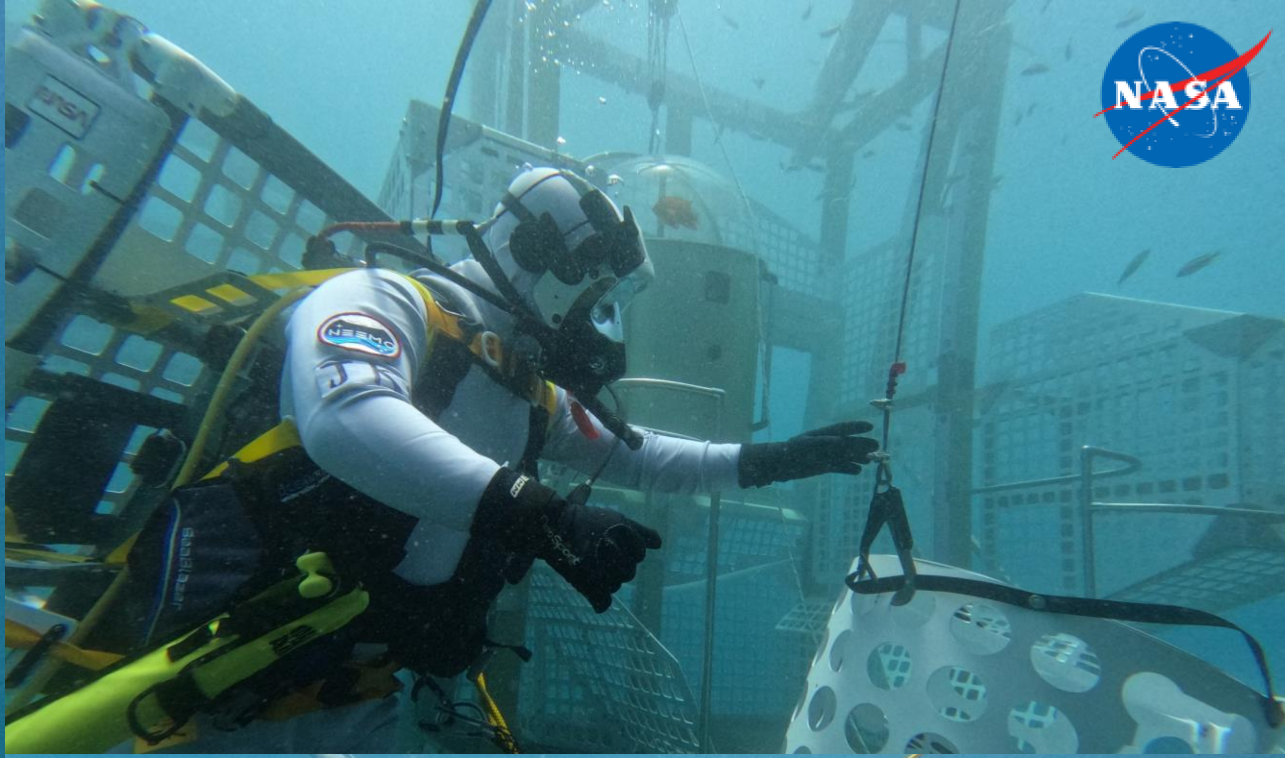

SEATEST 6 Detailed Final Report Charts

August 15, 2023

Report Authors

Mission Management Team:

- Marc Reagan
- Bill Todd
- Barbara Janoiko

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- Kara Beaton
- Chip Litaker
- Allison Porter
- Shonn Everett
- Taylor Phillips-Hungerford
- Grier Wilt
- Jason Poffenberger

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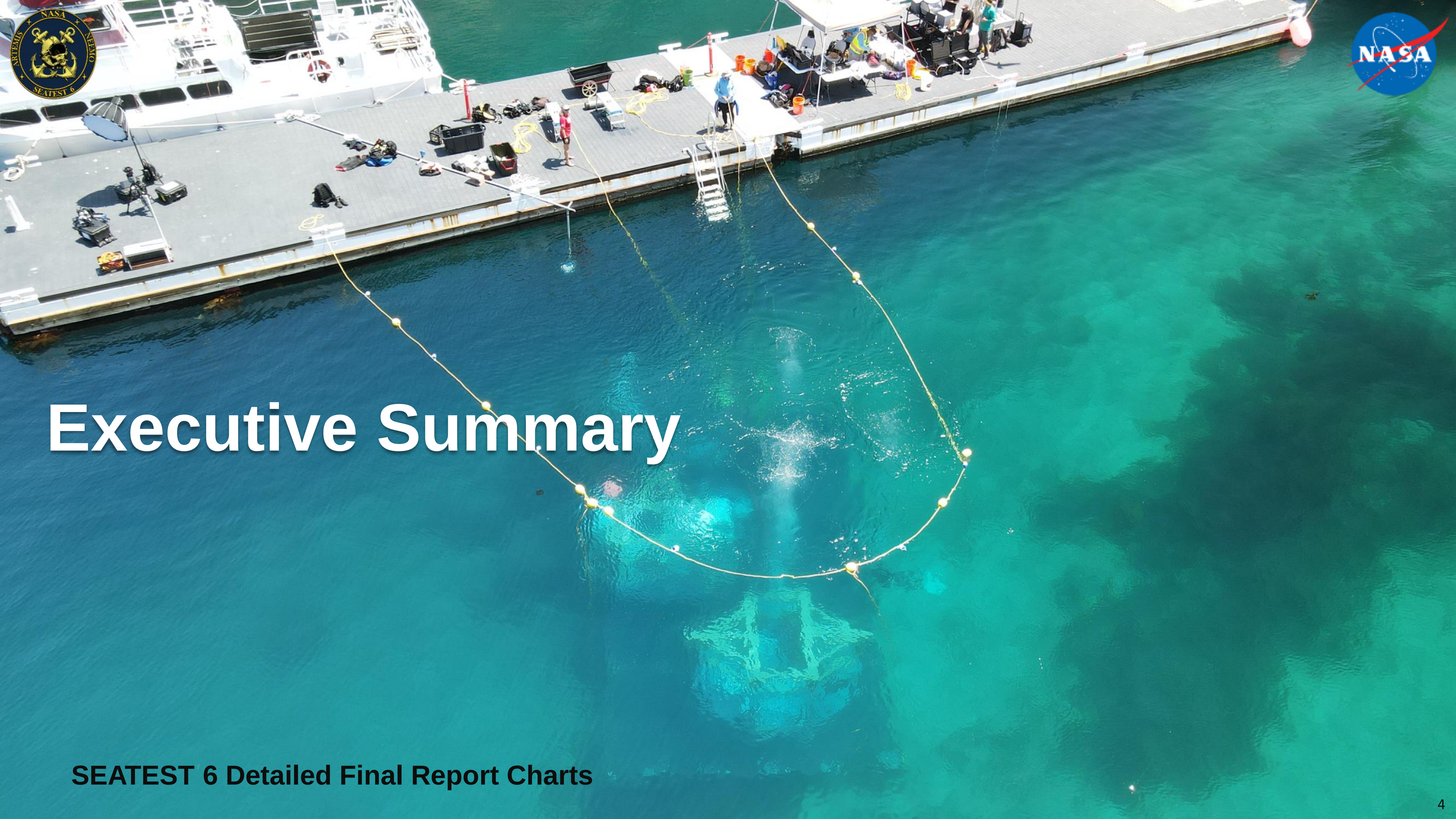
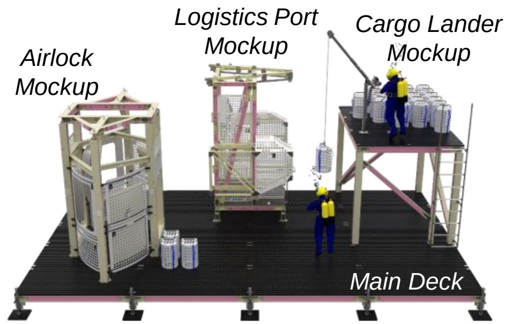


