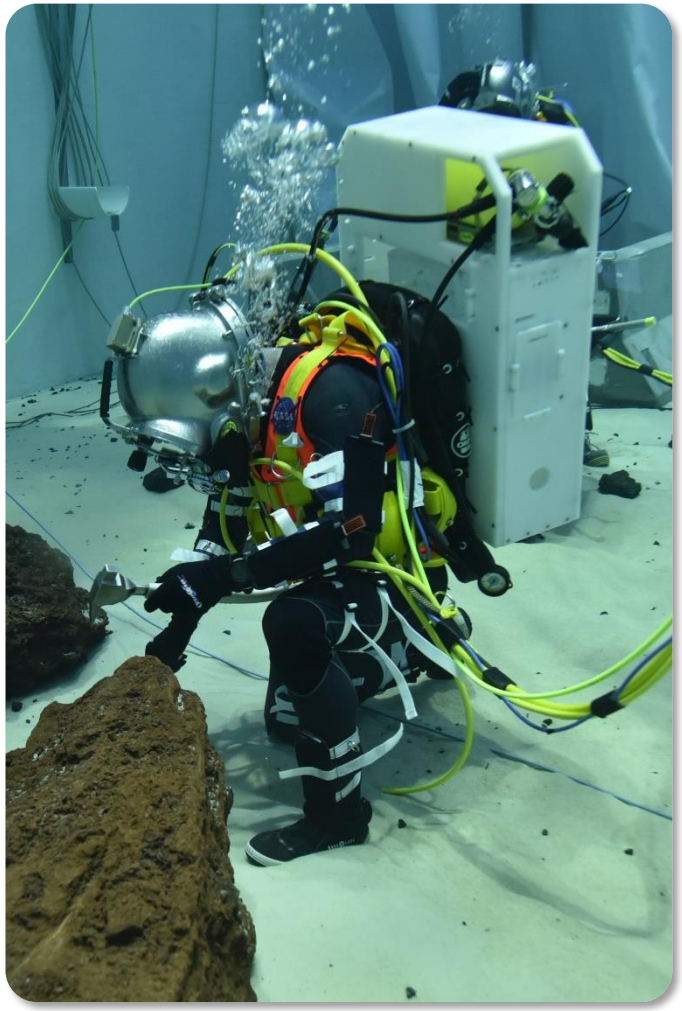
xEMU concept

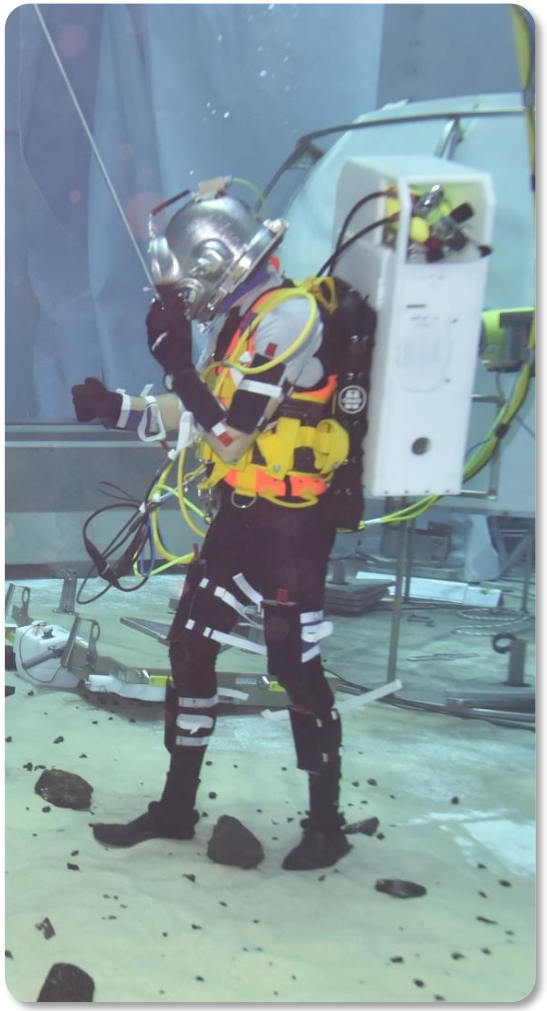


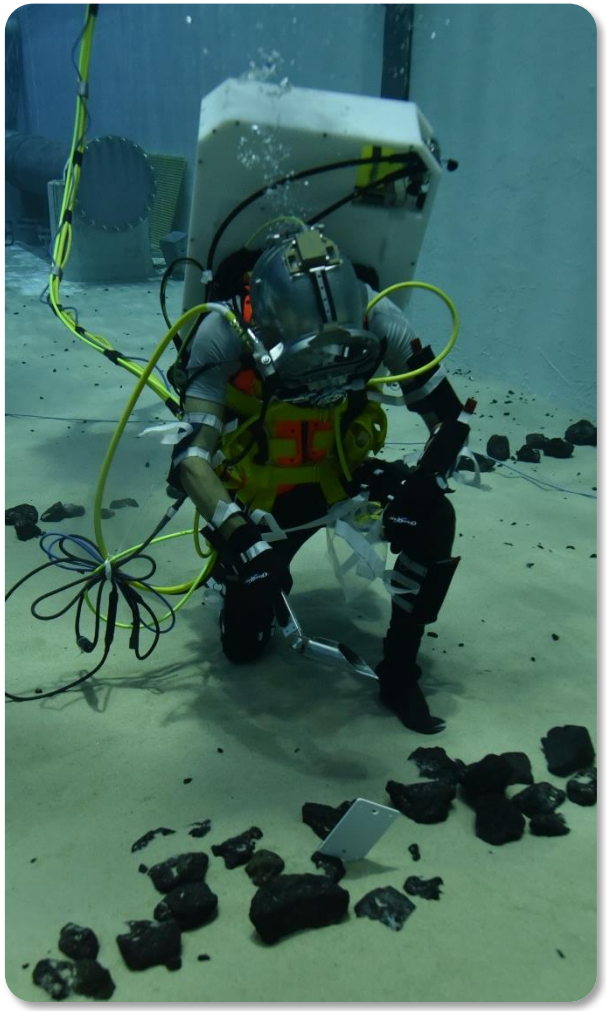
TBD mEMU concept
(courtesy of *The Martian*)

NBL Weighout Wetsuit & Mockup PLSS









EVA Science Sample Acquisition Tools and Tool Management System

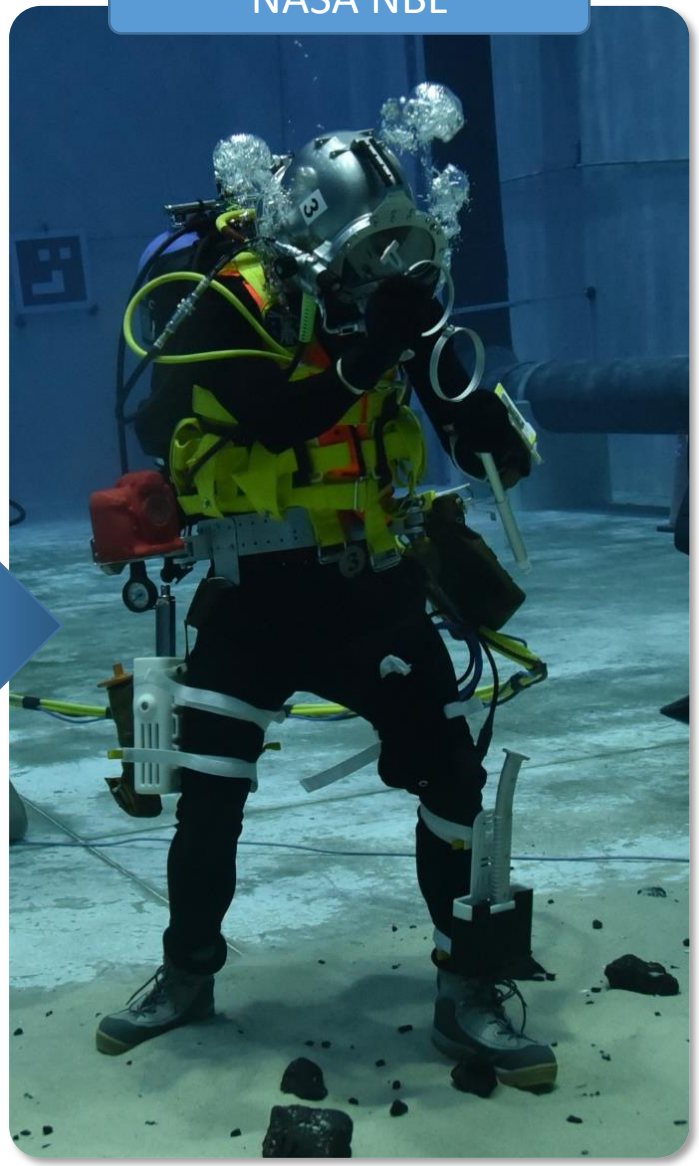
Lunar Surface Geology Tools

- Contingency Sampler
- Geology Hammer
- Tongs
- Scoops
- Rake
- Extension Handles
- Slide Hammer
- Drive Tube Kit
- 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

JSC Rock Yard

Multi-environment testing

NASA NBL



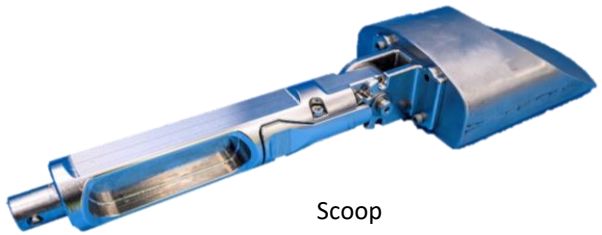
EVA Science Sample Acquisition Tools

Regolith Sample Acquisition

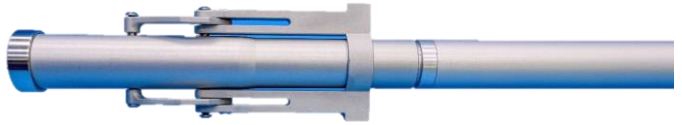
- **Bulk**: representative loose surface material [Scoop]
- **Core**: cylindrical sample of regolith at depth [Drive Tube / Drill]

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]



Scoop



Extension Handle

Scoop

Tongs, Straight

Rake

Contingency Sampler

Slide Hammer

Tongs, Angled

Hammer

Suit-Mounted Tool Management System Configuration

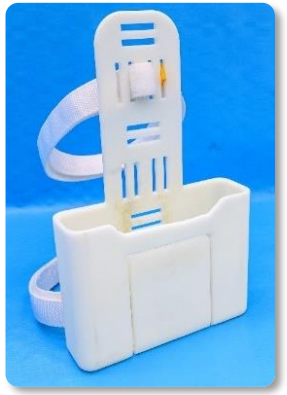
Utility Belt

Sample Dispenser

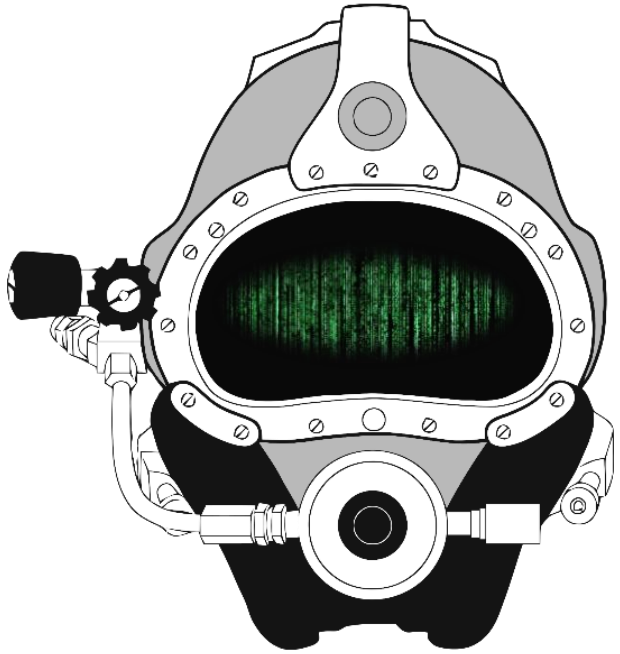
Camera

Leg Holster for Scoop and Chisel

Pocket for Contingency Sampler



Leg Holster for Hammer



Test Configuration & Dive Plan

Test Team

Test Team POCs

- Test Lead/Sponsor: David Coan
- NBL Flight Lead: Tim Morgan
- TC & Ops Lead: Daren Welsh
- Navy Lead: Paul McMurtrie
  - Coda Octopus: Blair Cunningham
  - DAVD Navy Project Manager: Allie Williams
- IV: Bridget Scheib
- Informatics: Matthew Miller and Skye Ray
- Science: Trevor Graff
- EVA Geology Tools: Adam Naids & Mary Walker
- Dive Integration: Mike Geyer & Jim Fuderer

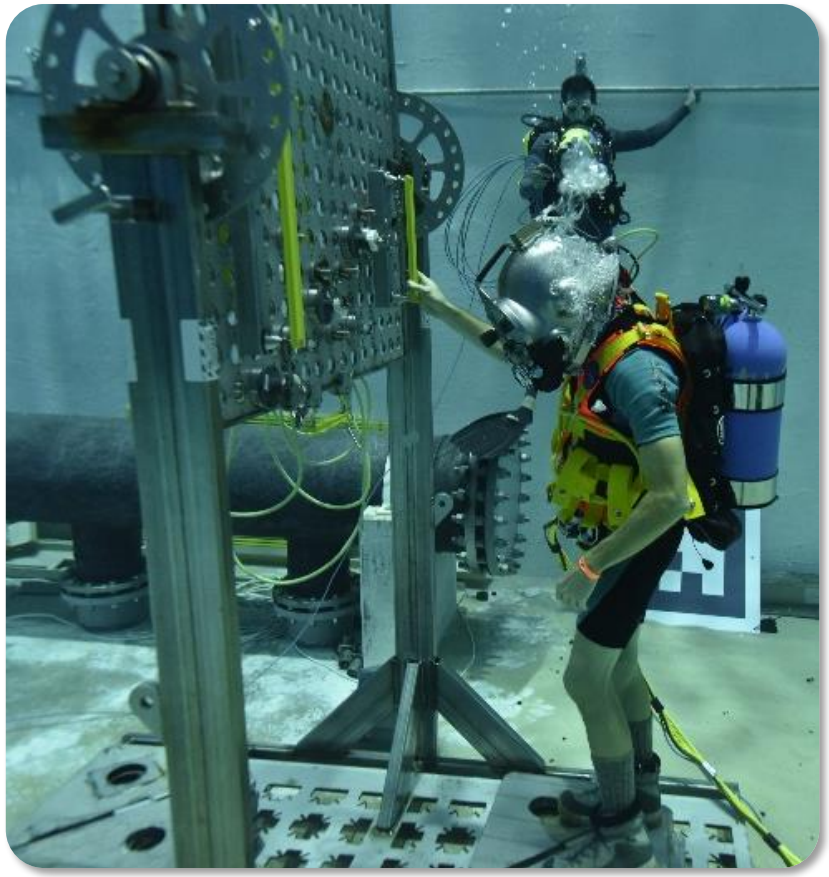
Test Subjects/Divers

- Vic Basher (NAVSEA 00C)
- Steve Bowen (CB/USN/Astronaut)
- David Coan (XX/EVA)
- Joshua Dumke (NAVSEA 00C/MDV)
- Drew Feustel (CB/Astronaut)
- Trevor Graff (XI/ARES)
- Art Levine (CX12/NBL)
- Adam Naids (EC7/EVA Tools)
- Don Pettit (CB/Astronaut)
- Scott Wray (CX3/FOD EVA)

NBL Pool Config for xEVA Lunar Area

xEVA Engineering Task Board (Central Station)

- Reconfigurable task board utilized primarily for ISS EVA training
- NZGL electrical connectors configured on board for use as an engineering task
- DAVD displays utilized to guide the crew through tasks on the board



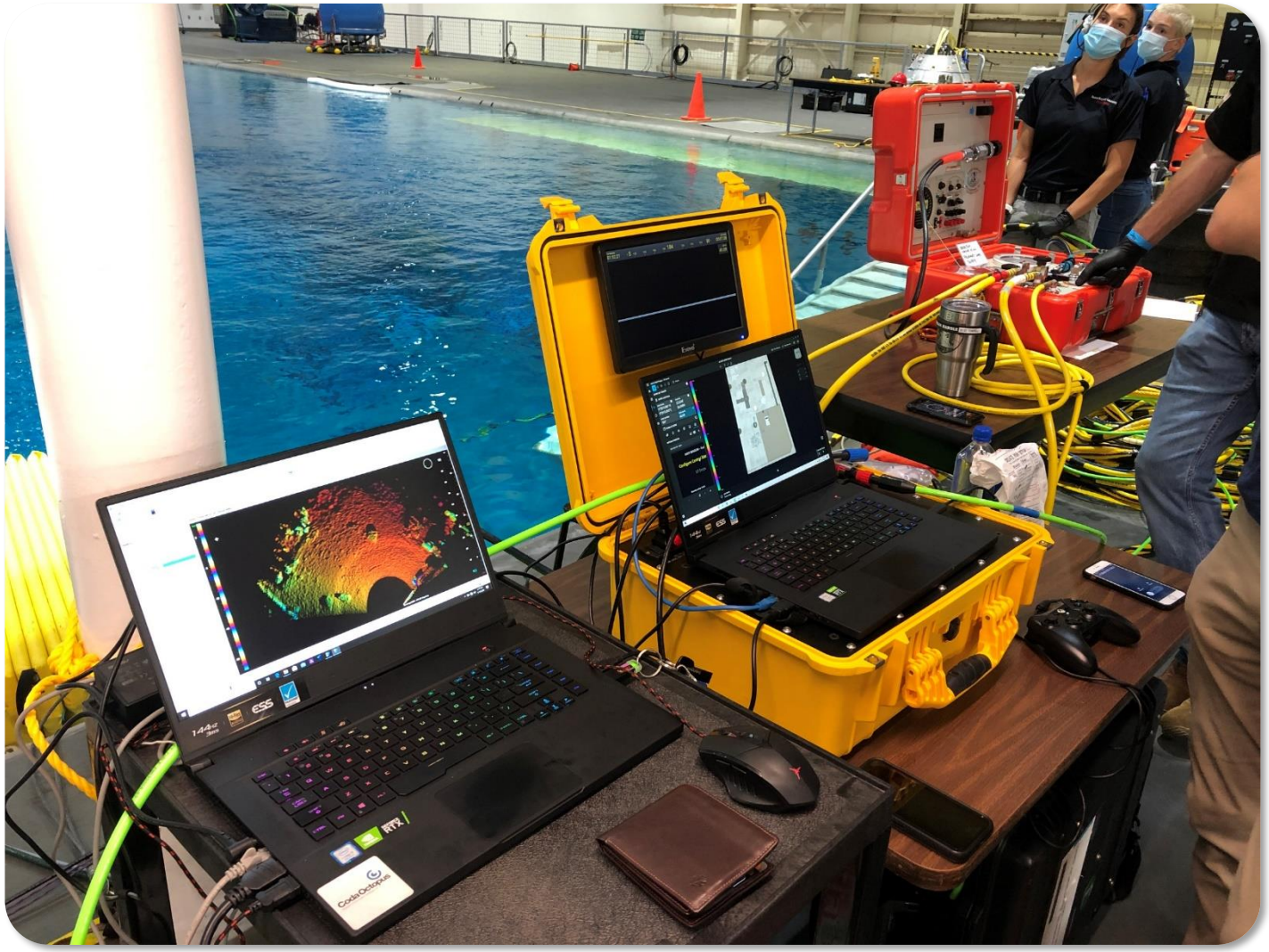
Dive Duty Stations

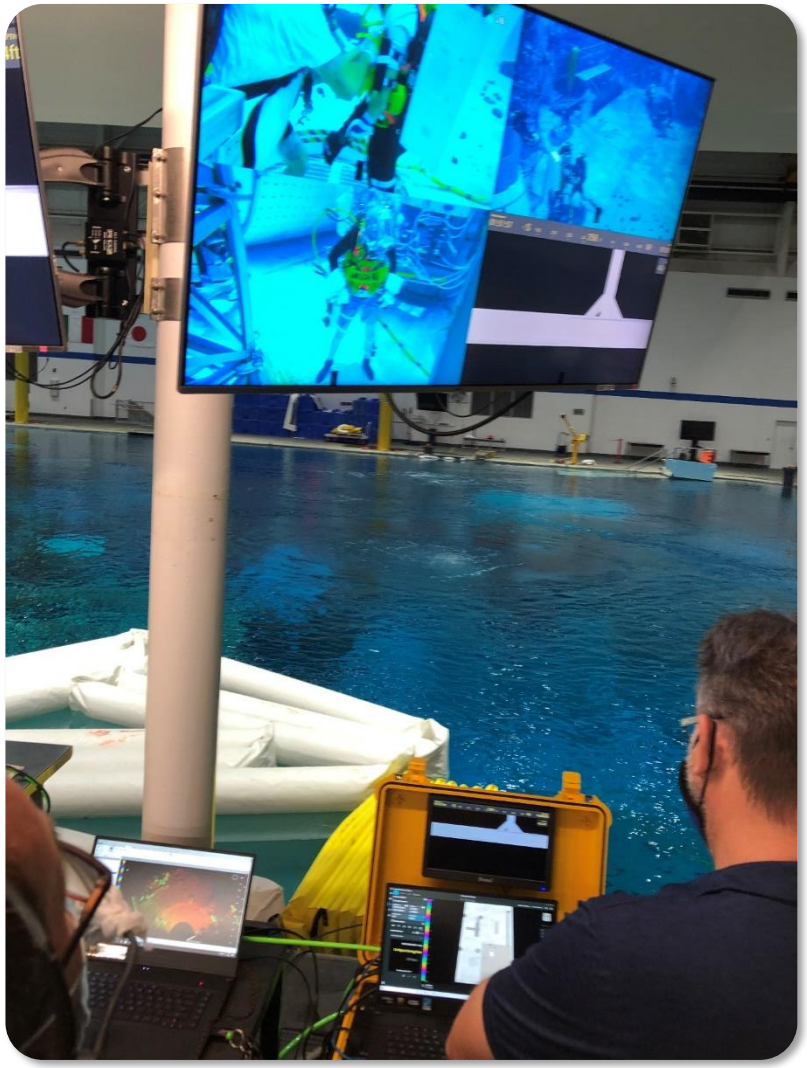
Diver Hatting

SSD Panel Operator

Navy/Coda Octopus

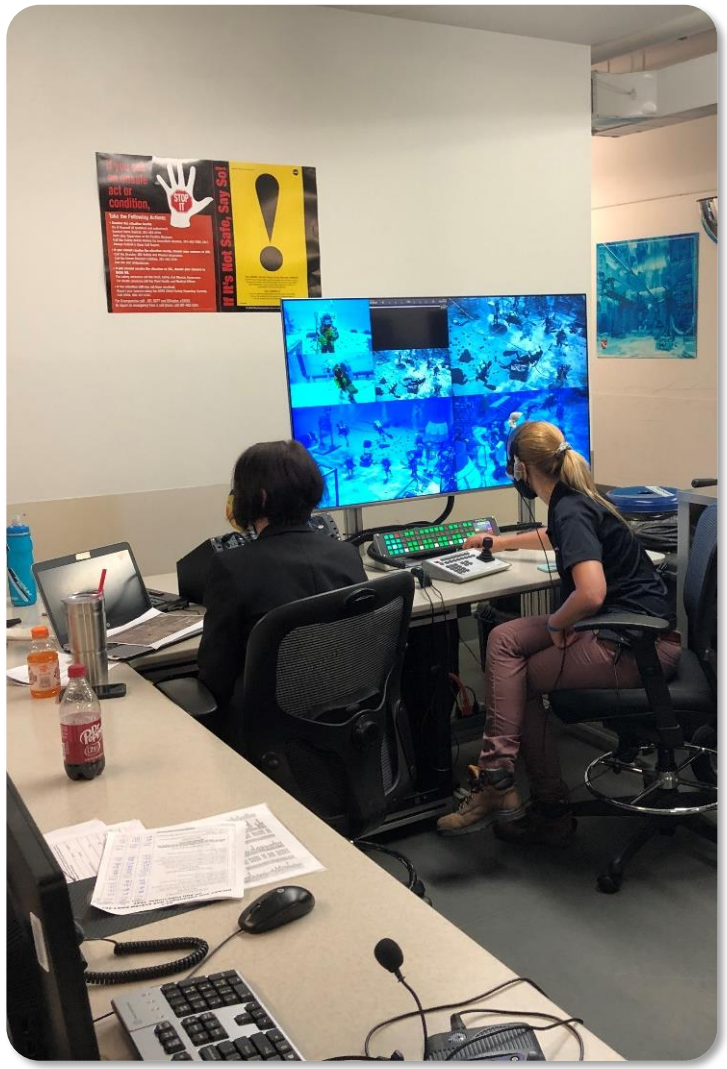
Topside Configuration of DAVD and C-500 Systems





EVA Simulation Duty Stations

Ground IV



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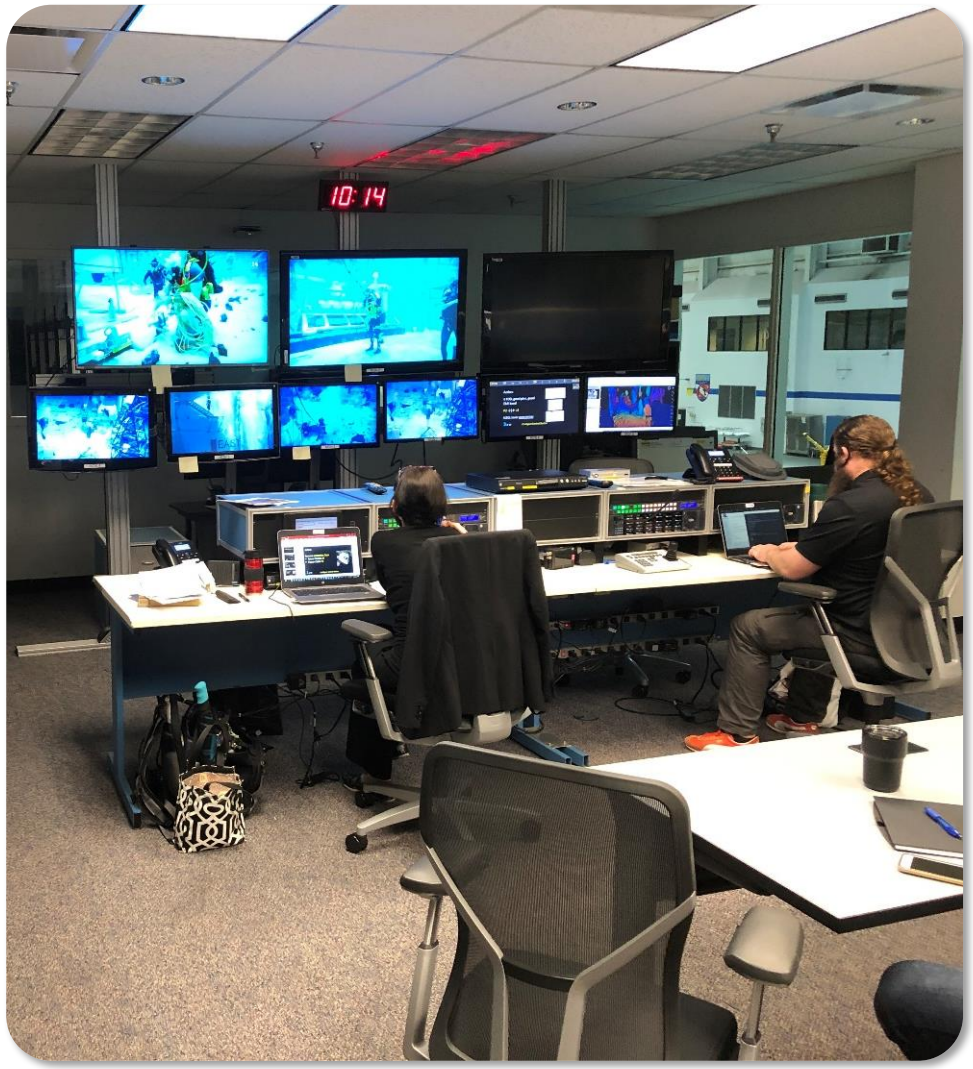
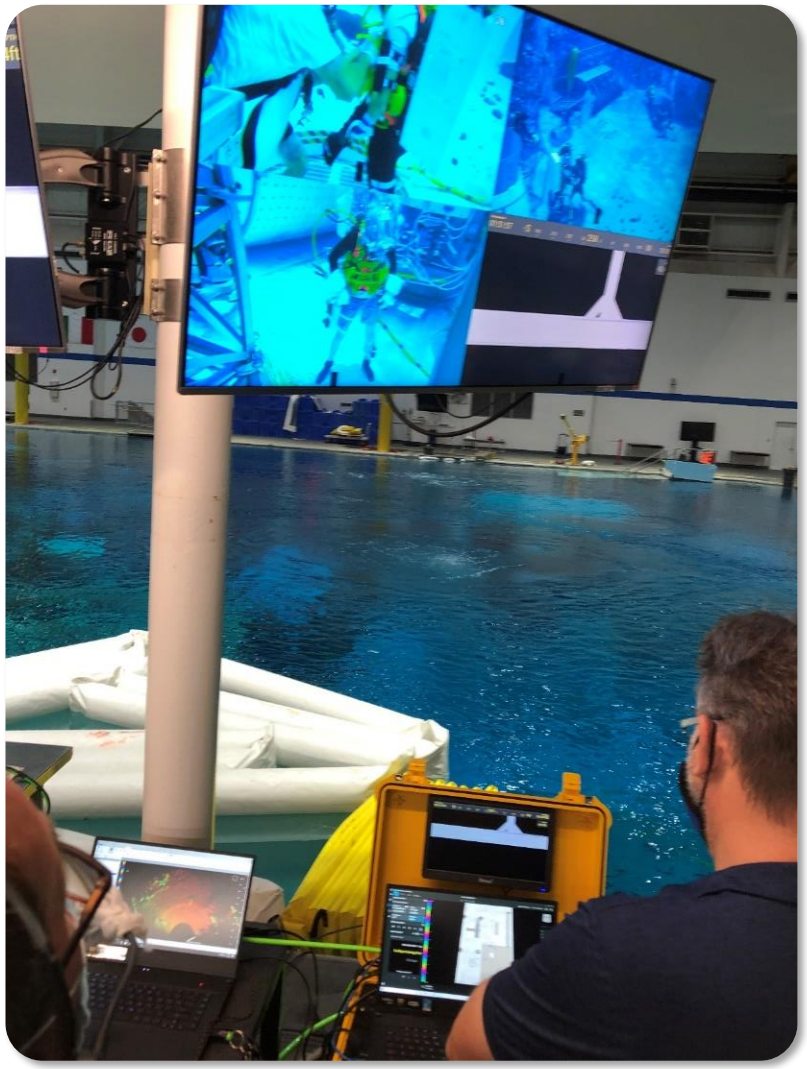


MPSR/MER



Underwater Weighout Board

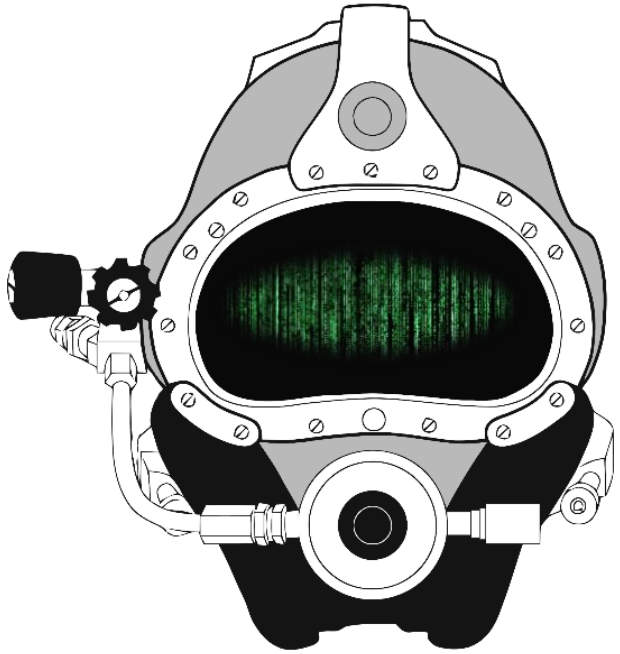
Dive Rotations

Dive Rotation Timeline for 16 July 2020

Time			
NBL Support	1st team - 1st dive 2:00 bottom time	Surface interval/lunch 1:50	1st team - 2nd dive 3:00 bottom time
White/EV1 (KM37 w/DAVD)	1st DAVD test subject 2:00 bottom time	Lunch Clean helmet	2nd DAVD test subject 2:15 bottom time
Red/EV2 (KM97)	1st KM97 test subject 2:00 bottom time	Lunch	2nd KM97 test subject 1:00 bottom time 3rd KM97 test subject 1:00 bottom time

Dive Rotation Timeline for 17 July 2020

Time				
NBL Support	1st team - 1st dive 3:00 bottom time		Surface interval/lunch 1:50	1st team - 2nd dive 2:00 bottom time
White/EV1 (KM37 w/DAVD)	1st DAVD test subject 1:15 bottom time	Clean helmet 2nd DAVD test subject 1:15 hour bottom time	Lunch	3rd DAVD test subject 2:00 bottom time
Red/EV2 (KM97)	1st KM97 test subject ~~1:30~~ 3:00 bottom time	~~2nd KM97 test subject~~ ~~1:15 bottom time~~	Lunch	~~3rd~~ 2nd KM97 test subject 2:00 bottom time



Dive Ops & Test Evaluations

Including cue cards utilized with DAVD

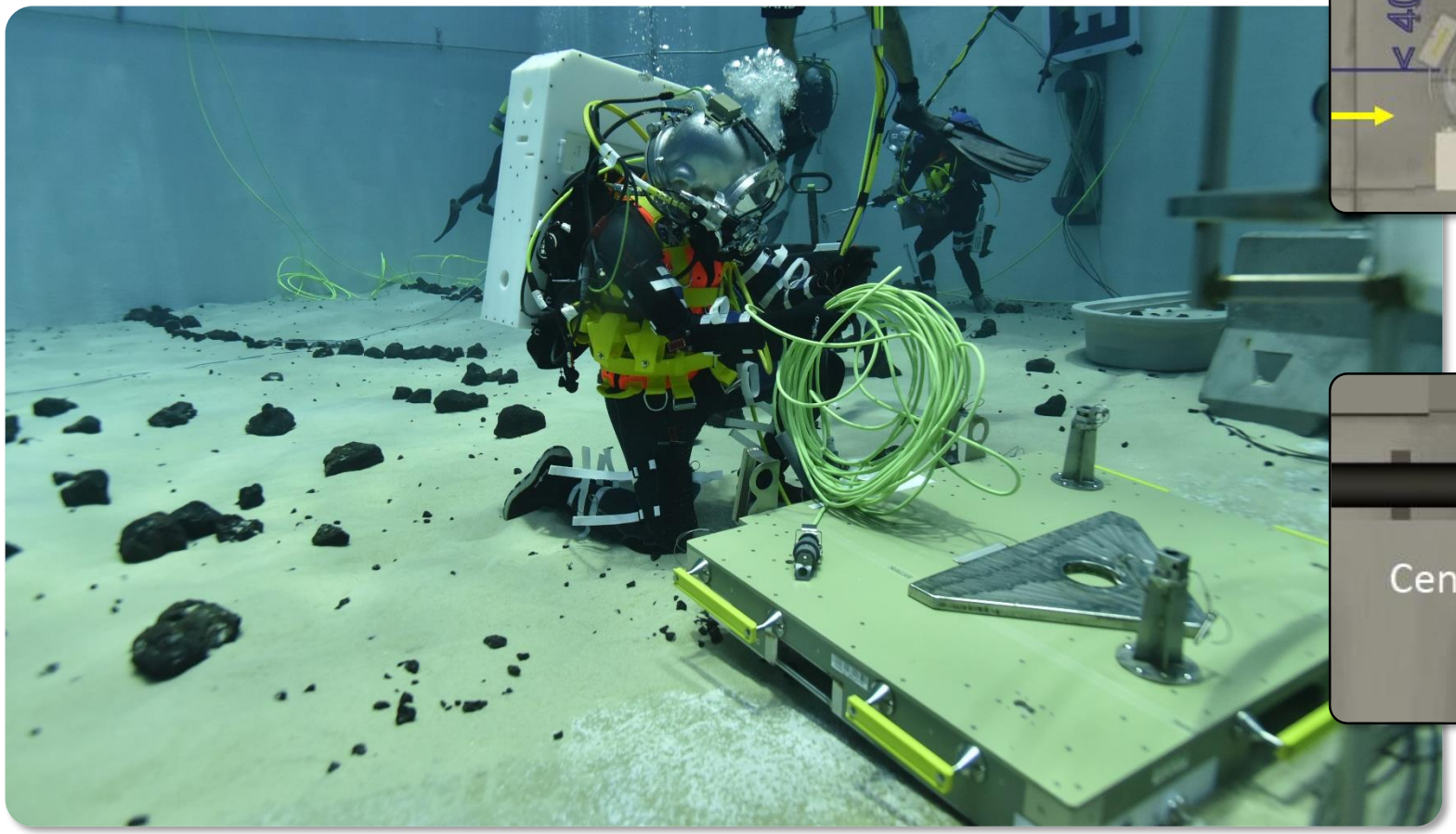
General Dive Plan Outline

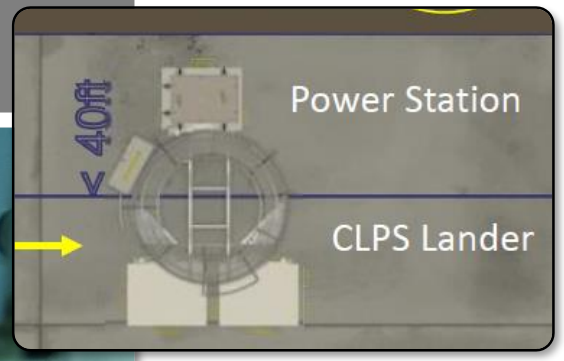
White/EV1 (KM37 w/DAVD)	Red/EV2 (KM97 w/Tools)
Suit up and topside checks (hat that diver)	Suit up and topside checks (hat that diver)
Splash and install weights	Splash and install weights
Weigh-out check and evaluation DAVD: cue cards with process and model of platform	Configure tools
Translate to lander/airlock and ingress DAVD: Map of pool config and text directions	Translate to lander/airlock
Egress lander	Egress lander
Route cable from Power Station to Central Station DAVD: Map and text directions	Translate to lunar area with METS
Configure Central Station DAVD: Cue cards directing how to reconfig board	Contingency sample and stow
Scoop sample procedure with extension handle DAVD: Cue cards with graphics	Scoop sample procedure with extension handle
Hammer sample with chisel (from boulder) and sample bags DAVD: Cue cards with graphics and text directions	Hammer sample with chisel (from boulder) and sample bags
Navigate across lunar area with C-500 data DAVD: Real-time feed of sonar	Core sample with drive tube and slide hammer
Traverse to lander and ingress	
Remove tools and weights	Remove tools and weights
Egress water	Egress water