Executive Summary

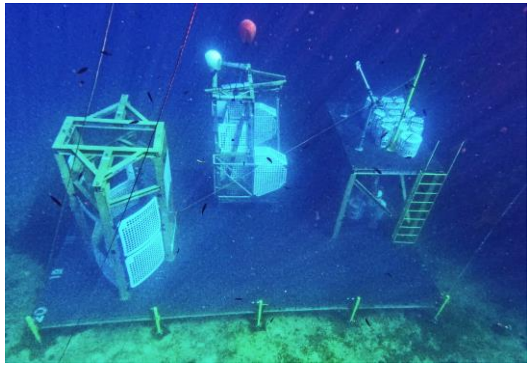
SEATEST 6 Detailed Final Report Charts

Executive Summary

- **<u>Sponsor</u>:** NASA Exploration Systems Development Mission Directorate (ESDMD) Strategy and Architecture Office (SAO)
- **<u>Objective</u>:** Perform a Human-in-the-Loop (HITL) trade study on major EVA-intensive concepts related to logistics transfer from a notional cargo lander to a surface element (SAC Task 23.12.6)
  - Feasibility of Extra-Vehicular Activity (EVA) crew transfer of logistics
  - Best practices, considerations and constraints that inform ConOps for logistics transfer
- **<u>Rationale</u>:** Results will inform ACR/SAC 23 tasks and Artemis SAO teams responsible for:
  - Logistics management
  - Cargo resupply lander requirements
  - Dust mitigation
- **<u>Methodology</u>:**
  - Five astronaut/engineers (crewmembers) performed scenario evaluations with cargo containers at 1/6g
  - Objective and subjective data was captured using rigorous metrics and protocols
- **<u>Location</u>:** Wrigley Marine Science Center, University of Southern California (USC) - Dornsife
- **<u>Test Dates</u>:** July 18-30, 2023



Conceptual mockup rendering


Mockup post-assembly


Local MCC w/ video/voice for PIs & room for observers

Executive Summary

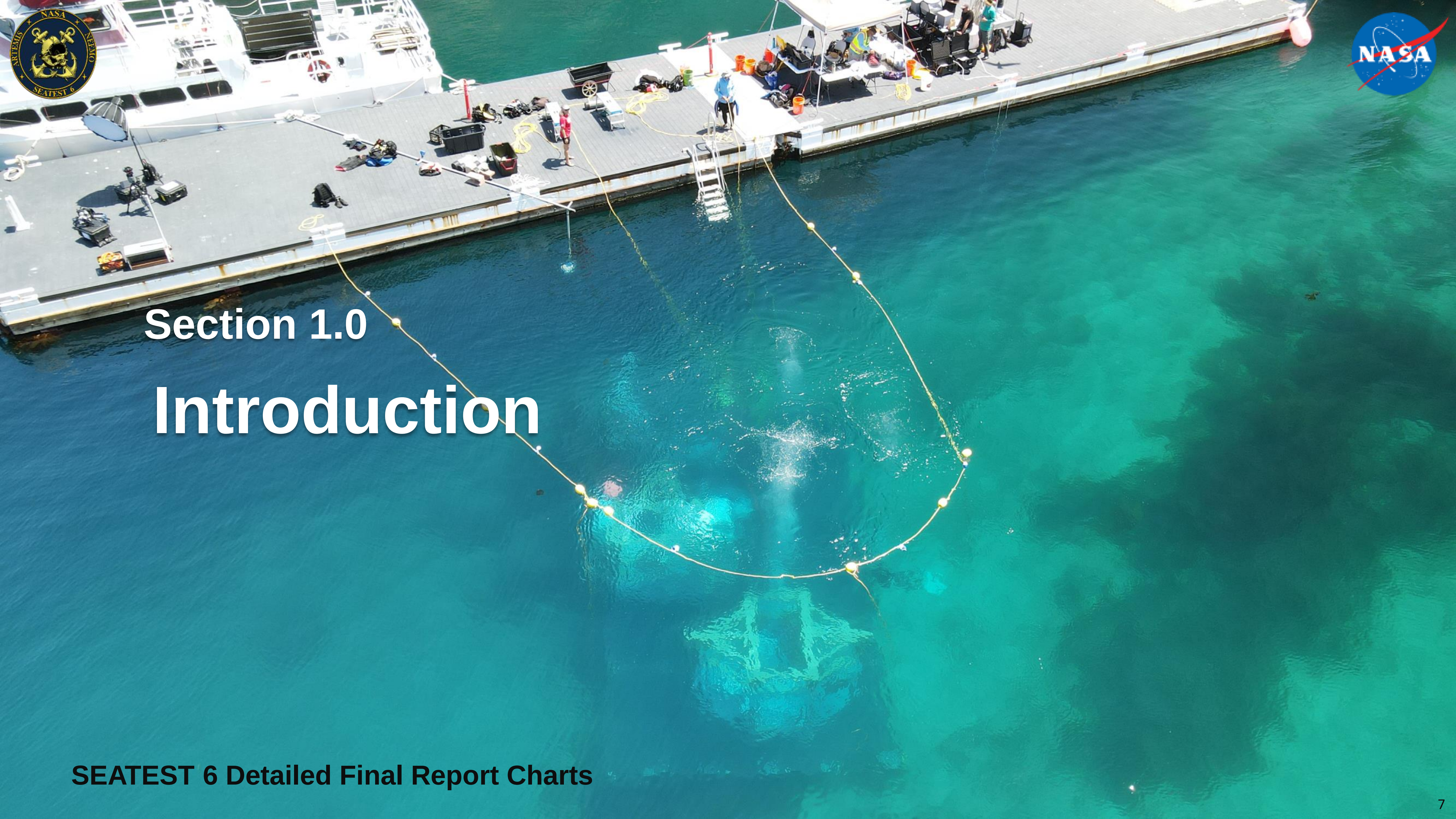
- **SEATEST 6 planned to evaluate:**
  - Logistics transfer ConOps using notional Small Pressurized Logistics Containers (SPLC) of 1.0 and 2.0 Crew Transfer Bag Equivalent (CTBE) volumes, as well as a Medium Pressurized Logistics Container (MPLC) of 14-16 CTBE*
  - Use of a Logistics Port compared to transfer through an Airlock hatch
  - Offloading methods based on either a Davit or a Zipline system
  - Choreography of cargo in the airlock to permit ingress and suit doffing
  - Inclusion of dust removal protocols for an understanding of the overall impact to transfer ops
- **Five astronauts/engineers evaluated 8 scenarios of cargo lander logistics unloading and re-loading with extensive data collected:**
  - Objective data:
    - Task times for conducting overall tasks and subtasks
    - Full audio/video of test activities
    - Inadvertent # of “dings” on hardware
  - Subjective data:
    - Crew consensus of:
      - Task acceptability and capability assessment ratings related to best practices, considerations, and constraints for EVA-driven logistics transfer ConOps
      - Sim quality of the test environment
    - Crew debrief comments

Results informed SAC23 tasks and will inform the Architecture Definition Document (ADD), SAC24 tasks, and ConOps for various cargo lander options

* Was not evaluated due to early test termination

Section 1.0

Introduction



SEATEST 6 Detailed Final Report Charts

SEATEST Test Series

SEATEST (Space Environment Analog for Training, Engineering, Science and Technology) was conceived to accomplish two primary goals:

- **Develop the capability to conduct Human-in-the-Loop (HITL) testing that can benefit from undersea testing**
  - Rapid prototyping and assessment of Artemis ConOps and Capabilities
  - Integrated ConOps development testbed
  - Medium fidelity, partial gravity environment
  - Dedicated crew input toward Artemis architecture questions
  - Direct cost offset via International Partner Astronaut participation costs
  - Dedicated feedback from other relevant end-operators (e.g., CapCom, EVA Officer)
- **Provide an “Expeditionary Training” experience for the International Astronaut Corps**
  - Leadership/followership opportunities
  - Extreme environment mission operations
  - Real risks, demanding critical training, good buddymanship, and high individual and team performance
  - “Detachment mentality” where the questions being answered are front and center for an extended period of time

SEATEST is a capability to rapidly assess ConOps questions with dedicated crew and end-user feedback

SAC23 Logistics Task and SEATEST 6

- **Three options for habitable element interfaces and pressurized logistics containers were considered:**
  - **EVA Hatch (no dedicated interface) / small pressurized container (i.e., hand-held "suitcases")**
    - All logistics brought into pressurized volume via EVA hatch – either directly into cabin or via airlock
    - No specific interface
    - "Small" size driven by need to maneuver carriers through hatch(es) into a pressurizable volume
    - Practical range to handle manually ~1CTBE – 2CTBE
  - **Dedicated logistics port / medium pressurized container** (i.e., too large to be hand-held by crew alone, but can be moved with support from crew and/or robotic assistance)
    - Logistics container mates with habitable volume through a port with hatch on the exterior shell – container remains outside and provides additional storage volume
    - "Medium" size driven by need to maneuver container to attach to habitat and to travel with mobile elements
    - Practical range is large ~5 CTBE – 25 CTBE+ (with significant robotic or mechanical assistance)
  - **Berthing or docking port / large pressurized container** (e.g., Cygnus-like module)
    - Logistics module docks/berths with surface element and has crew-sized hatch
    - Crew enters logistics module via hatch
- **SEATEST 6 studied the first two EVA-intensive options**

There are a range of potential sizes and configurations that could work with each logistics container and interface. Point solutions were identified as a starting point for sensitivity analysis and HITL testing.

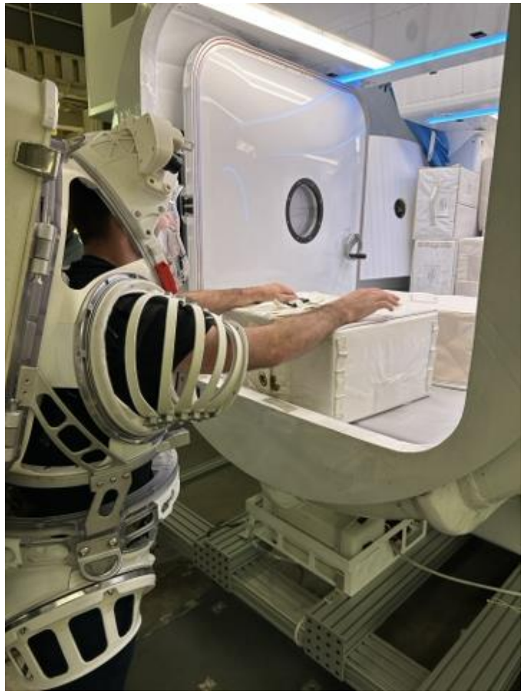
Primary Use of Data

- **Exploration Systems Development Mission Directorate (ESDMD)** is responsible for defining and managing systems development for programs critical to NASA's Artemis program and planning for NASA's Moon to Mars exploration approach
- **Architecture Concept Reviews (ACR) are conducted annually by ESDMD** - during these ACRs, NASA architecture teams analyze the Moon to Mars Objectives and distill them into mission elements and how they function together to accomplish human missions to the Moon to Mars
- **To support the Nov. 2023 ACR, a series of Strategic Analysis Cycle (SAC) tasks are ongoing**
- **SAC 23 tasks informed by SEATEST 6 include:**
  - SAC Task 23.3 and 23.10 Use Case and Functions Refinement
  - SAC Task 23.9: Multi-Region Use Case Assessment
  - SAC Task 23.12: Define Artemis Logistics Architecture
- **Results will ultimately inform:**
  - Architecture Definition Document (ADD)
  - SAC24 tasks
  - ConOps for various cargo lander options, e.g.
    - HDL-CONOPS-007 HDL (Human-class Delivery Lander) Large Cargo Lander ConOps
    - ESA Argonaut Lander ConOps doc #TBD
    - Mid-sized Lander ConOps doc #TBD

Community Integration

SEATEST 6 significantly moved the community forward on EVA logistics concepts

- **Arbitrary but inflexible milestone of a crew office supported mission brought all stakeholders together to work on a common solution:**
  - Logistics Team, Cargo Lander Team, FOD EVA, Dust, EHP, HITL Testing teams
- **Design of mockups forced previously unanswered touch points to get addressed:**
  - Actual design decisions for notional concepts
  - Actual techniques
  - Full consideration of suit capabilities and limitations (balance, work envelope, reach, etc.)
  - Full consideration of human capabilities and limitations (weight, size, CG limitations)
  - Standalone testing at JSC and CAD analysis was used to inform assumptions and designs
    - When we started, Logistics team was thinking SPLC sizes of 3.0 and 5.0 CTBE would be the bounding cases. JSC testing showed even a 3.0 CTBE SPLC is too big and bulky for two crewmembers to manipulate manually while suited. Determined 1.0 and 2.0 are the real bookends.
    - Assumptions for "reasonable" activities made and followed (see section 2.5)
- **Resulting HITL testing collected data from relevant End Operators**
  - Focused crew input over multiple days brought deep insights



Logistics test at JSC mockup utilizing various CTBEs

> "The thing I've always liked about analogs is they have an arbitrary, but inflexible deadline. Work goes through an amazing step function of maturity when everyone's under the spotlight trying to perform."
>
> \- Rob Ambrose