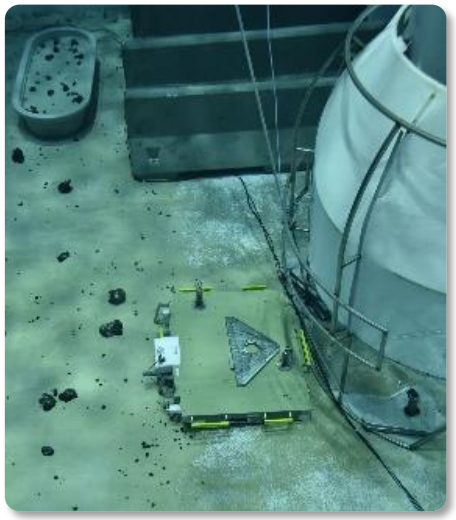
Surface EVA Engineering Tasks

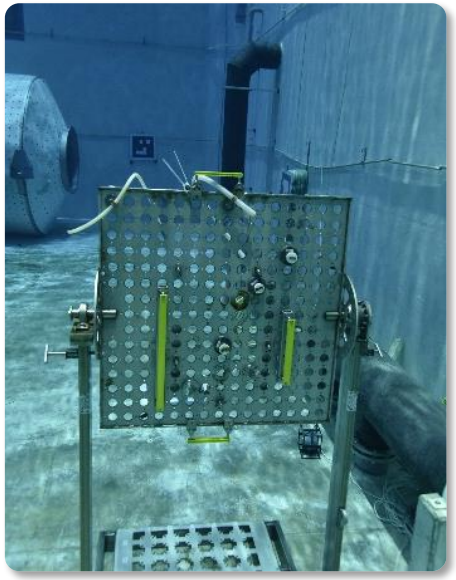
Construct Surface Infrastructure

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



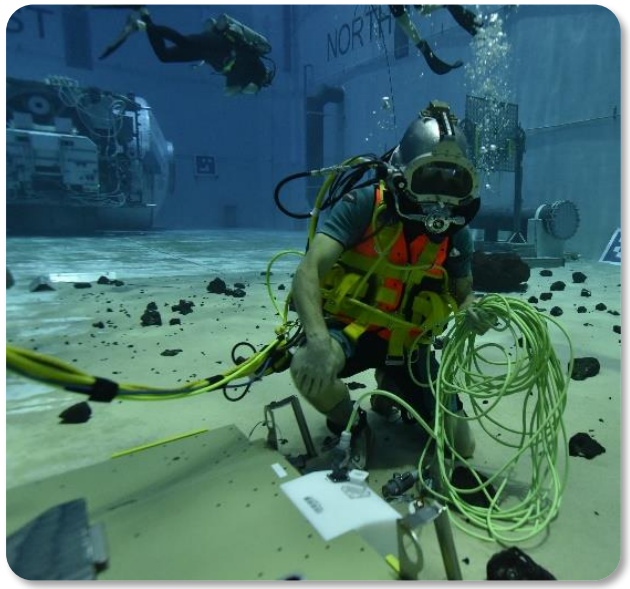


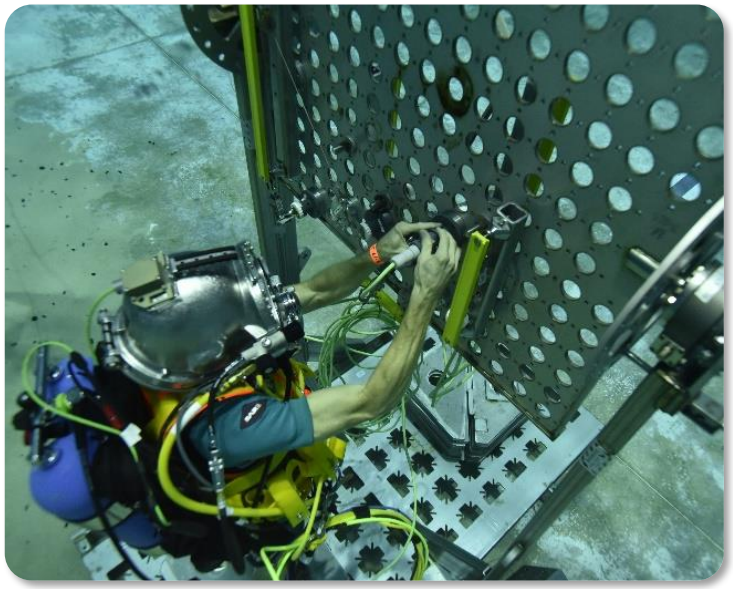


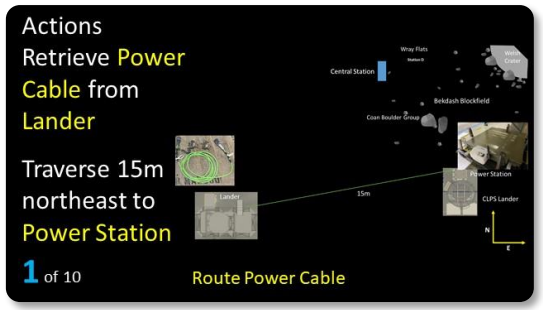


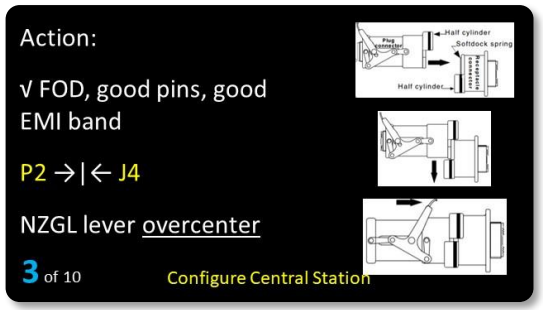
Evaluating Utilizing DAVD for xEVA Engineering Tasks

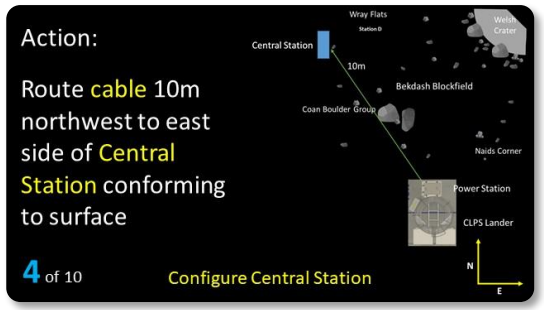
Retrieve power cable → Connect cable to Power Station → Route cable → Connect cable to Central Station

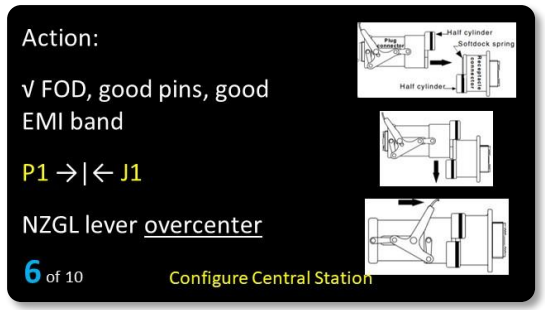






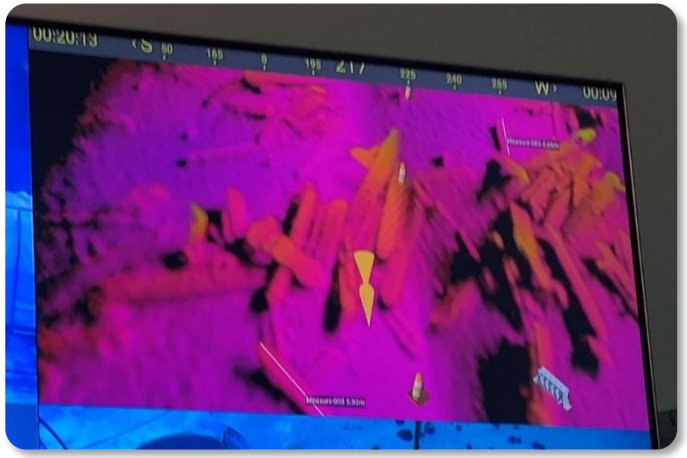




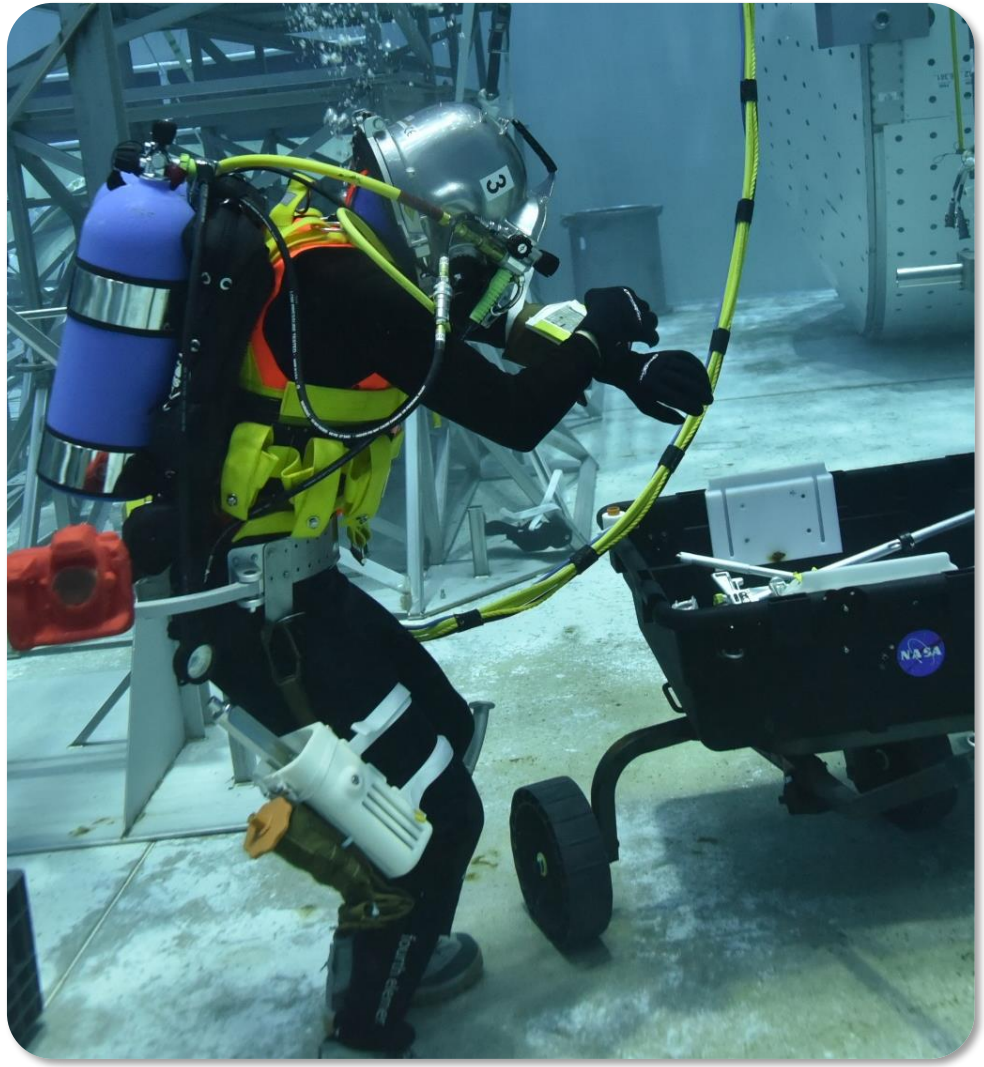


Evaluating Navigation with DAVD and C-500

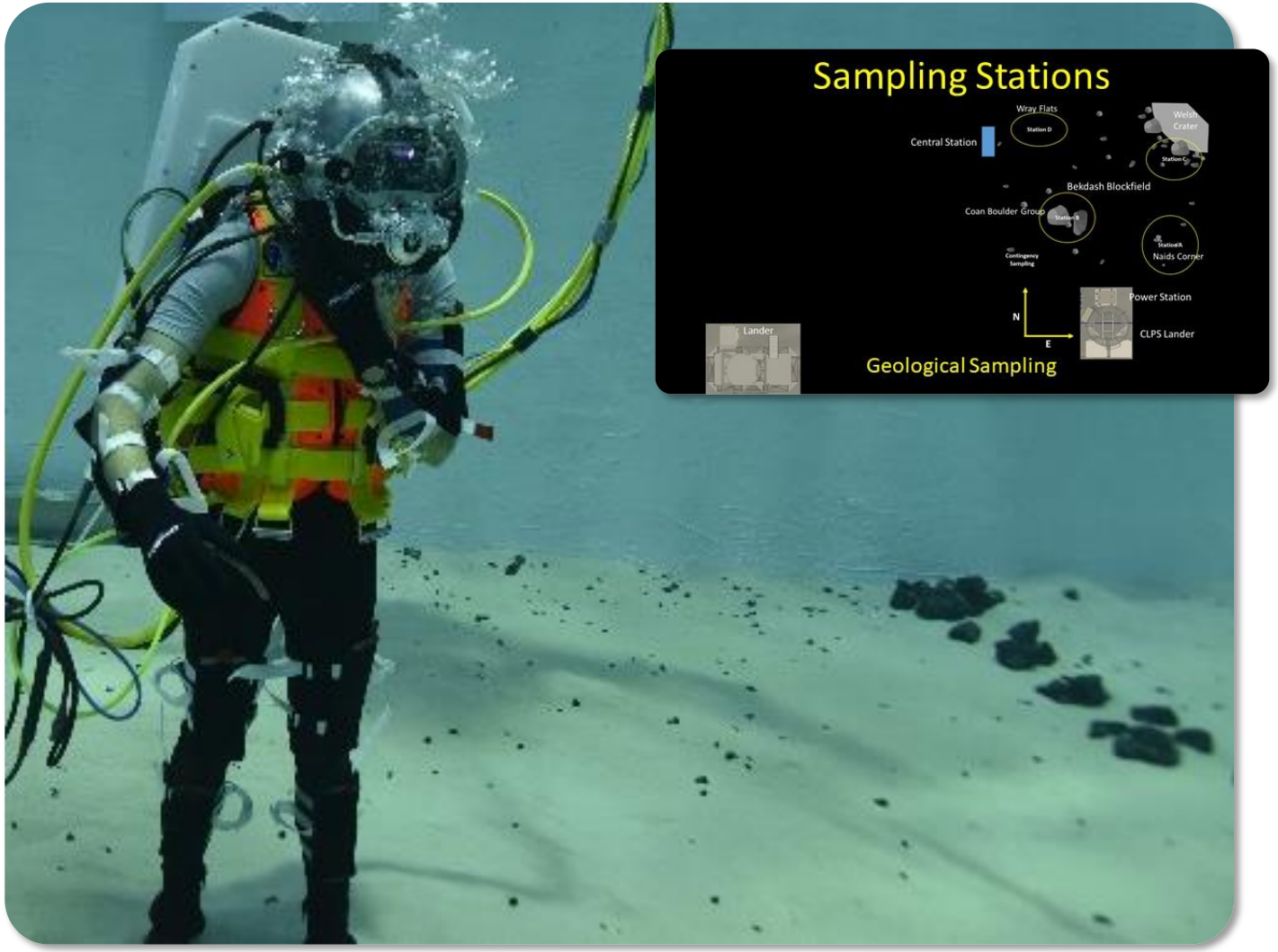
- Utilized Coda Echoscope 3D sonar to scan area, much like a LIDAR system for spaceflight
- Sent navigation data from the sonar to the diver via DAVD