Test Participants & Test Support

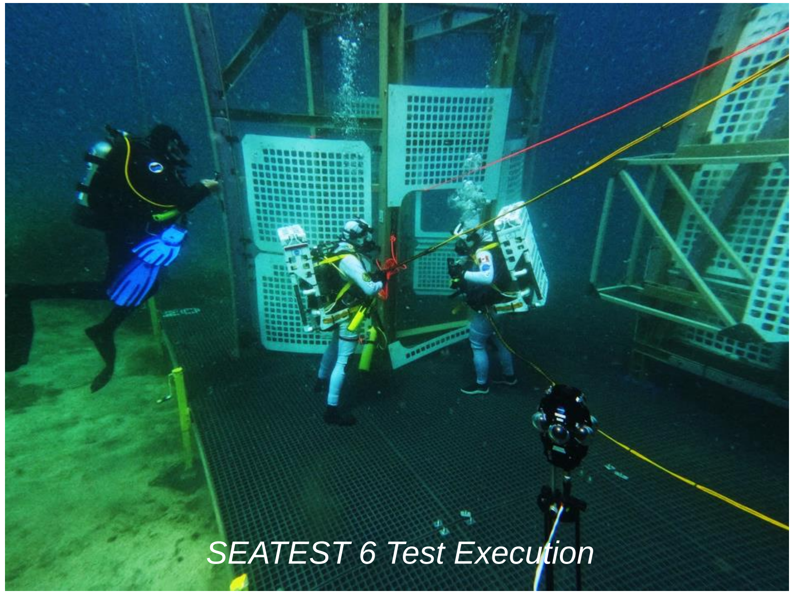
Crew
- Jonny Kim (CB)
- Suni Williams (CB)
- Hazzaa Almansoori (CB/UAE)
- Jenni Sidey-Gibbons (CB/CSA)
- Tamra George (XM)

Stakeholders
- Strategy & Architecture Office (SAO)
  - Lunar Architecture Team
  - Logistics sub-architecture
  - Cargo Lander requirements
  - Surface Robotics & Mobility team
- STMD – Lunar Dust Mitigation team
- Moon to Mars (M2M) Program Office
- EVA and Human Surface Mobility Program (EHP)
- Flight Operations Directorate (FOD)

University Partner
- University of Southern California (USC)/ Wrigley Marine Science Center

Commercial Partner
- Felix & Paul Studios

Field Participants
- **Topside Divers**
  - Bill Todd (XM)
  - Marc Reagan (XM)
  - Barbara Janoiko (XM)
  - Kara Beaton (DI)
  - Jason Poffenberger (XM)
  - Taylor Phillips-Hungerford (ER)
- **Comm Support**
  - Juan Busto (KSC)
  - Mike Miller (KSC)
- **Mockup Support**
  - Brett Montoya (SF)
  - Lily Douglas (SF)
  - Emory Fesel (SF)
  - Clark Thompson (ER)
- **MCC Participants**
  - CapCom – Jay Marschke (CB)
  - EVA – Grier Wilt (CX)
  - Protocol – Chip Litaker (SF)
  - Protocol – Allison Porter (XM)
  - Imagery/Report – Shonn Everett (XM)
- **Public Affairs Office (PAO)**
  - Nilufar Ramji (AD)



SEATEST 6 Test Execution

SEATEST 6 Team

Team Leadership

Key leadership positions during testing and mission operations were:

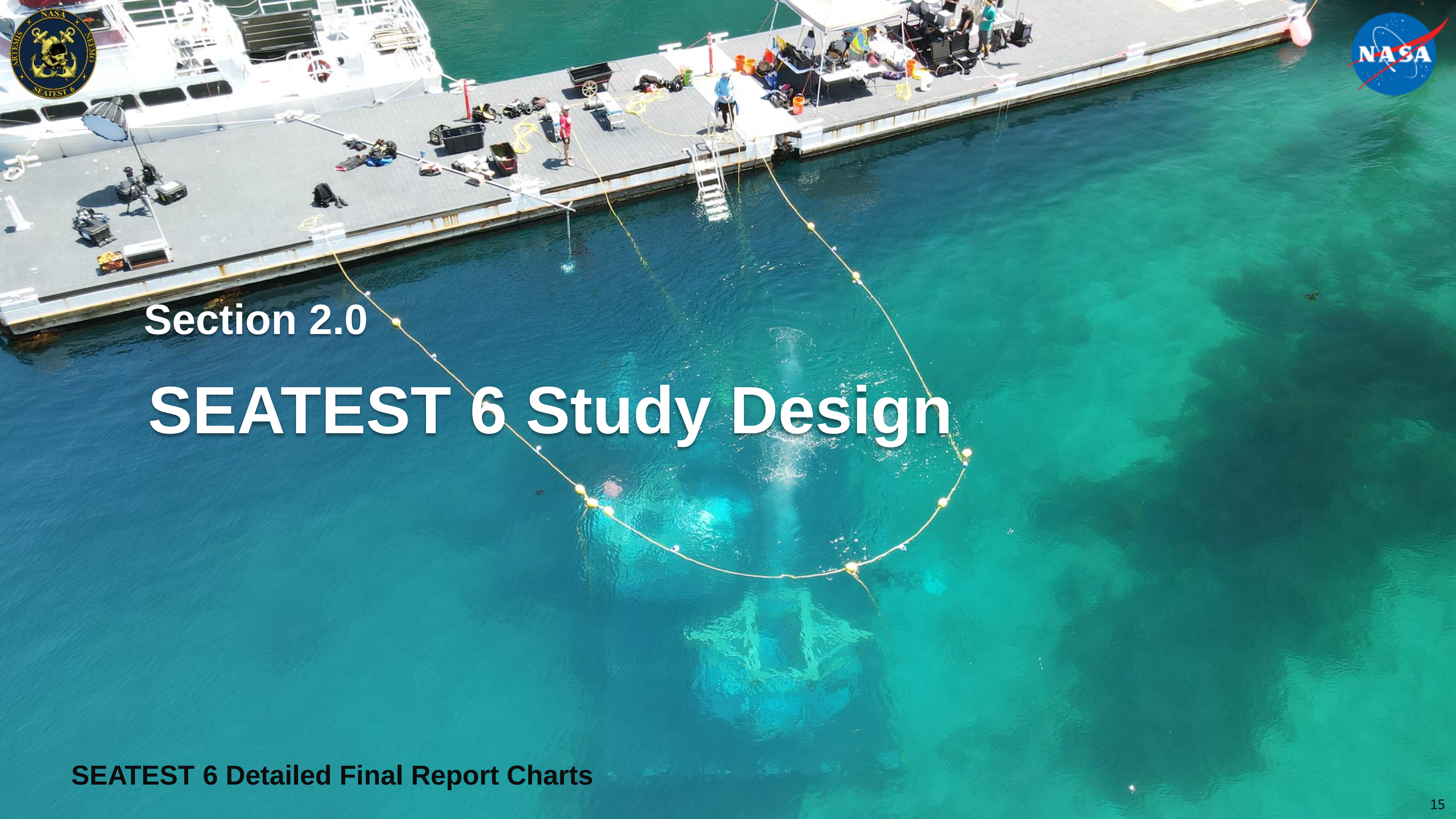
- Mission Director – The final decision maker regarding big picture objectives, priorities, safety, etc. during the testing. This is Marc Reagan or his designee if he is unable.
- Diving Lead – The person responsible for ensuring safe diving operations, including Dive Sup and support diver rotations, as well as ensuring dive plans and other USC-required products are submitted and accurate. This is Bill Todd or his designee if he is unable.
- MCC Lead – The person responsible for ensuring MCC functionality, and oversight of the data collection, report writing, imagery and comm teams. They will also serve as the POC for any logistics questions related to USC facilities or livability support. This is Barbara Janoiko or her designee if she is unable.
- Mission Management Team – Will make mission priority and other decisions jointly when time permits. Consists of the Mission Director, Diving Lead, and MCC Lead.
- Dive Sup – Responsible for oversight of diving operations. Will be dockside during all diving and will supervise donning, doffing, and record keeping of dive ops. Will man the comm box and have control of the dive from water entry until test subject fins are off and additional weight belts on, at which point control of the test will pass to the CapCom/Ground IV. At the end of the test, the Dive Sup will take control of the dive and comm again when fins are donned and weight belt doffed. The Dive Sup has authority to take control of the dive at any time during testing at his discretion.
- CapCom – The CapCom/Ground IV will direct test activities from beginning to end. They will take the handoff of authority from the Dive Sup and pass it back at the end of the test. They will also take note of any time lost due to technical issues, for use in troubleshooting decision making.

Schedule

- **General test timeline:**

Test Dates	17-Jul Monday	18-Jul Tuesday	19-Jul Wednesday	20-Jul Thursday	21-Jul Friday	22-Jul Saturday	23-Jul Sunday	24-Jul Monday	25-Jul Tuesday	26-Jul Wednesday	27-Jul Thursday	28-Jul Friday	29-Jul Saturday	30-Jul Sunday	31-Jul Monday	1-Aug Tuesday
Dive Team	Flight to CA	Miss C. AM Assembly, Dive Re-qual	Mockup Deploy, Diver re-qual	Mockup Deploy	Mockup Deploy	Mockup Deploy	Dry Runs	Emer Trng & Dry Runs	Scenarios 1-4	Scenarios 5-8	Debrief	Teardown	Teardown	Teardown	Packing Miss C. PM	Fly Home
Crew				Flight to CA	Miss C. AM Gear c/o, orientation, Basic Trng	Basic Training, FFMs	Basic Training, FFMs	Emer Trng & Dry Runs	Scenarios 1-4	Scenarios 5-8	Debrief	Fly Home Miss C. PM				
MCC & Comm				Flight to CA	Miss C. AM Setup	Setup	Dry Runs	Dry Runs	Scenarios 1-4	Scenarios 5-8	Debrief	Teardown/ Reporting	Teardown/ Reporting Ferry CE PM	Fly Home		
Data/Protocol				Flight to CA	Miss C. AM Setup	Setup	Dry Runs	Dry Runs	Scenarios 1-4	Scenarios 5-8	Debrief	Teardown/ Reporting	Teardown/ Reporting	Teardown/ Reporting Ferry CE PM	Fly Home	
H/W Suppt. Team	Flight to CA	Miss C. AM Mockup Assy	Mockup Assy	Mockup Assy	Mockup Assy	Mockup Assy	Mockup Assy	Mockup Support	Mockup Support Miss C. PM	Fly Home						
Visitors/Observers									July 25th Visitor Op.	July 26th Visitor Op.						

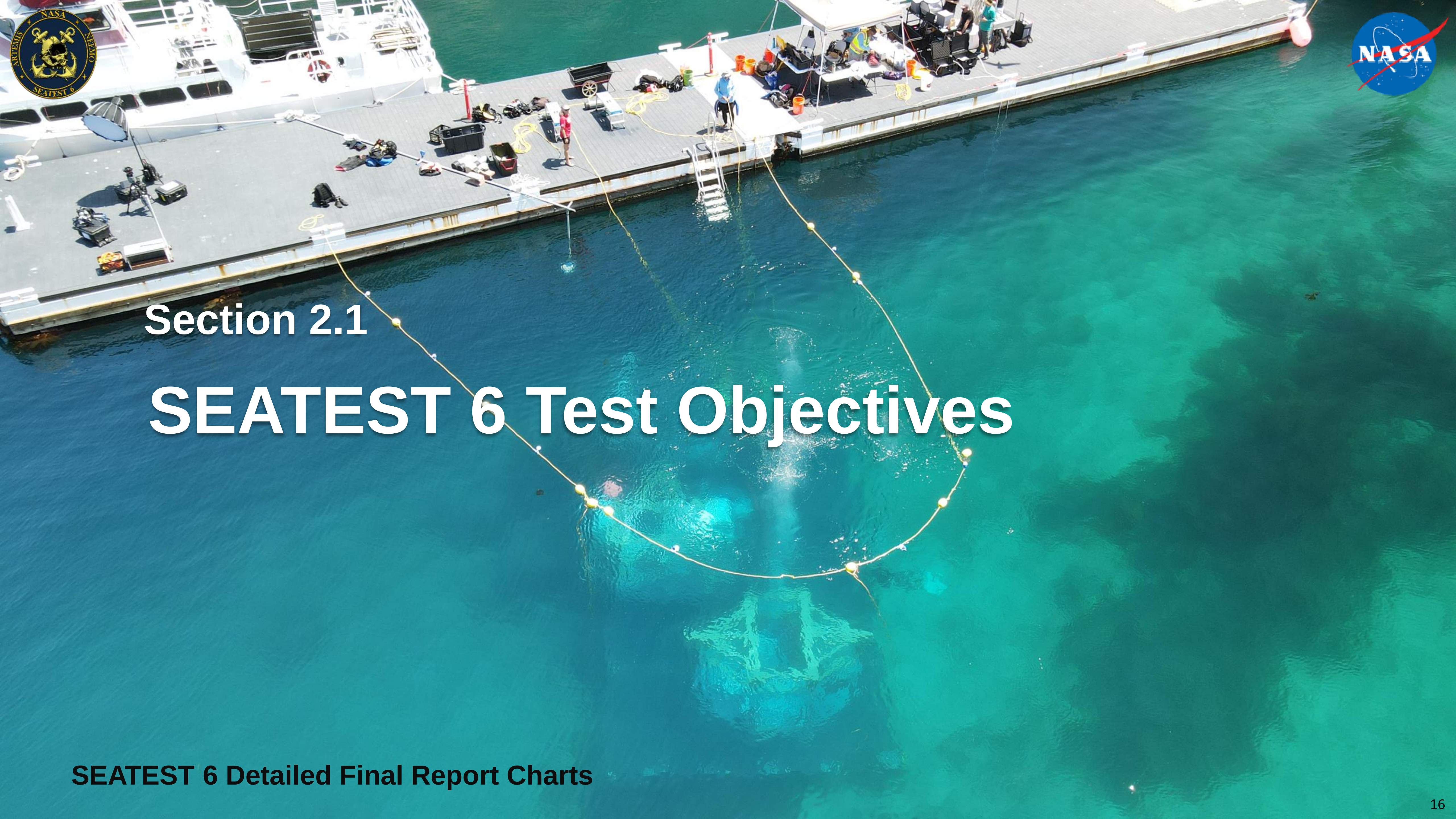
- Note: Five days of scenario testing were planned but only two were able to be executed.