Evaluating Printed Cue Cards and Digital Cue Cards



Reading Printed Cue Cards on Cuff Checklist

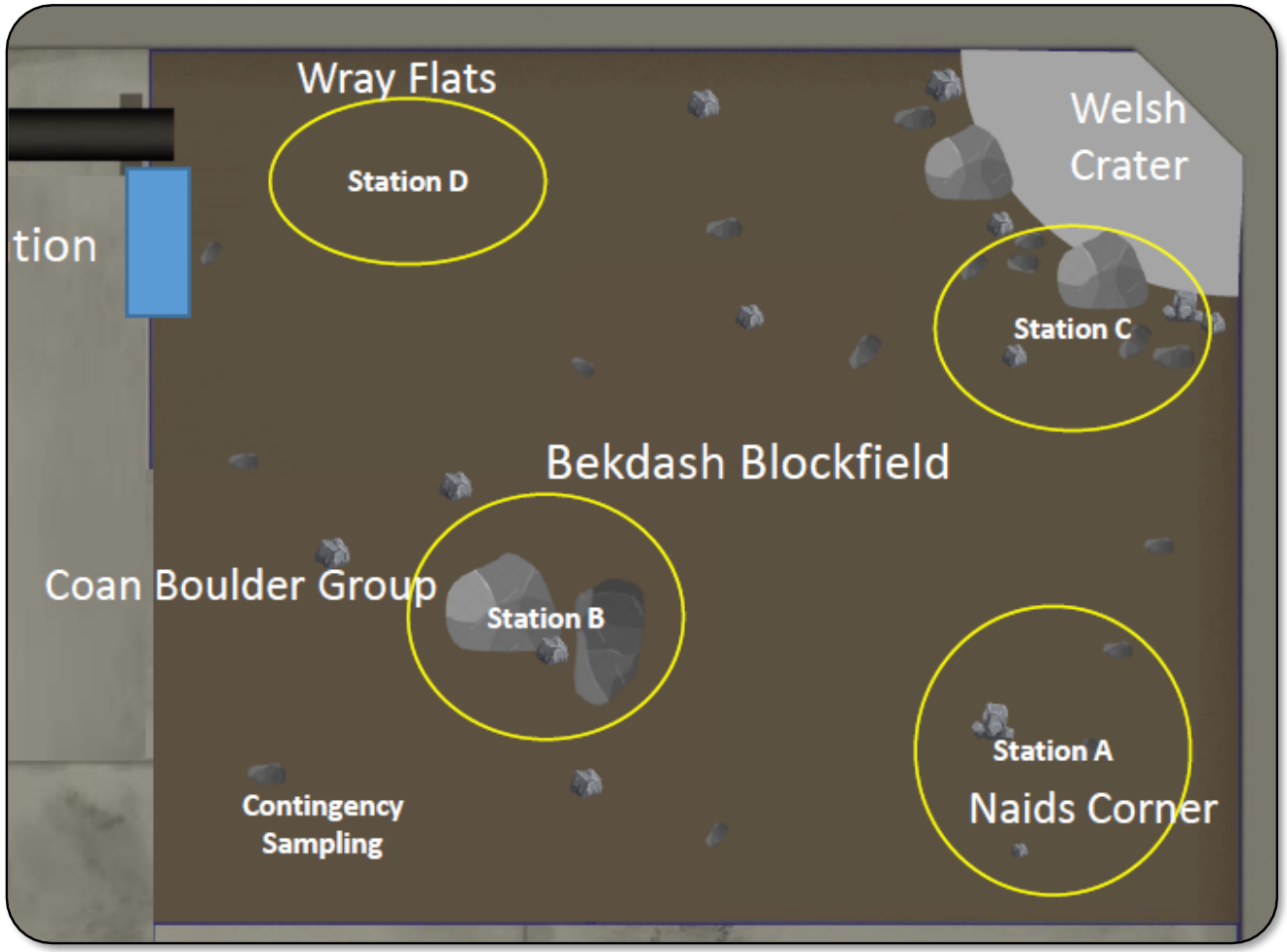


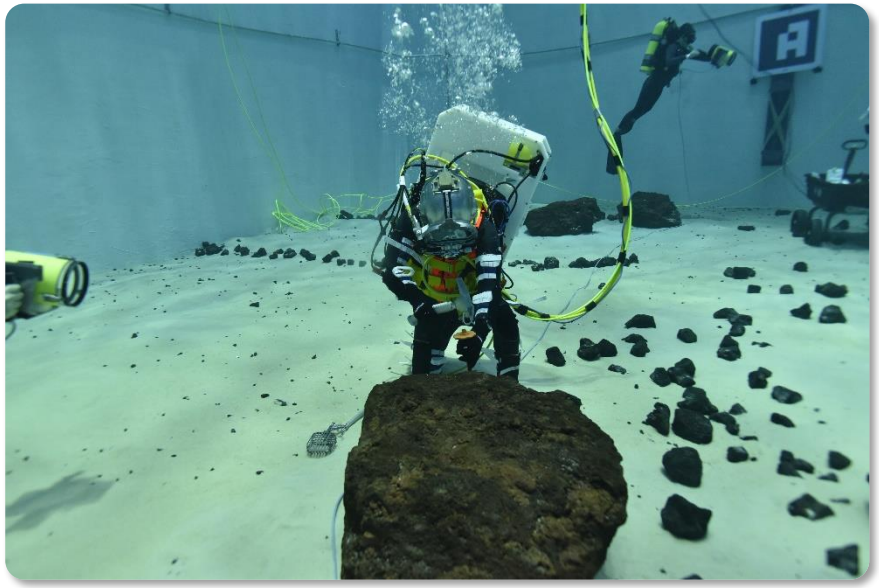
Viewing Digital Cue Cards via DAVD

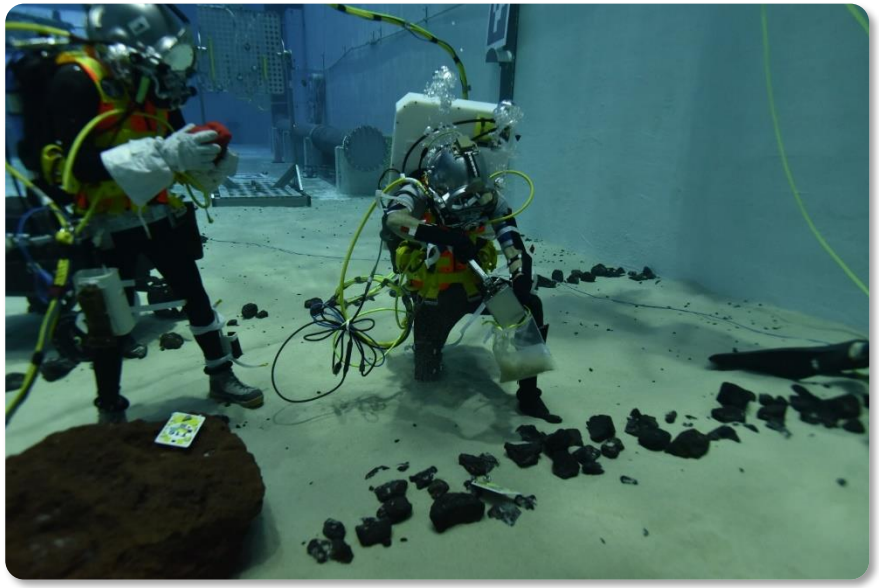
Surface EVA Science Tasks with Geology Tools

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

Regolith Sample
- Bulk with Scoop
- Core with Drive Tube







Evaluating EVA Tool Management on Suit

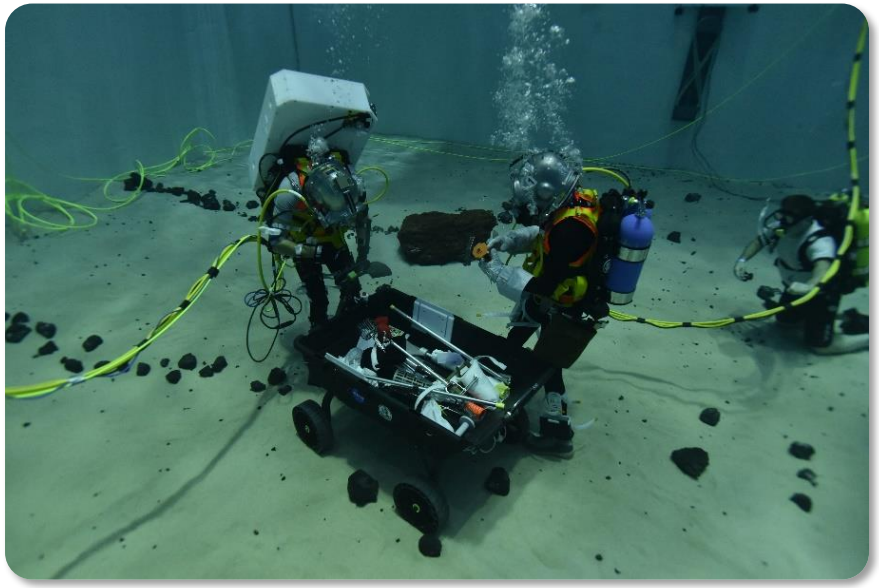
Suit-Mounted Geology Tools

- 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

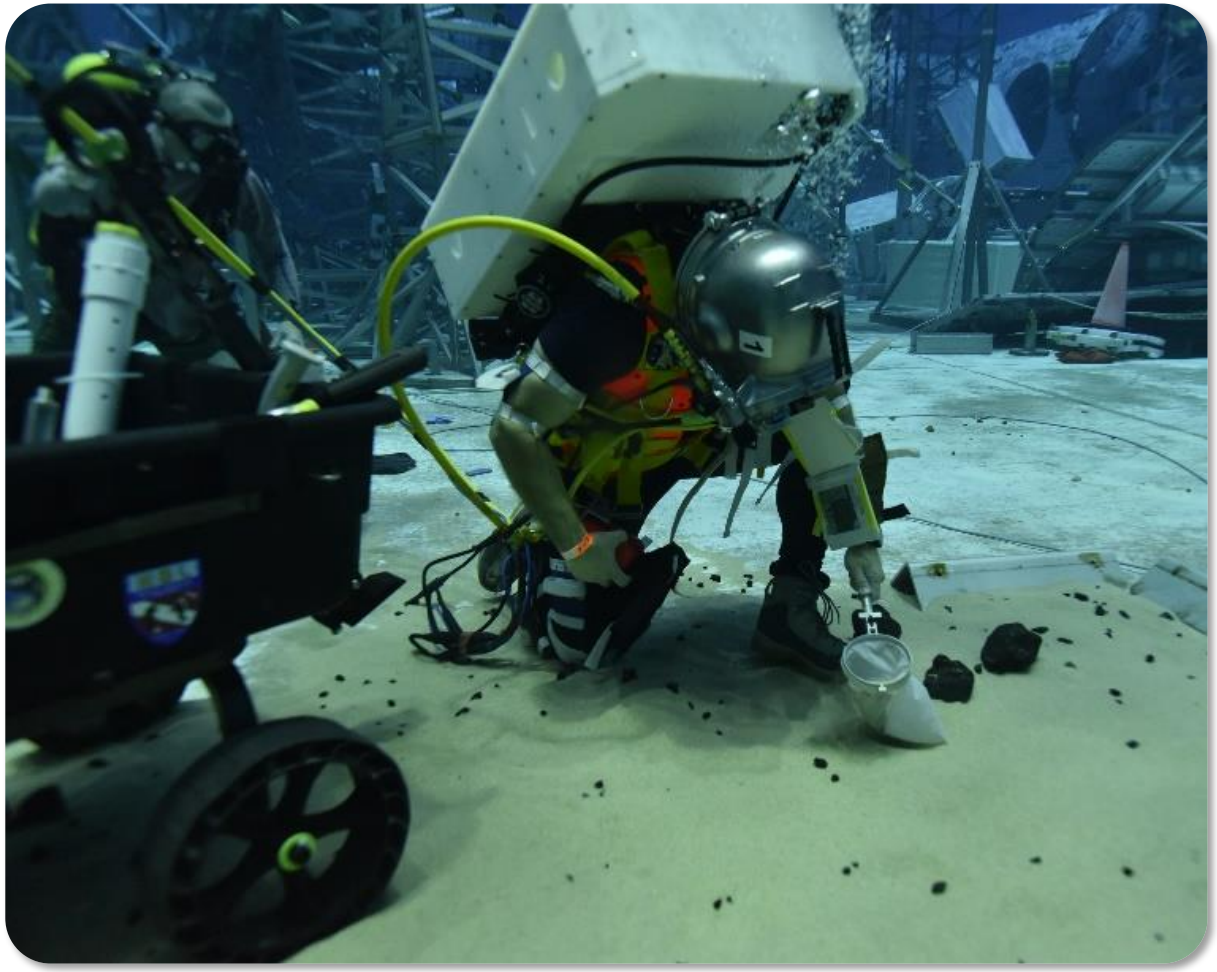
Evaluating EVA Tool Management with METS (Wheeled Carrier)

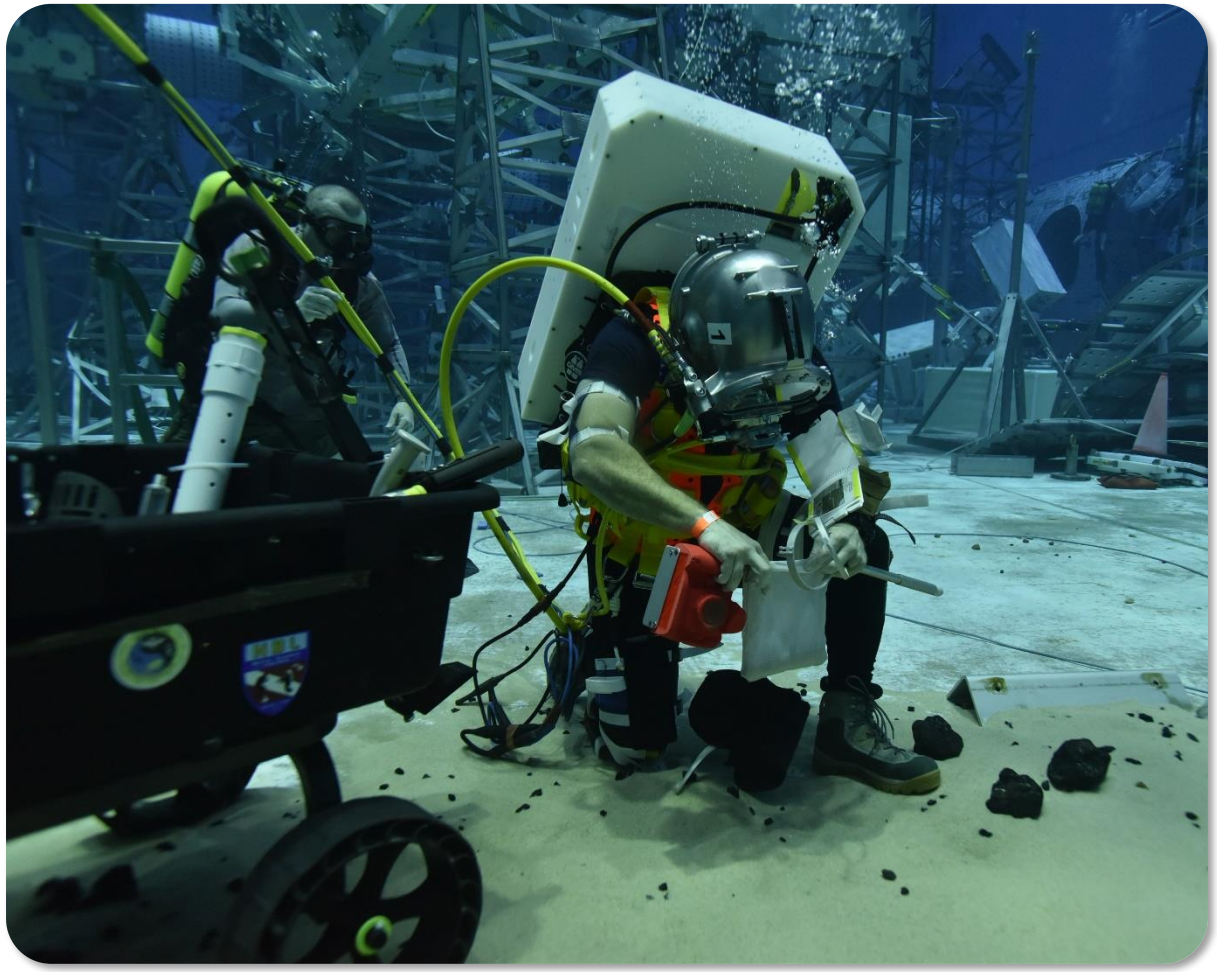
Geology Tools in METS

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

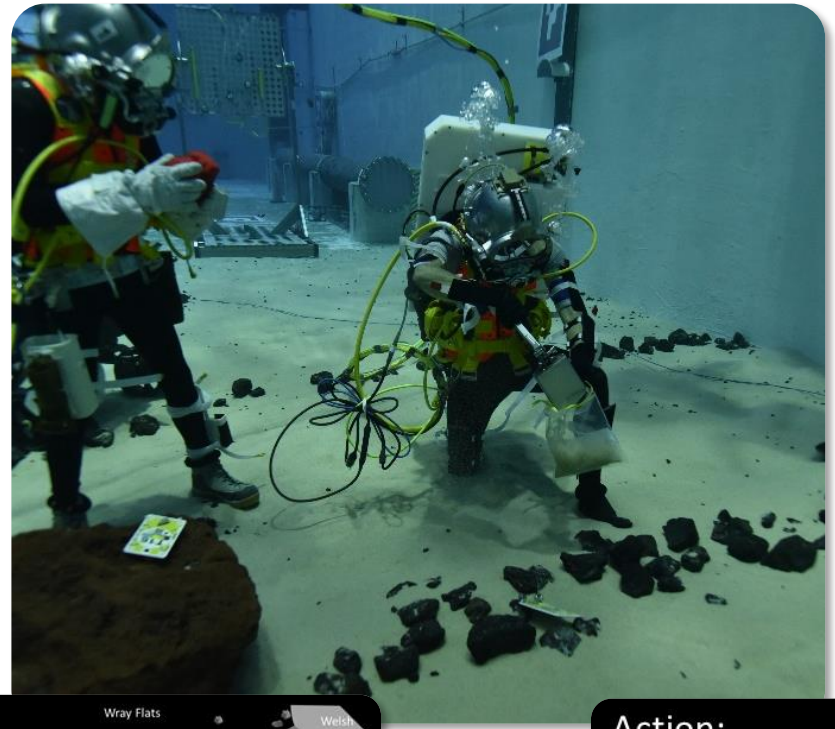


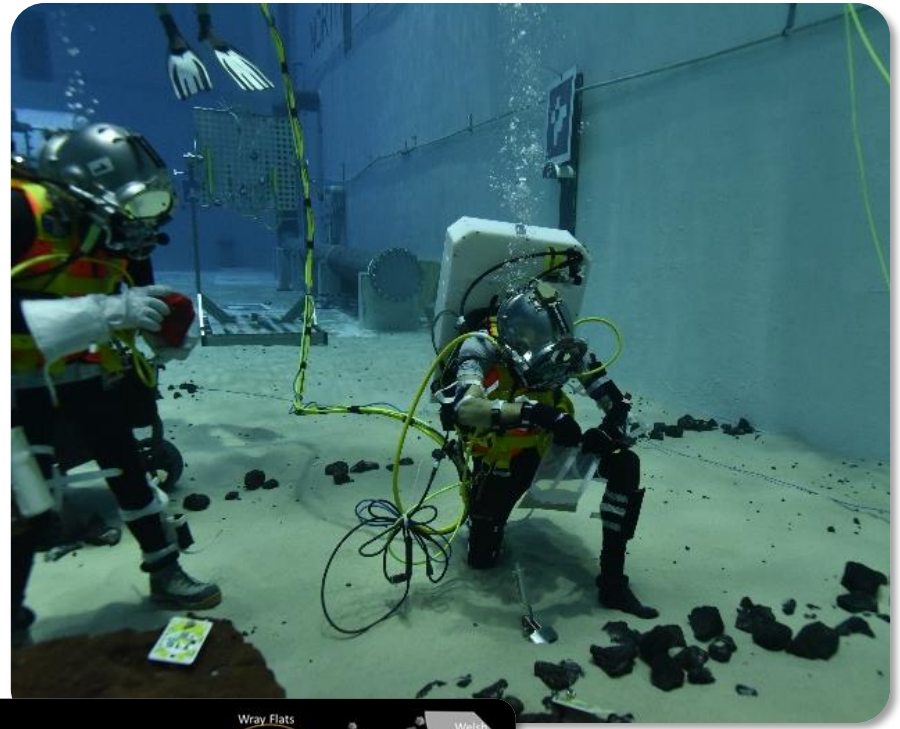
Evaluating Contingency Sampling



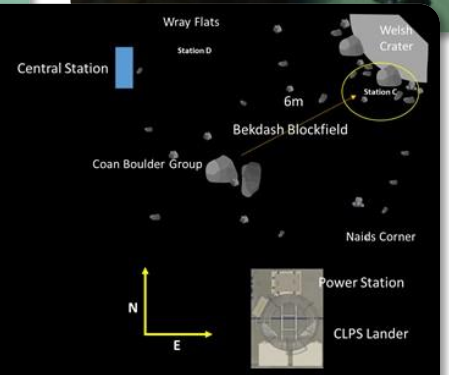


Evaluating Regolith Sampling (with Scoop)



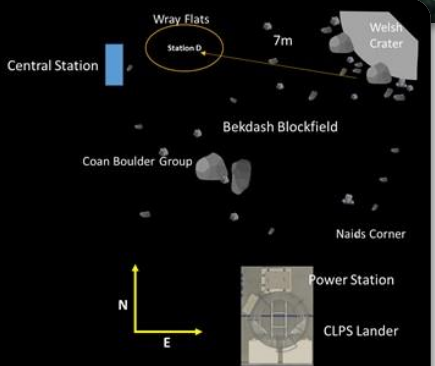


Action:
Traverse 6 m north-east to Station C
Sample:
Regolith, rock chips
Tools:
Scoop, Hammer/ Chisel, Tongs



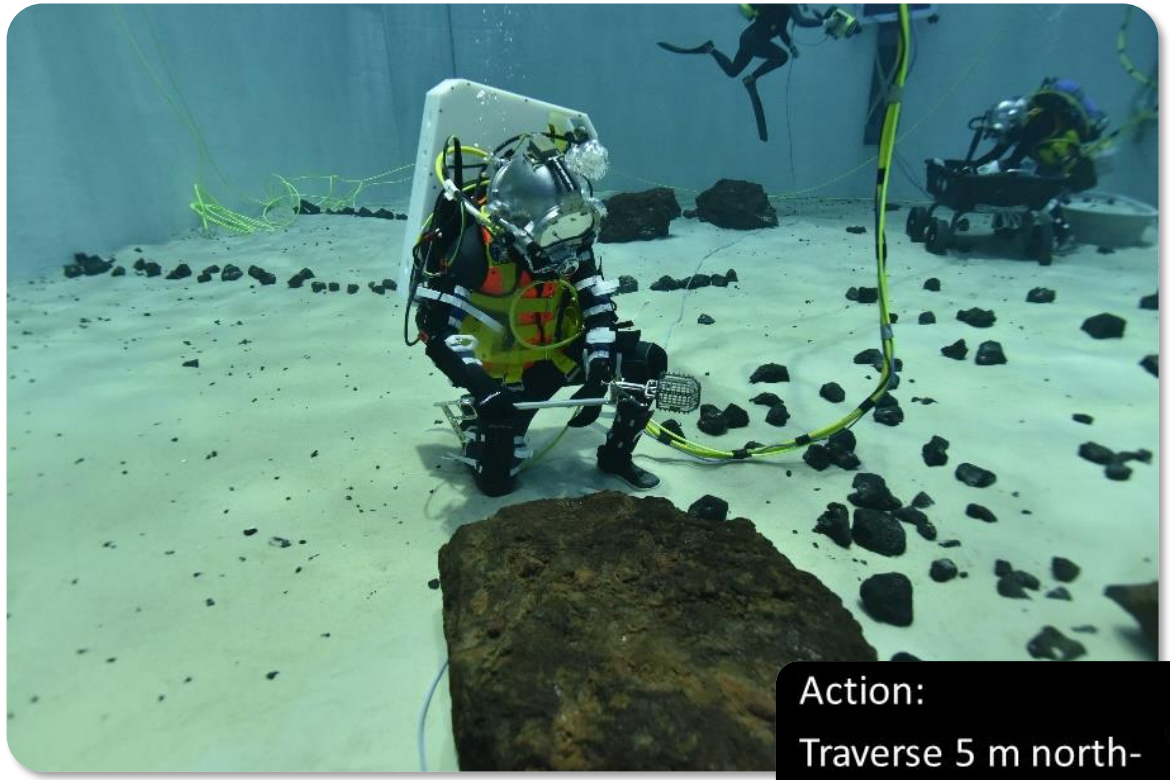
3 of 5 Geological Sampling

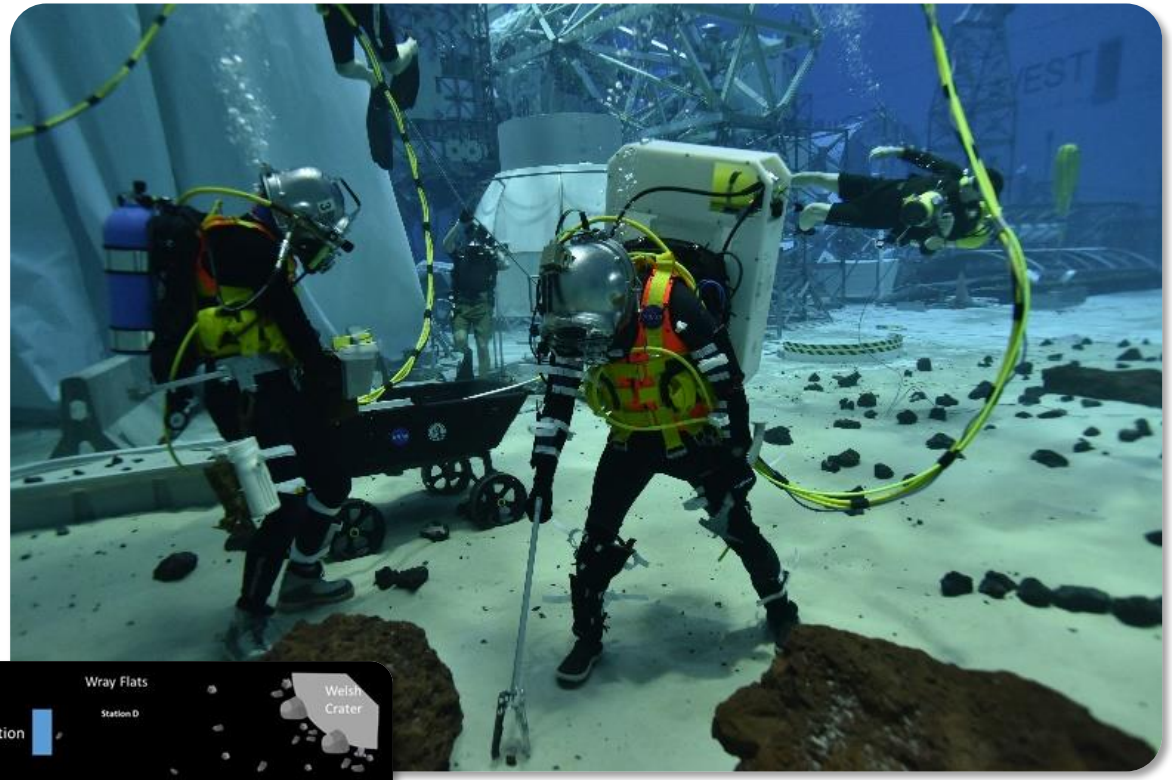
Action:
Traverse 7 m north-west to Station D
Sample: regolith
Tools:
Scoop ± Ext. Handle



4 of 5 Geological Sampling

Evaluating Rock Float Sampling (using Tongs)



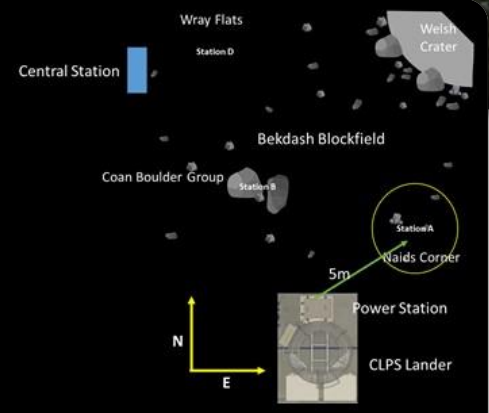


Action:

Traverse 5 m north-east to Station A

Sample:
small rocks

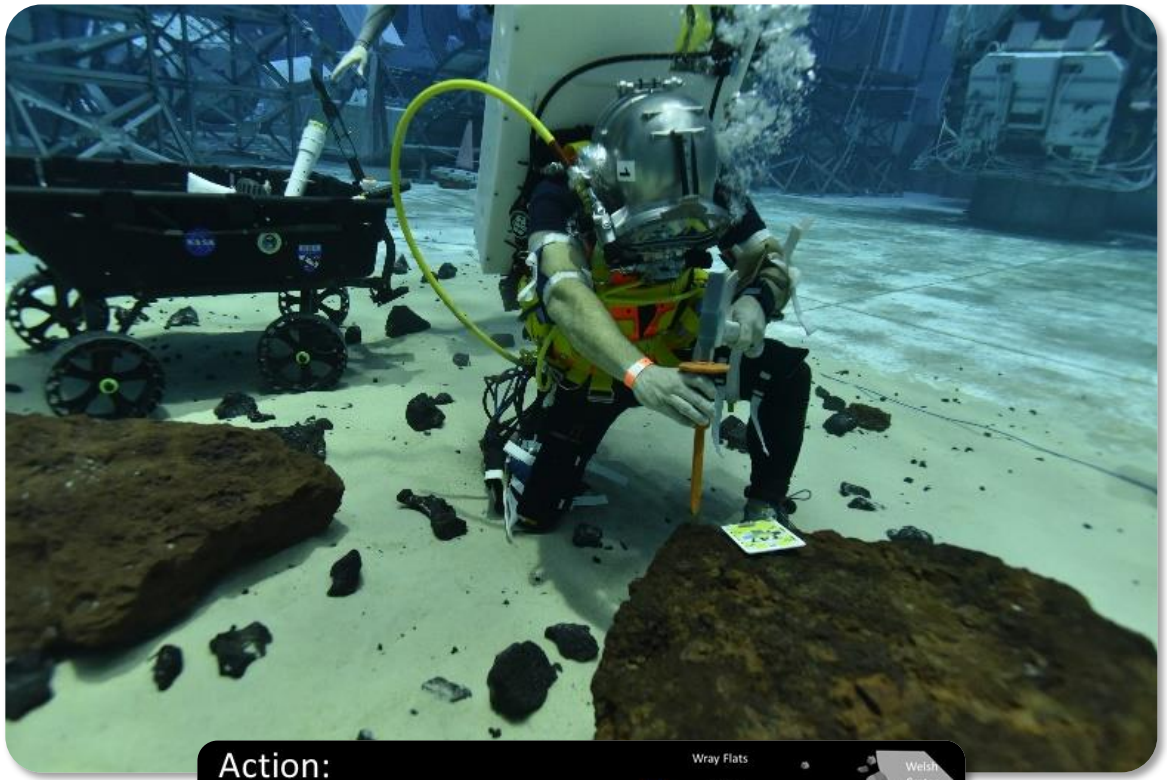
Tools:
Rake ± Ext. Handle
Tongs



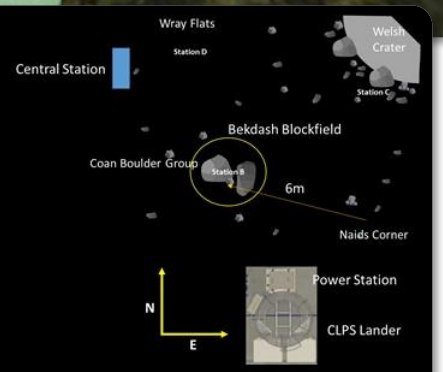
1 of 5

Geological Sampling

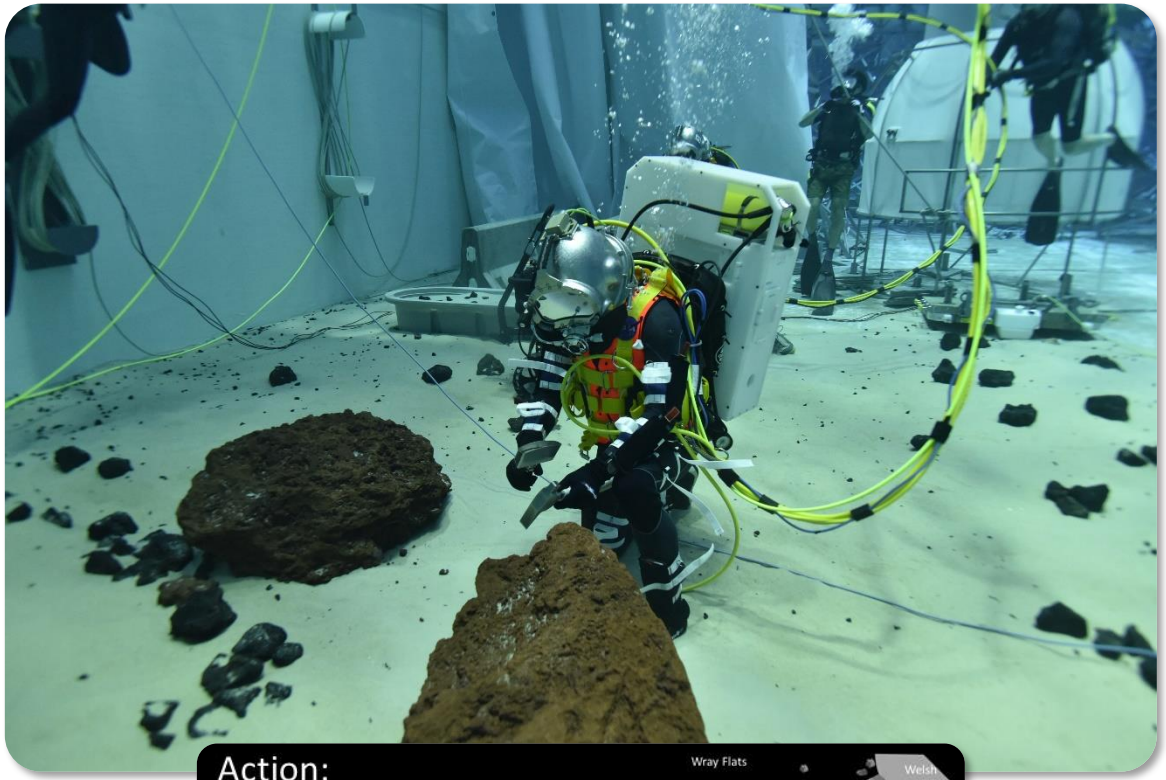
Evaluating Rock Chip Sampling (with Hammer and Chisel)



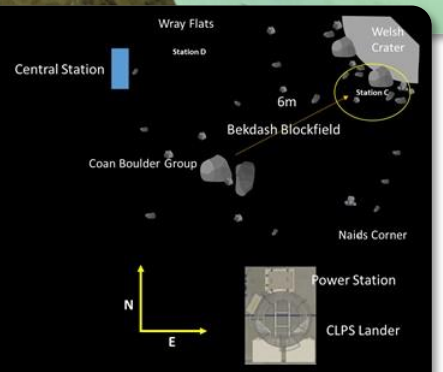
Action:
Traverse 6 m north-west to Station B
Sample:
Rock Chips
Tools:
Hammer/Chisel
Tongs



2 of 5 Geological Sampling

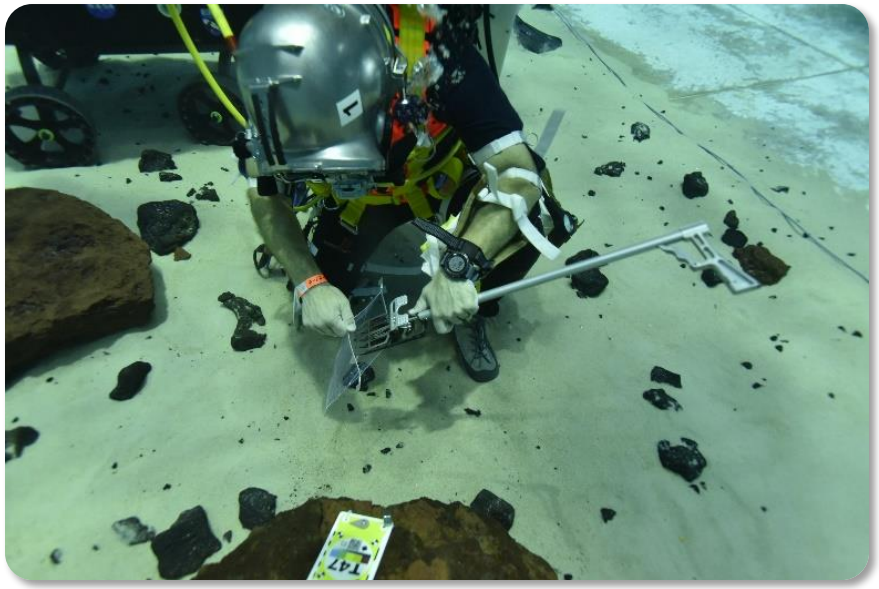


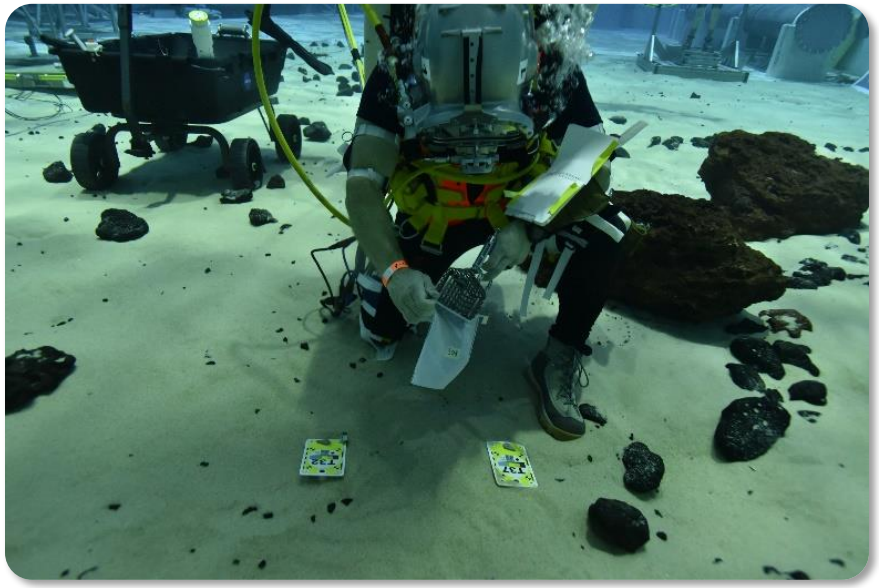
Action:
Traverse 6 m north-east to Station C
Sample:
Regolith, rock chips
Tools:
Scoop, Hammer/ Chisel, Tongs