Section 2.0

SEATEST 6 Study Design

SEATEST 6 Detailed Final Report Charts



Section 2.1

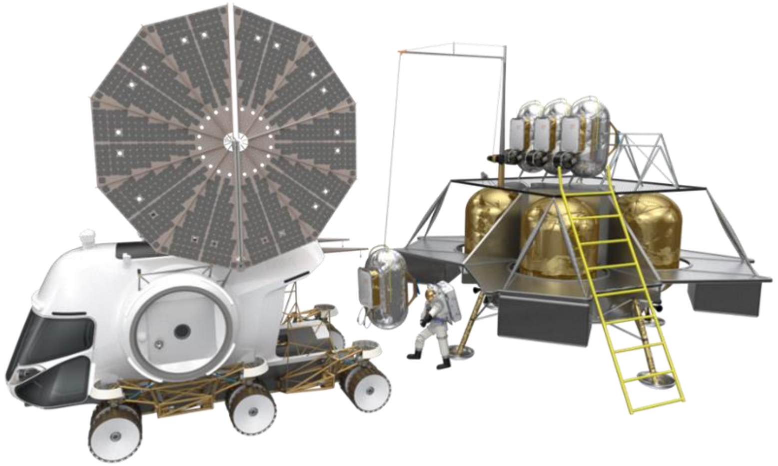
SEATEST 6 Test Objectives

2.1.1 SAC23 Test Objectives

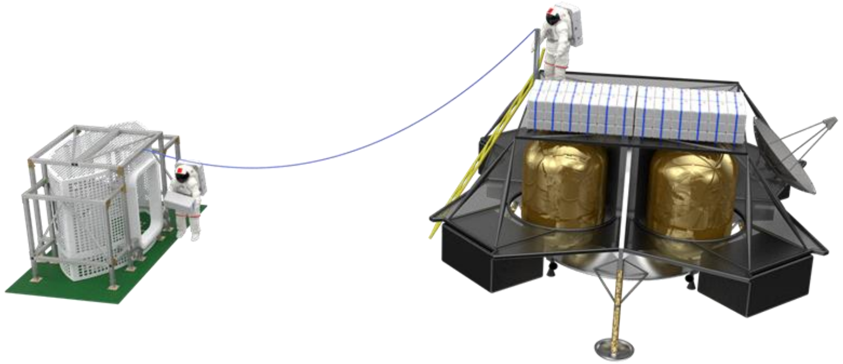
- **SEATEST 6 (ST6) objectives are traced directly to NASA's Strategy and Architecture Office (SAO) Strategic Analysis Cycle (SAC) 23.12:**
  - ***"To evaluate different offloading and logistics transfer methods and dust effect to inform ConOps analysis, trades and assessments."***
- **The overall objective of SEATEST 6 was: Conduct a Human-in-the-Loop (HITL) trade study on major, EVA-intensive concepts related to logistics transfer from a notional cargo lander to a surface element (SAC Task 23.12.6)**
  - Assess feasibility of EVA crew transfer of logistics
  - Capture best practices, considerations and constraints that inform ConOps for logistics transfer
  - Capture dedicated feedback from relevant end-operators
- **To provide the necessary data for the above requirement, the study objectives were:**
  - To assess options for end-to-end medium pressurized logistics containers (MPLC) and small crew-portable containers (SPLC) into a pressurized vehicle via a transfer port and/or a side hatch
  - To assess two different offloading techniques including a davit arm and zipline system to offload logistic containers to the ground from the cargo lander deck
  - To assess conceptual dust mitigation ConOps including using tools to brush off dust, adding guards to protect seals, note abrasions and potential damage to hatch seals and the time required for dust mitigation

2.1.2 Data and Knowledge Generated

- **Understand logistics transfer ConOps with time hacks for each method**
  - Evaluate using medium sized and small (1 CTBE and 2 CTBE) containers
  - Evaluate logistics port and hatch
- **Evaluate different crew-assisted offloading methods**
  - Davit
  - Zipline
- **Evaluate impact of dust removal requirements**
  - Note times for container and crewmember dusting
- **Collect Objective Data:** Task times, full audio/video of test activities, inadvertent # of “dings” on hardware, etc.
- **Collect Subjective Data:** Task acceptability and capability assessment ratings related to best practices, considerations, and constraints for EVA-driven logistics transfer ConOps



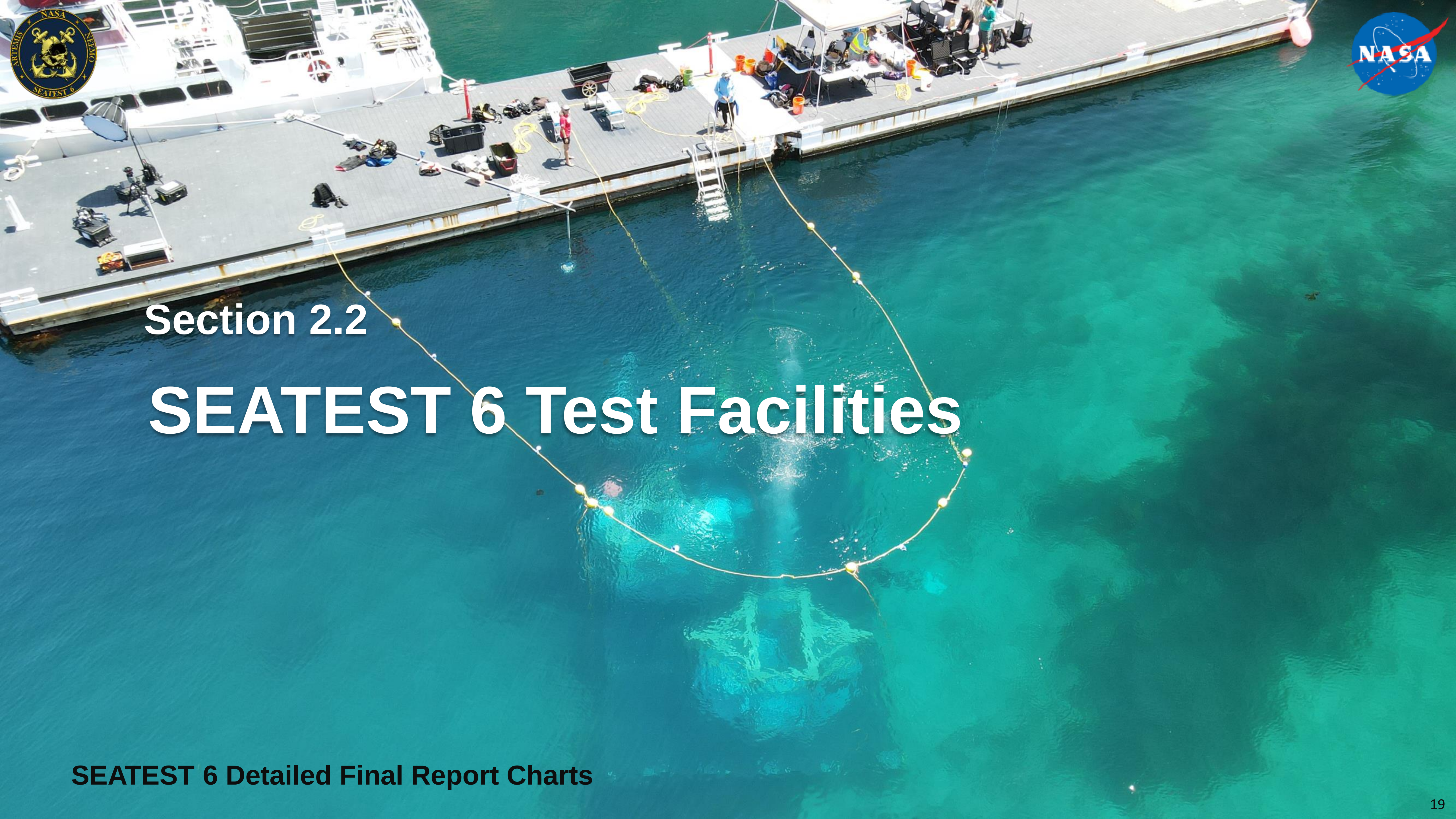
Artist concept of crew utilizing a davit to offload MPLCs to a pressurized rover logistic port