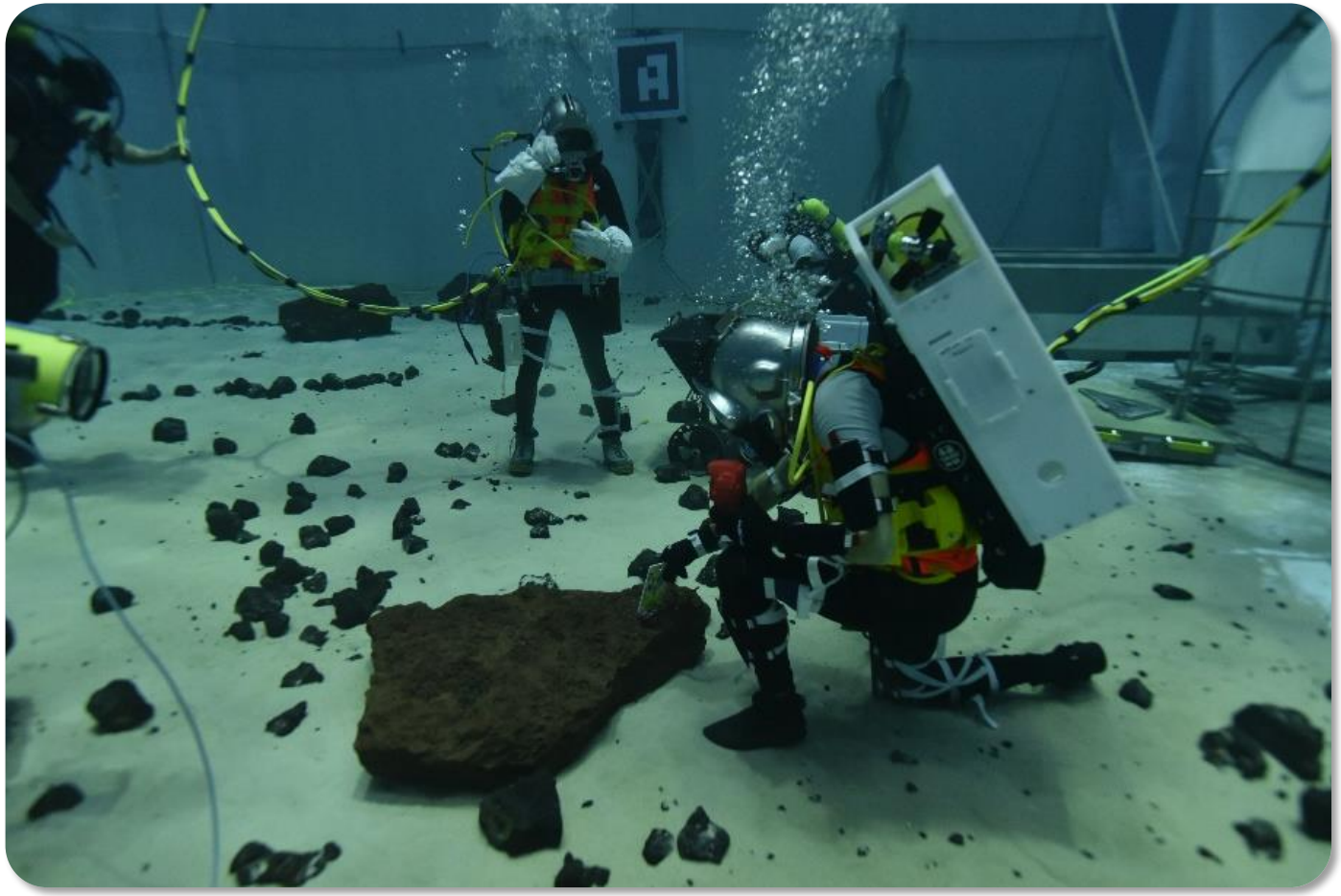
3 of 5 Geological Sampling

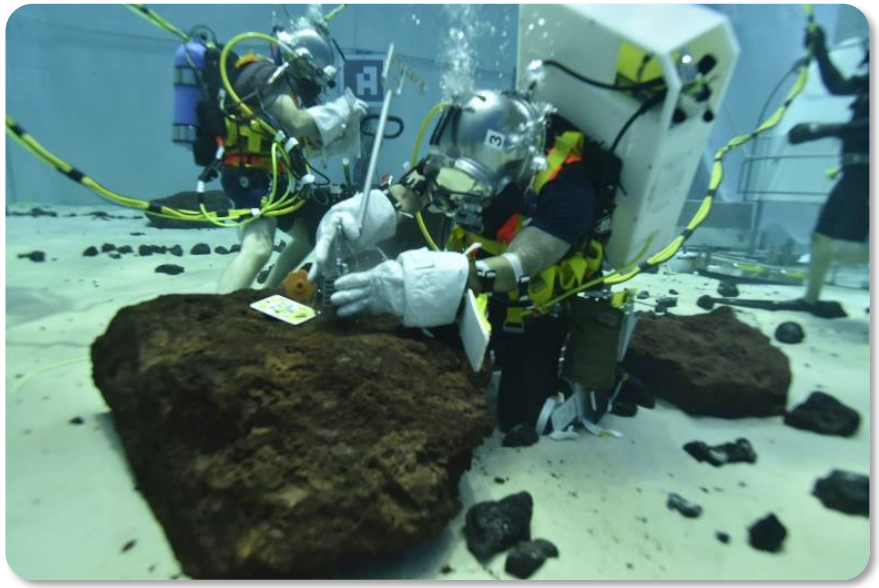
Evaluating Collecting Chip Samples with Tongs & Sample Bags



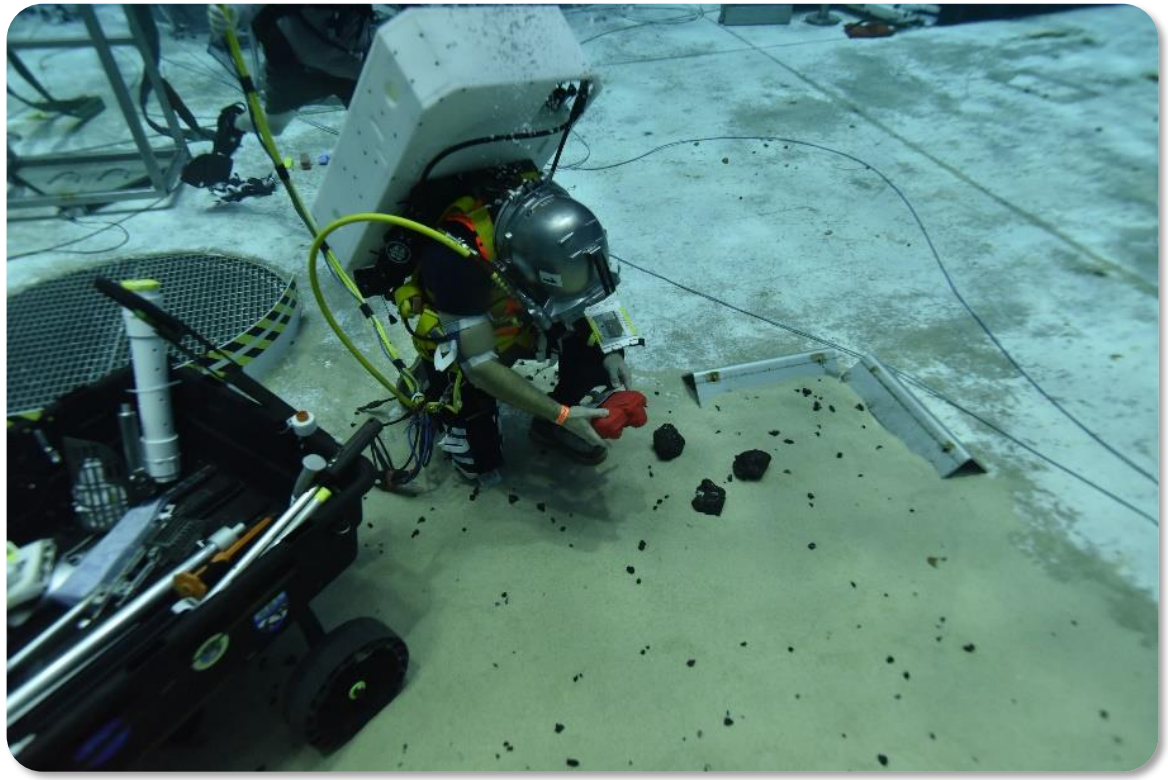


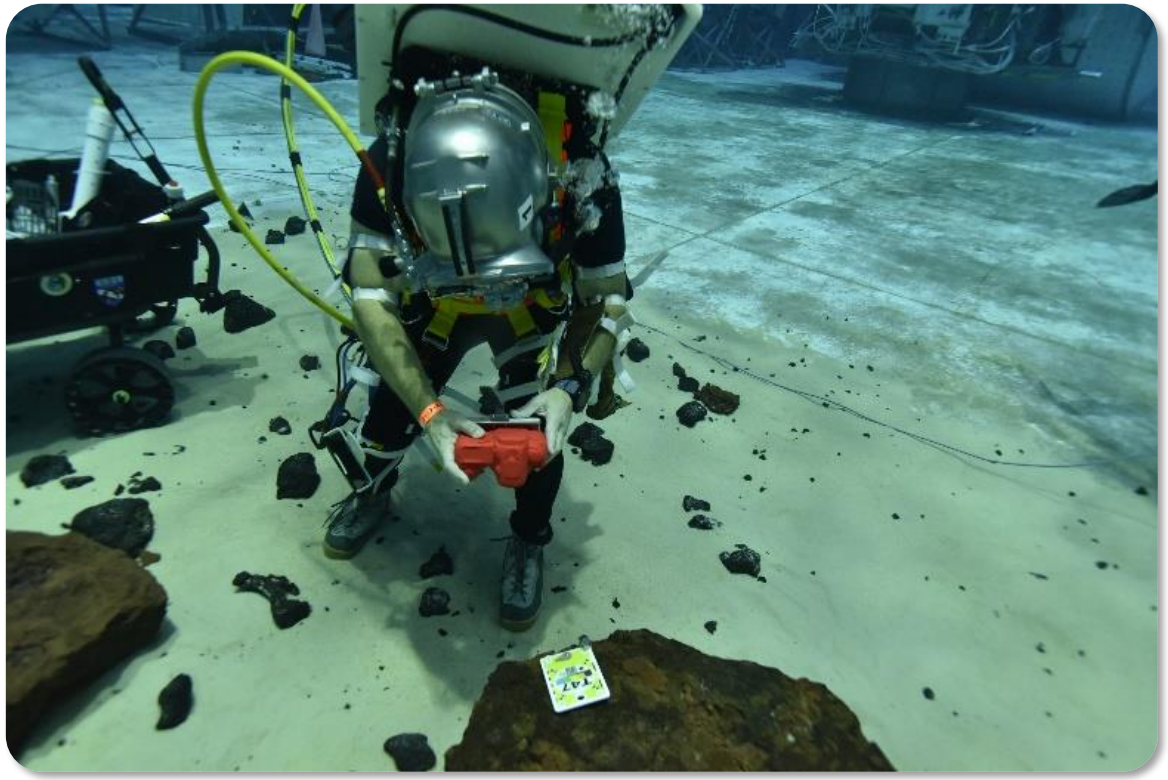
Evaluating Use of Sample Markers



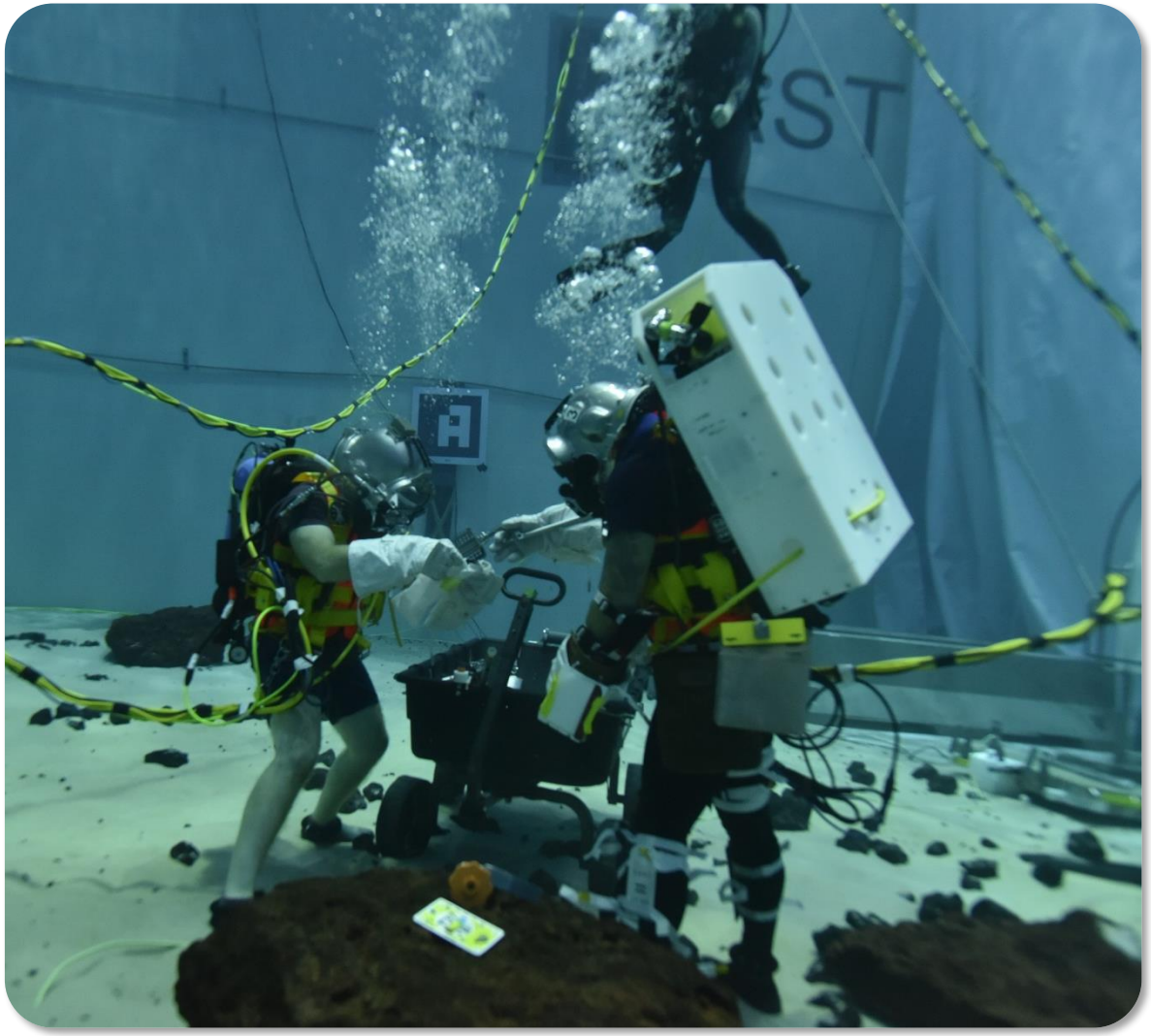


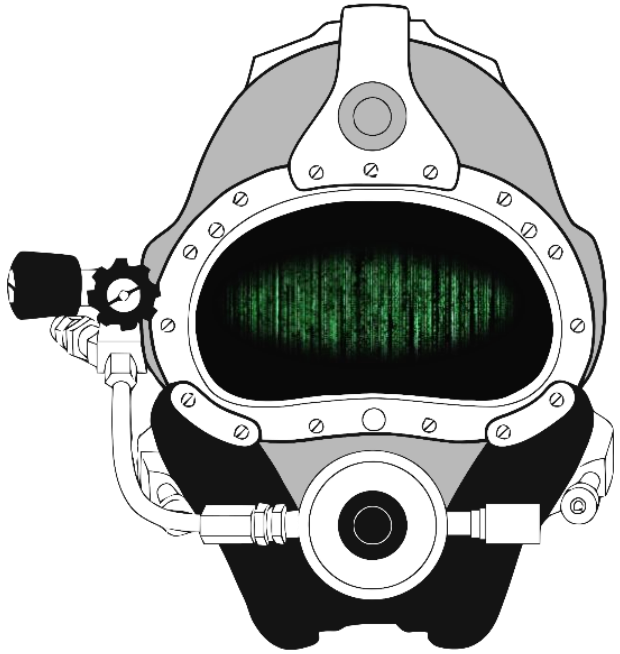
Evaluating Utilization of Science Camera





Evaluating Two-Person Sampling Operations





Key Finding & Summary

Diver Augmented Vision Display (DAVD)

Evaluate the Diver Augmented Vision Device (DAVD) as an xEVA Informatics testing platform

Key Findings for DAVD

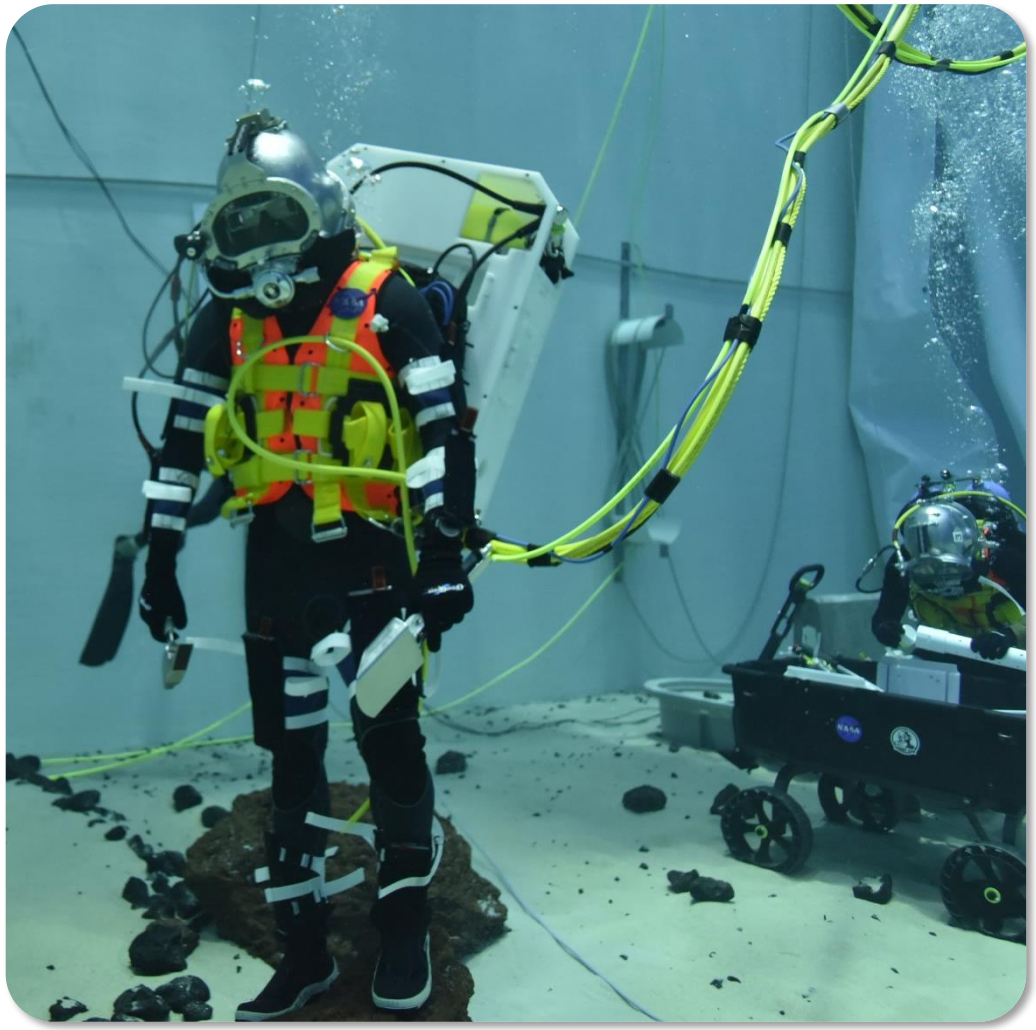
- DAVD passed acceptability testing for NBL use
- DAVD worked well for testing capabilities of an xEVA informatics HUD
  - Gen 1 is good for capability testing
  - Gen 3 will be a projection system that is even more relevant
  - NAVSEA/Coda working on voice commands and gestures for next generations
- Test subject feedback and lessons learned were recorded by the xINFO team
  - Multiple types of content were used to demonstrate the flexibility of DAVD as a system
  - JARVIS learned a lot from the DAVD software and capability (Display / UX observations from JARVIS Team)
- DAVD system is 100% O2 compatible (for decompression stops)
  - JARVIS could utilize an in-the-helmet projection system that is O2 compatible, which would protect the system better from impacts and dust
- xEMU has a helmet camera that could be tied into a similar system, and/or an optic LASER/LIDAR camera system could be utilized

Surface Supplied Diving and Dive Helmets for xEVA

Evaluate utilizing a dive helmet as an analog to a spacesuit for testing xEVA concepts of operations and equipment in the NBL

Key Findings for SSD/Dive Helmet Testing of xEVA

- "Only way we'll be able to train realistically in the near term"
- Better than scuba, need two way comm that helmets provide
  - Need to improve helmet comm
- More limited FOV in dive helmet may impact training, however helmet moves, which may balance the difference
- Take waist belt and build stand offs for swing arm to put them in more realistic FOV and even suit volume
  - One subject reported not being able to see the tool belt swing arms through the helmet visor
  - Need to make the visibility of tools using the SSD config as similar as possible to on the xEMU
- Dive time on air totaled ~4:30 per run/day
  - ~3:15 usable time (after weighout/config) per day
  - Compares to ~5:30 usable time with an EMU run
  - Time will increase with experience and use of Nitrox

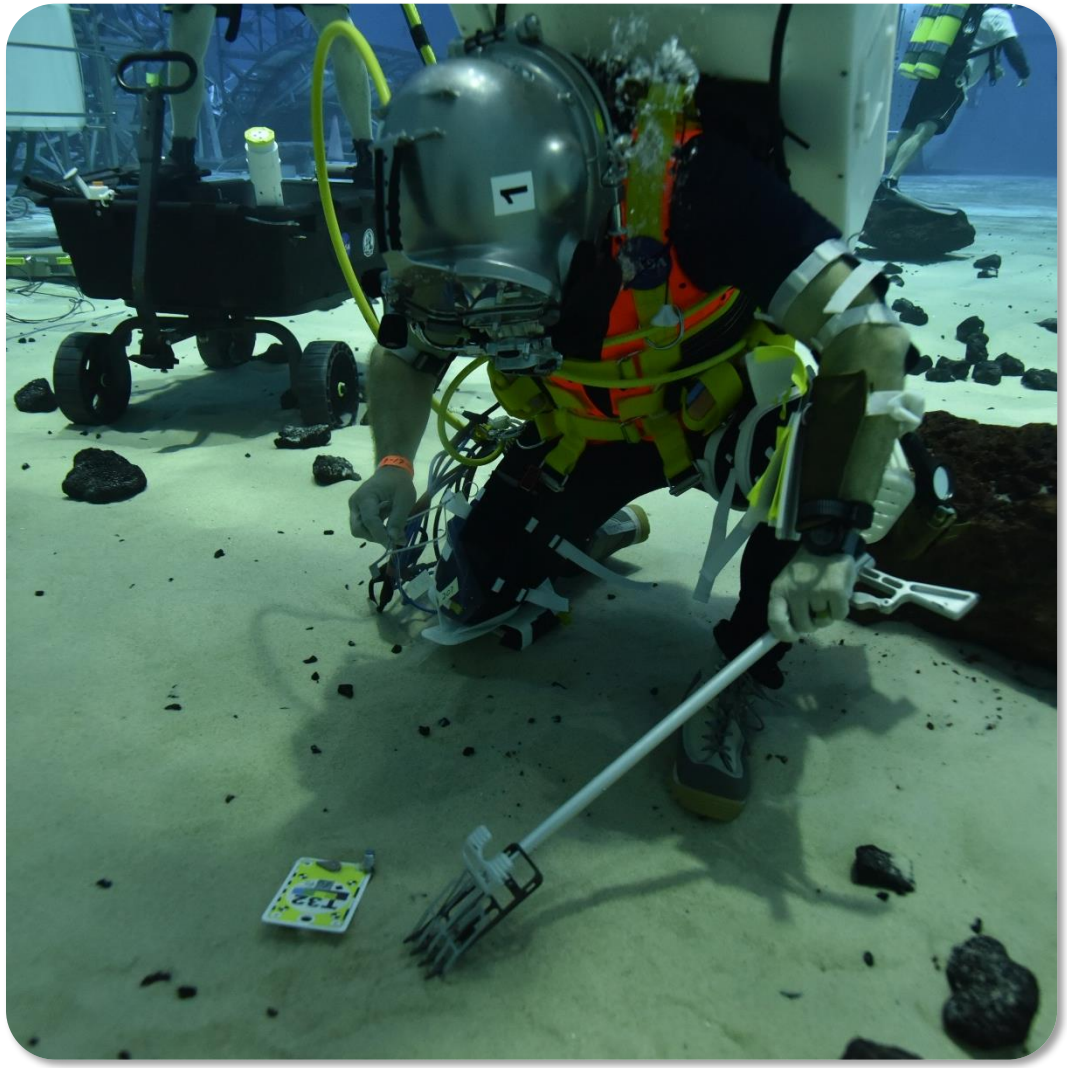


EVA Geology Sampling Tools

Evaluate EVA geology sampling tools for a lunar surface mission

Key Findings for EVA Geology Tools

- Tools feedback was recorded by the EC7 EVA Tools team and/or given to the team during the debrief, with specific data collected on:
  - Use of point and shoot camera
  - Sample bag and dispenser
  - Hammer and chisel
  - Scoop
  - Rake
  - Tongs (straight and angled)
  - Slide hammer
  - Drive tube and cap dispenser
- Should attach tools at the bottom of the pool
- Make short training videos of how to use each tool to put on the wiki – doesn't replace hands on training, but supplements and allows people to review in advance



EVA Tool & Sample Management

Evaluate and determine tool & sample management and transportation

Key Findings for EVA Tools & Sample Management

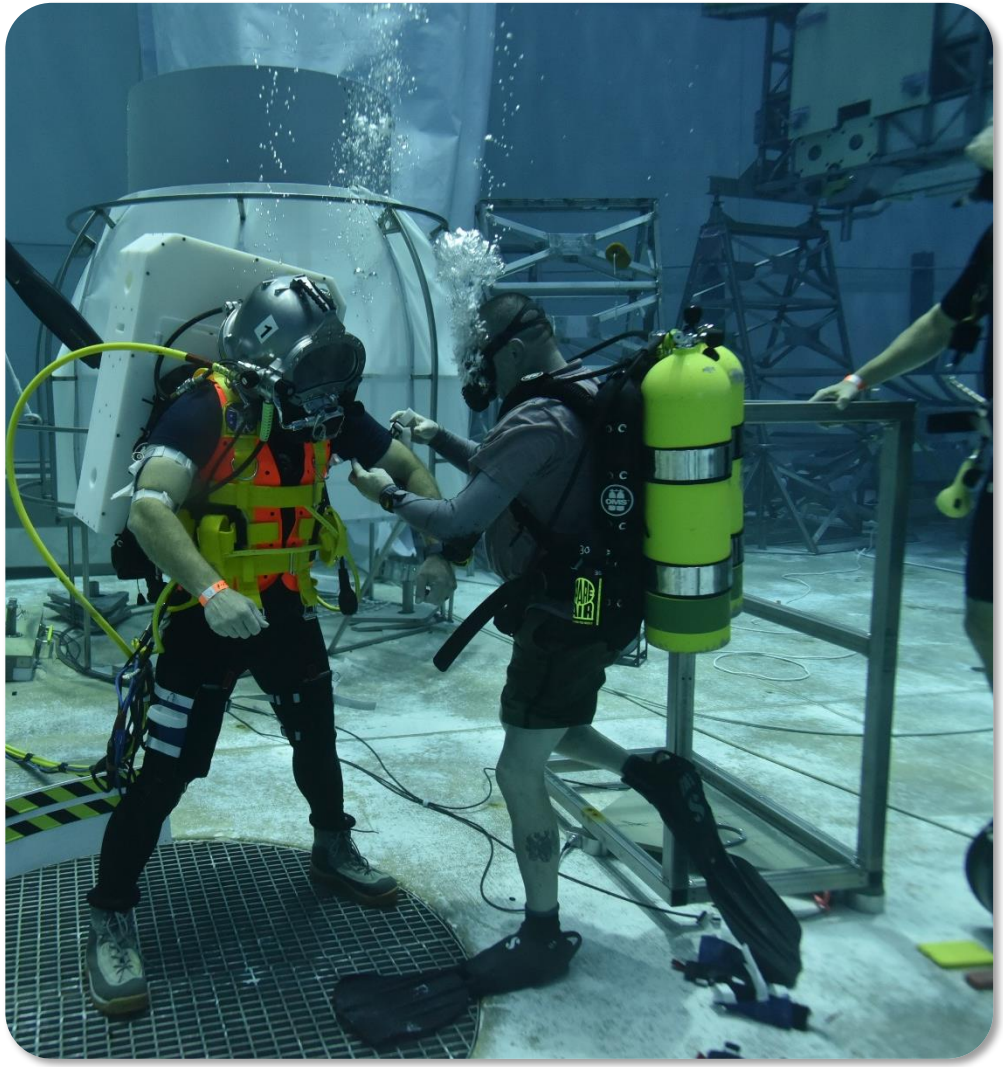
- Tool management feedback was recorded by the EC7 EVA Tools team and/or given to the team during the debrief
- Data was received for equipment mounted on suit
  - Utility belt
  - Hammer holster
  - Scoop/chisel holster
  - Contingency sampler bag
  - Waist pack
- Feedback was received on the METS and utilizing a wheeled carrier

NBL Weighout Wetsuit and Mockup PLSS

Evaluate the NBL Weighout Wetsuit and Weighout Board

Key Findings for Weighout Wetsuit

- In general the weighout suits and mPLSS worked well for simulating 1/6 gravity level on the lunar surface
- Weighout wetsuit:
  - Some of the weights shifted with various movements, but were fairly easily repositioned
    - Thigh weight movement could be resolved by adding Velcro to the wetsuit and weight pack
  - Hip weights interfered with the version of the tool belt tested
  - There was no discomfort with the weights in the suit
  - Test subjects did get hot due to the warm temperature of the water
- Mockup PLSS (mPLSS)
  - Modifications were made real-time with feedback from test subjects and Navy divers, such as adding “burp” holes and centering the bailout bottle for better weight distribution



Evolving Partnerships – NASA and the United States Navy

DEPARTMENT OF THE NAVY
NAVAL SEA SYSTEMS COMMAND
1333 ISAAC HULL AVE SE
WASHINGTON NAVY YARD DC 20376-0001

IN REPLY REFER TO

NAVSEA 00C
3150
Ser 3073
7 Jul 20

NASA EVA
7 Jul 20

MEMORANDUM OF AGREEMENT
BETWEEN
COMMANDER, NAVAL SEA SYSTEMS COMMAND (NAVSEA 00C)
AND
NASA EXTRAVEHICULAR ACTIVITY (EVA) OFFICE

Subj: MEMORANDUM OF AGREEMENT

Ref: (a) Future Naval Capabilities, FNC Requirements for Divers Augmented Vision Display, DAVD Program

Summary of NBL xEVA Lunar Test Series 1 (DAVD)

From Deep Sea to Deep Space

Dive Helmet Test for DAVD Informatics and EVA Geology Tools

Successful acceptance testing and evaluation of the Diver Augmented Visions Display (DAVD) as a capability testing platform for developing an EVA Informatics Heads-Up Display (HUD)

Good integration of xINFO/JARVIS with DAVD HUD

Successful acceptance testing of the CODA Echoscope C-500 3D sonar as a potential capability testing platform for developing EVA navigation on the lunar surface (e.g., with a LIDAR system)

Successful look at utilizing NBL runs for Exploration EVA concept of operations testing for Artemis lunar missions

Successful test of the current geology sampling tools and tool management equipment (Artemis Geology Tools)

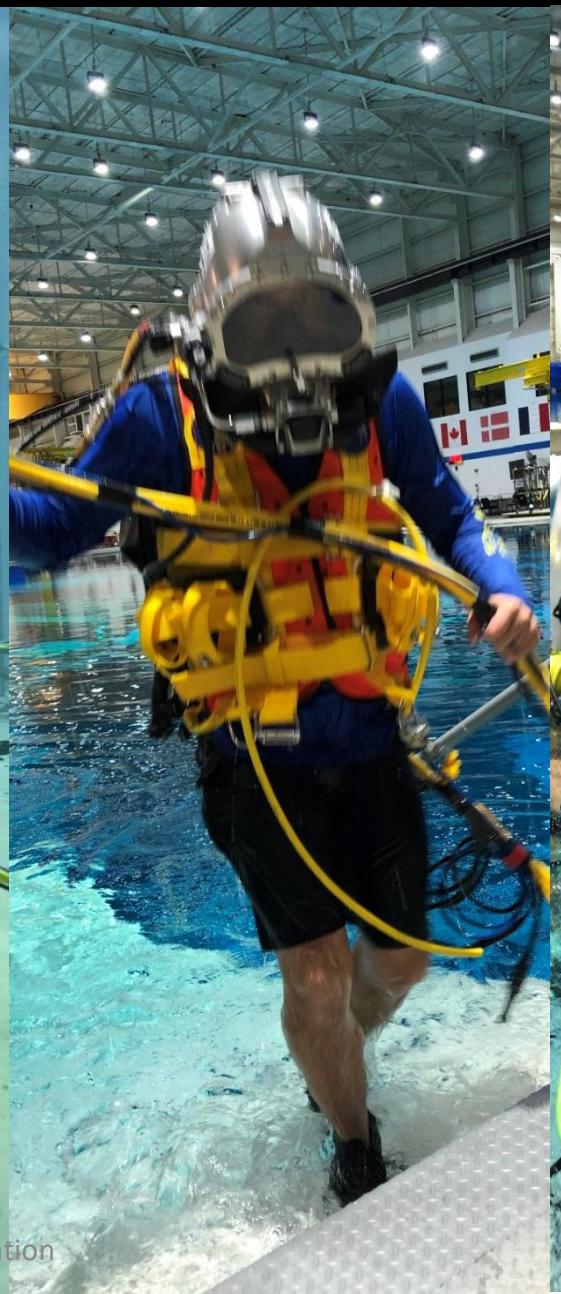
First operational use of new Surface Supplied Diving and KM37/97 dive helmets in NBL