Artist concept of crew utilizing a zipline to transport SPLCs to a crewmember at an airlock

Section 2.2

SEATEST 6 Test Facilities

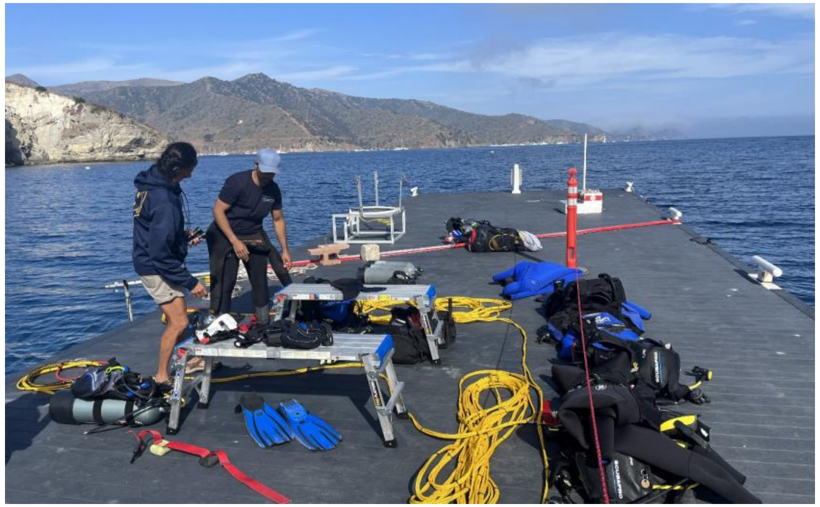


2.2.1 Testing Facilities

- University of Southern California Wrigley Marine Science Center (WMSC) on Santa Catalina Island, CA
  - Diving infrastructure
  - Protected cove to exercise test scenarios
  - Team housing and dining facilities
  - Meeting area configurable as an MCC

Fisherman's Cove dock: ST6 Test Area

Wrigley Marine Science Center

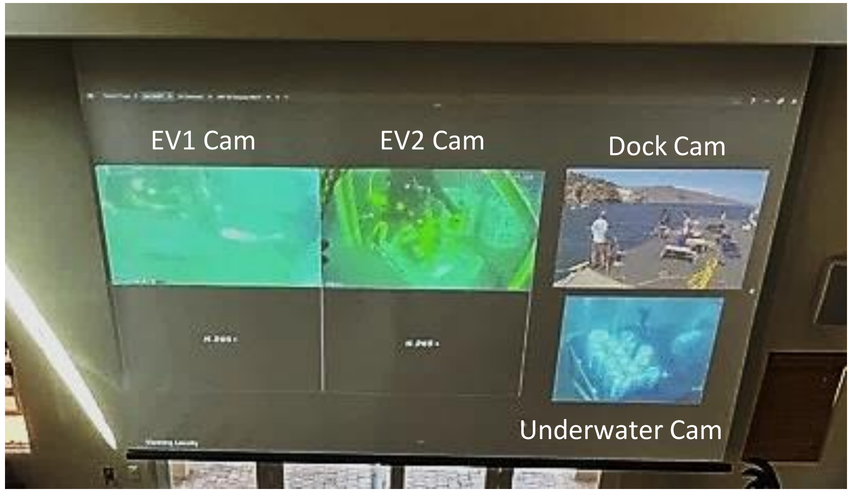


Diver Suit-Up Area

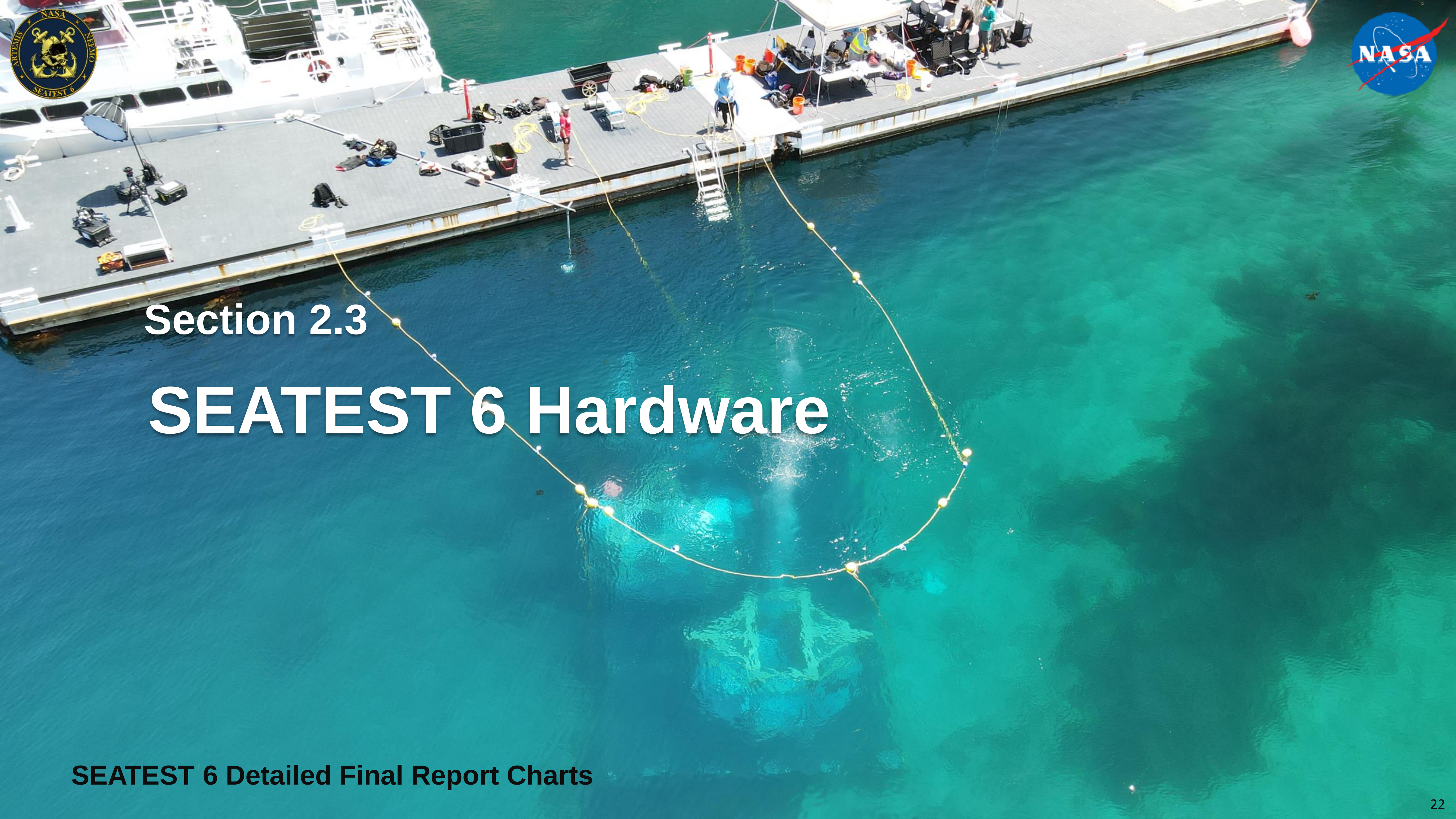
2.2.1 Testing Facilities (cont.)