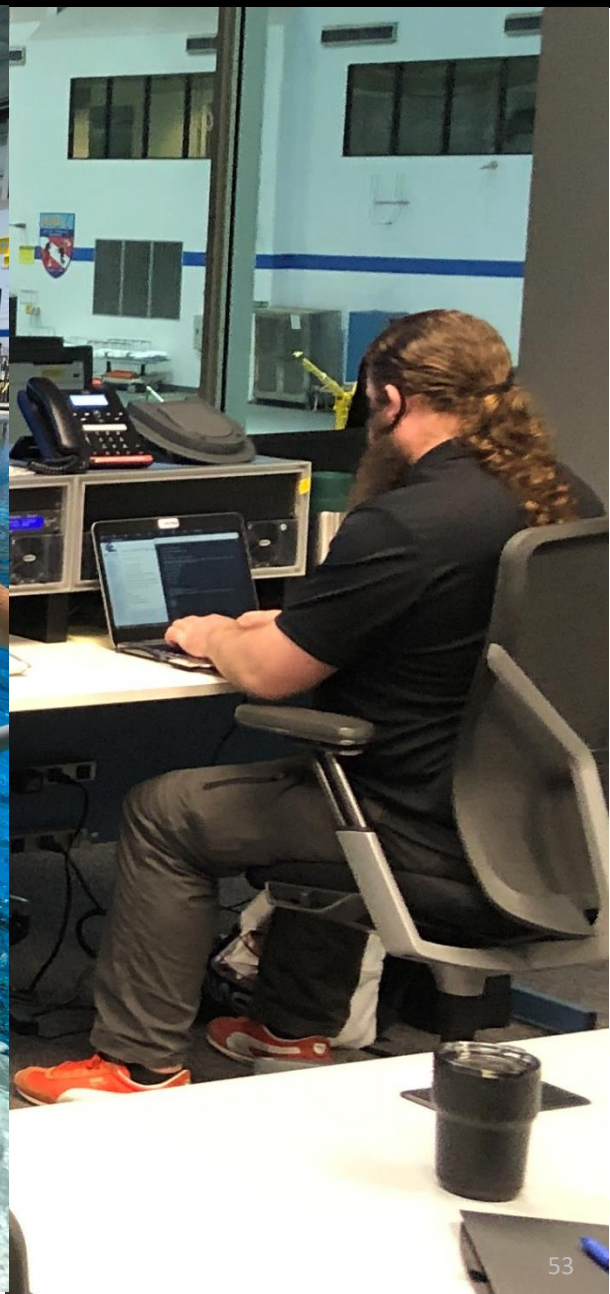
First test with the newly expanded lunar testing area in the NBL

First evaluation of the new weighout wetsuit and mockup PLSS in the NBL

Successful series of test dives for the Navy before they deploy DAVD to the USN fleet divers

Backup





Test Run Schedule

16 July 2020

- 0730-0800: Diver physicals
- 0800: Equipment fam for test subjects
- 0830: Dive brief in south high-bay
- 0900: Morning dive (2 hours)
  - White/EV1 (KM37 w/DAVD, weigh-out, PLSS): **Coan**
  - Red/EV2 (KM97 w/tools): **Naids**
- 1100: Surface interval and lunch (1.5 hours)
- 1230: Afternoon dive (2:15 hours)
  - White/EV1 (KM37 w/DAVD, weigh-out, PLSS): **Graff**
  - Red/EV2a (KM97 w/tools): **Wray**
  - Red/EV2b (KM97 w/tools): **NBL**
- 1600: Dive debrief

17 July 2020

- 0730-0800: Diver physicals
- 0800: Equipment fam for test subjects
- 0830: Dive brief in south high-bay
- 0900: Morning dives (2:15 hours)
  - White/EV1a (KM37 w/DAVD): **Bowen**
  - White/EV1b (KM37 w/DAVD): **Pettit**
  - Red/EV2 (KM97 w/tools, weigh-out, PLSS): **Basher**
- 1200: Surface interval and lunch (1.5 hours)
- 1330: Afternoon dive (2 hours)
  - White/EV1 (KM37 w/DAVD): **Feustel**
  - Red/EV2 (KM97 w/tools, weigh-out, PLSS): **Dumke**
- 1600: Dive debrief

Dive Logs for 16 July 2020

Date	7/16/20	TSM	COX/ARTERY	DS	ALEXANDER	CDS-1	
TD				B/U DS		CDS-2	

AIR DIVING ONLY

DIVER CURRENCY

AIR DIVING

TANK PRESSURE LEGEND
"X" INDICATES A PRESSURE READING ***WITHIN*** THE SPECIFIED OPERATING RANGE
"O" INDICATES A PRESSURE READING ***OUTSIDE*** THE SPECIFIED OPERATING RANGE
ANY ANOMALY SHALL BE NOTED IN THE NOTES/ANOMALIES SECTION BELOW.

ATTENTION DIVE SUPERVISORS:
IT IS YOUR RESPONSIBILITY TO VERIFY DIVER CURRENCY FOR ALL UNSCHEDULED *GUEST DIVERS* AND *LIMITED WORKING DIVERS* PRIOR TO ALLOWING THEM TO DIVE. USE THE DIVER CURRENCY BUTTON ***ABOVE*** TO ACCESS THE DIVER CURRENCY LOG.

Diver #	DIVERS	Time In	Time Out	PSI 1500	PSI 500	Dive Time	REP	INT	RNT
1	COAN	10:18	11:59	X	X	101	K		
2	NAIDS	10:18	12:01	X	X	103	K		
3	GRAFF	13:54	15:26	x	x	92	J		
4	WRAY	13:58	14:44	x	x	46	F		

Diver #	DIVERS	Time In	Time Out	PSI 2750	PSI 700	Dive Time	REP	INT	RNT
5	levine	14:58	15:26	x	x	28	D		
6						0			
7						0			
8						0			
9						0			
10						0			

Diver #	DIVERS	Time In	Time Out	PSI 2750	PSI 700	Dive Time	REP	INT	RNT	Assignments:
11						0				
12						0				
13						0				
14						0				
15						0				
16						0				
17						0				
18						0				
19						0				
20						0				
21						0				
22						0				

NOTES / ANOMALIES: Memorial Hermann Hyperbaric Chamber: (Direct Line - 713-704-2912) (Switch Board - 713-704-4000) Ask for the duty hyperbaric technichian.

Dive Logs for 17 July 2020

7/17/20	TSM	COX/ARTERY					DS	ALEXANDER	CDS-1															
							B/U DS		CDS-2															

DIVER CURRENCY

AIR DIVING ONLY

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DIVERS	Time In	Time Out	PSI 1500	PSI 500	Dive Time	REP	INT	RNT
BOWEN	9:41	10:58	X	X	77	I		
PETTIT	11:29	12:30	X	X	61	G		
BASHER	9:48	11:00	X	X	72	H	:29	72
FEUSTEL	14:22	15:28	x	x	66	H		

DIVERS	Time In	Time Out	PSI 2750	PSI 700	Dive Time	REP	INT	RNT
BASHER	11:29	12:30	X	X	61	M		
DUNKE	13:56	15:29	X	x	93	J		
					0			
					0			
					0			
					0			

Diver #	DIVERS	Time In	Time Out	PSI 2750	PSI 700	Dive Time	REP	INT	RNT	Assignments:
11						0				
12						0				
13						0				
14						0				
15						0				
16						0				
17						0				
18						0				
19						0				
20						0				
21						0				
22						0				

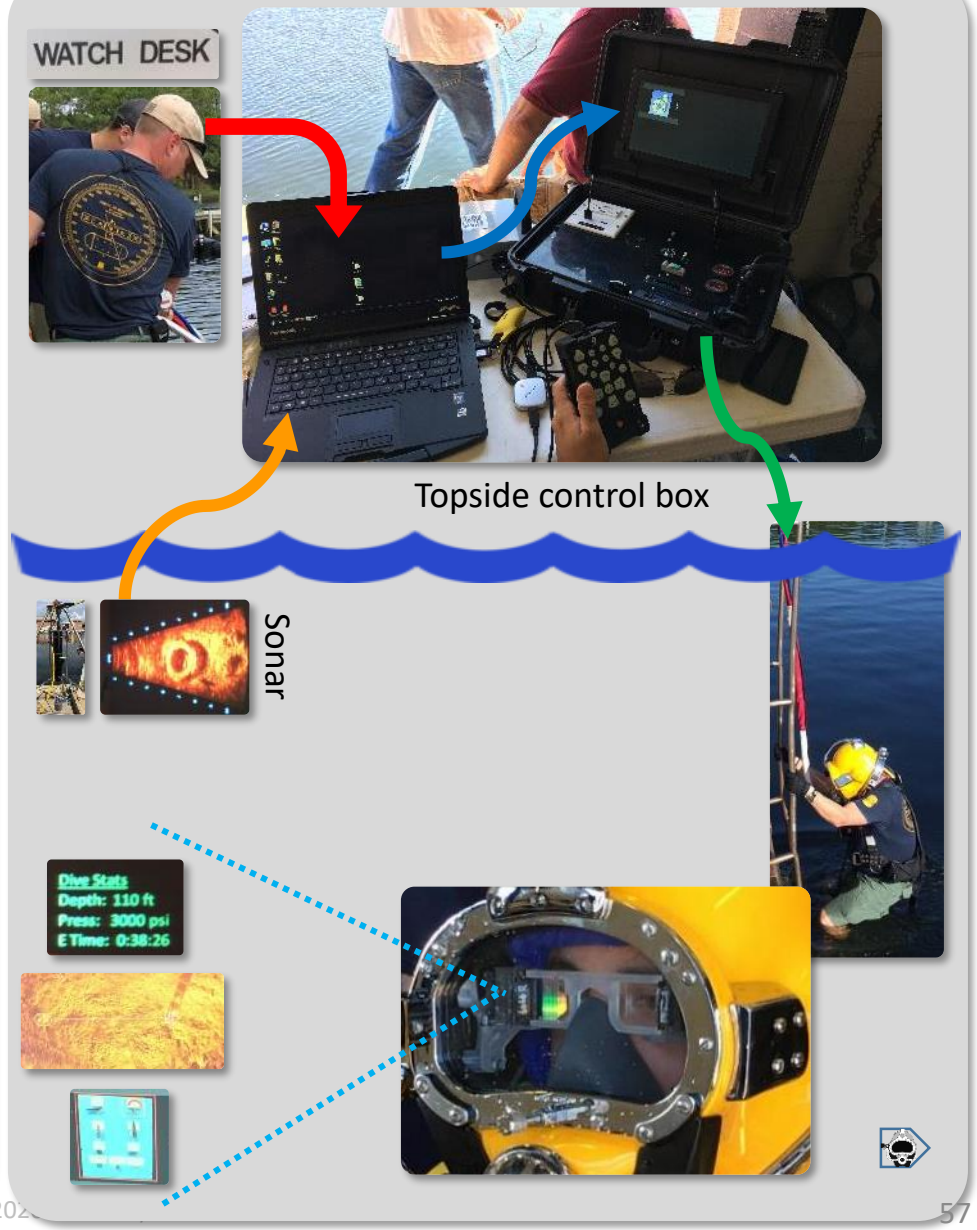
/ ANOMALIES: Memorial Hermann Hyperbaric Chamber: (Direct Line - 713-704-2912) (Switch Board - 713-704-4000) Ask for the duty hyperbaric technician.

U.S. Navy Divers Augmented Vision Display (DAVD)

KM37

MK20 FFM

- Sponsored by Naval Sea Systems Command Supervisor, Diving and Salvage (NAVSEA 00C), and developed by the Naval Surface Warfare Center Panama City Division
- The DAVD system
  - Binocular heads-up display (HUD) mounted inside a Kirby Morgan 37 (KM37) dive helmet and a MK-20 Full Face Mask (MK20 FFM)
  - Prototype uses commercial lenses (Lumus) and custom 3D printed frame/mounting systems
- DAVD capabilities
  - Allows a topside dive supervisor to relay visual mission data to the HUD via an Ethernet cable
  - Divers can view text messages, video, photographs, instructions, and augmented reality images
  - Divers can also utilize real-time sector scanning sonar imagery for navigation
  - Allows for operations even in murky, zero visibility conditions
- During diver testing, DAVD operated as advertised, with Navy divers able to utilize it for navigation, identification of objects, and for receiving task instructions real-time



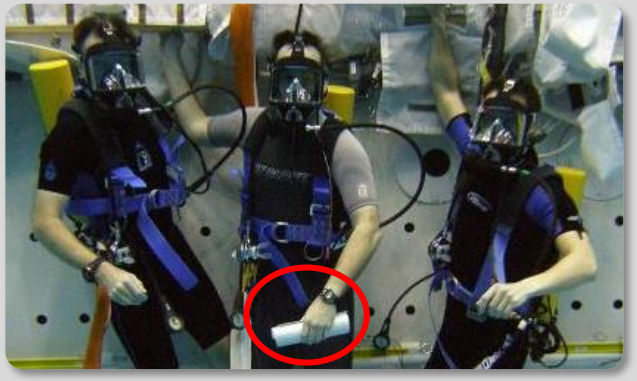
Application of DAVD for xEVA Informatics

NASA Exploration EVA Spacesuit and Operations

- An EVA Augmented Vision Heads-Up Display (HUD) would allow for real-time data update, augmented cue input, procedure viewing, enhanced task direction, and self-navigation capability
  - Enables Exploration mission concepts of operations baselined by the EVA Office, especially those on natural planetary surfaces
  - Relevant for current spacesuit (xEMU) development efforts and the xINFO system
- DAVD system abilities translate into capabilities needed by NASA for the Exploration EVA Suit and planetary operations

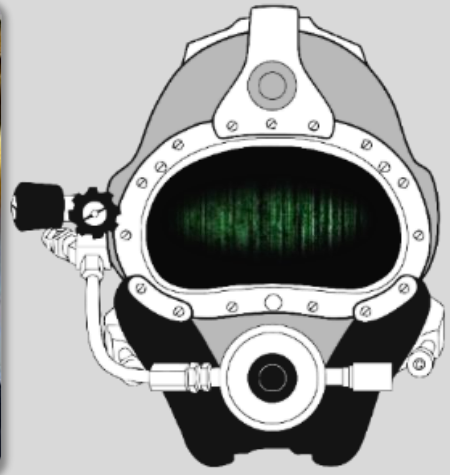
Enhanced ISS EVA Training

Utilize MK20 FFM version of DAVD to view procedures and graphics sent by Test Conductor

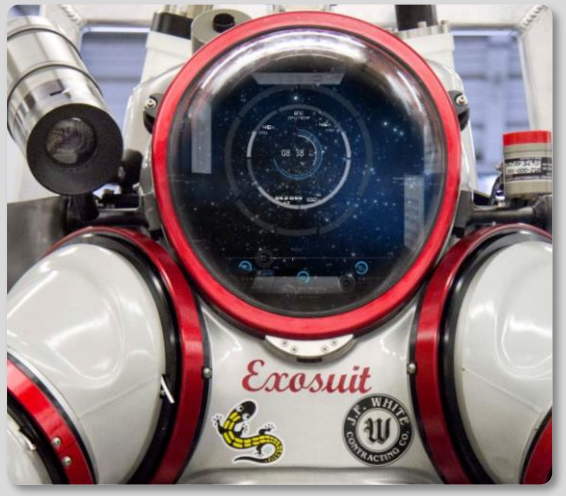


Potential Spacesuit (xEMU) Development

DAVD Mounted Lenses



DAVD Projection System



DAVD System in Suit

xEMU HUD

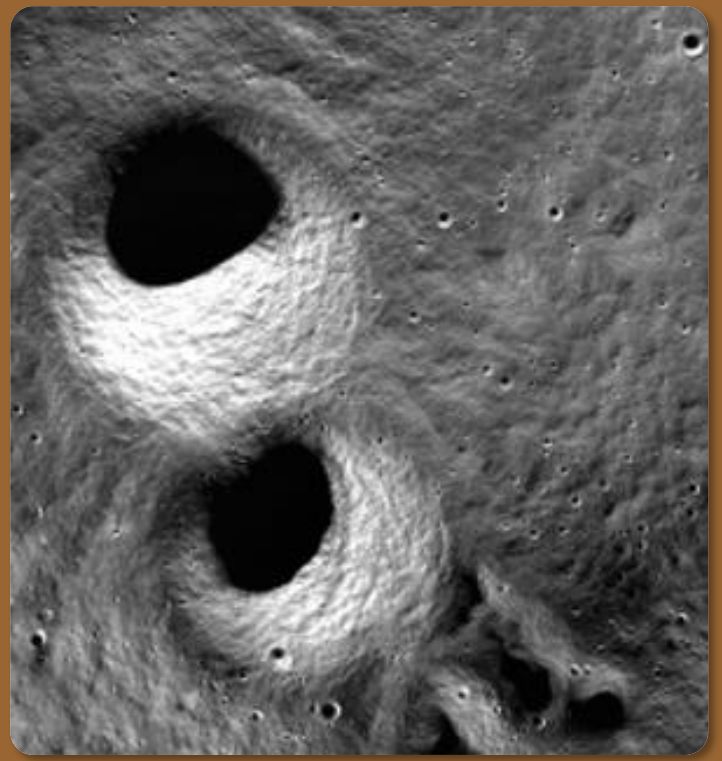
General Science Regions of Interest for Exploration on Lunar Surface

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

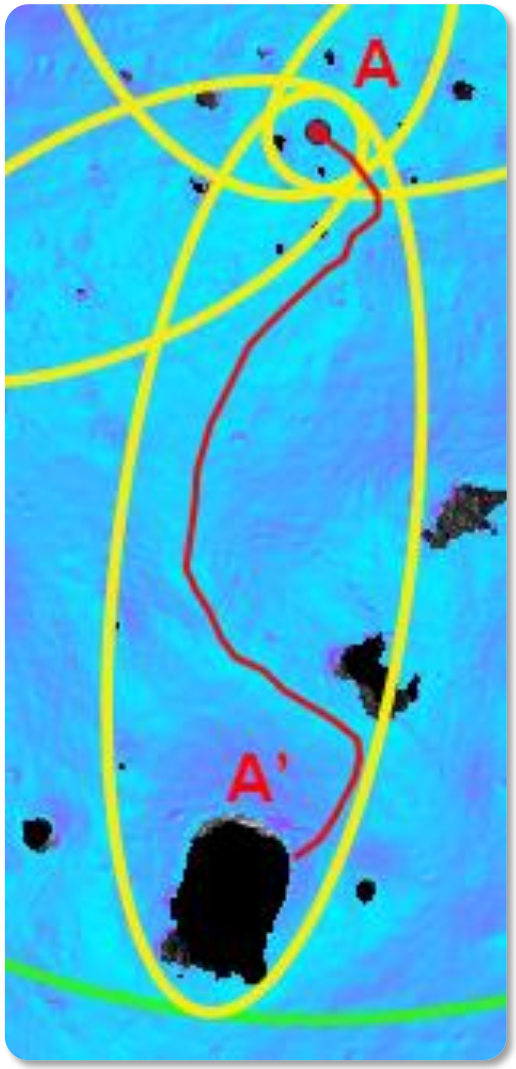


Volcanic Terrain

- Ingress into, perform science tasks, exit lava tube/flow
- May require equipment ancillary to the xEVA suit

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