- **WMSC Briefing Room served as ST6 Mission Control Center** (~500m from the dock where test operations took place)
  - Video Projected on front screen: EV1 & EV2 helmet cams, 1 underwater situational awareness camera, and 1 dock camera
  - Room audio with Ground IV on a headset
  - Stations for Team monitoring each test run:
    - In-sim: CapCom/Ground IV
    - Rotating (not making the current dive) Test Subjects
    - Out of sim:
      - Off-duty Test Subjects
      - Protocol/data
      - Imagery/Report
      - Comm

SEATEST 6 Mission Control Center



Camera views being monitored in SEATEST 6 MCC

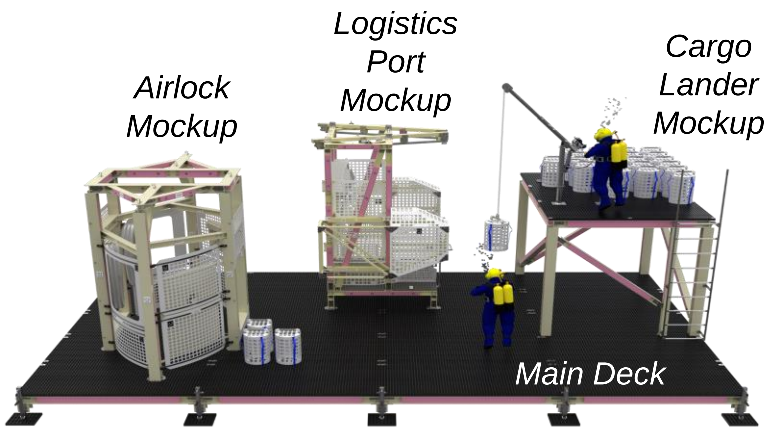


Section 2.3

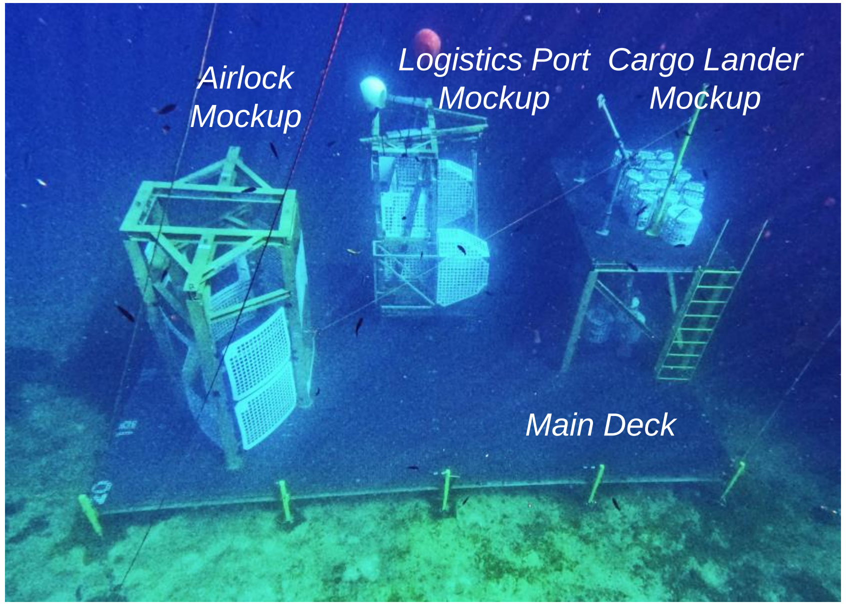
SEATEST 6 Hardware

2.3.1 Hardware Overview

- **Mockups included:**
  - Cargo lander with raised deck
  - Airlock
  - Logistics port (assumed to be on a pressurized rover)
- **Main deck provided a way to positively secure mockups to the seafloor and reduce silting. It sat at 9.1 m below the surface**
- **Hardware design and assumptions provided by:**
  - Logistics carrier assumptions provided by SAO Logistics Team + Campaign Analysis Team
  - Cargo lander assumptions provided by SAO Cargo Lander Team
  - Airlock assumptions provided by SAO Surface Habitat team
  - Logistics port assumptions provided by SAO Surface Robotics & Mobility Team
  - Offloading concepts provided by SAO Lunar Architecture Team (LAT), in coordination with Cargo Lander and Robotics/Mobility Teams
- **Note:** *All mockups are notional and do not reflect the architecture of the current lunar pressurized rover or cargo lander*



Notional rendering of mockup assembly

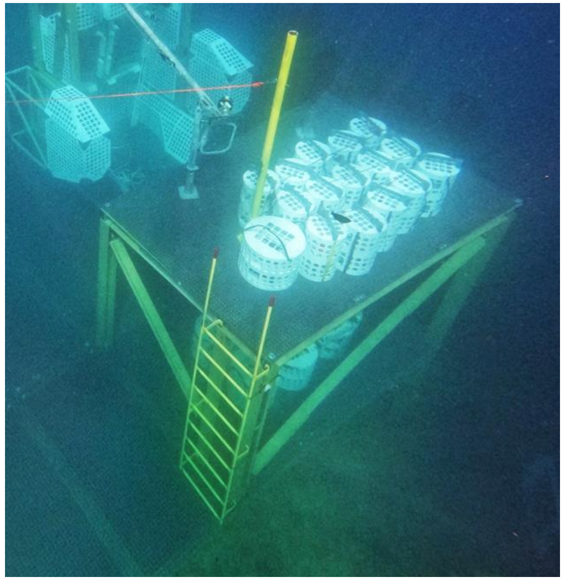


SEATEST 6 mockup assembly on sea floor

2.3.2 Conceptual Cargo Lander

- Height = 2.5m
- Lander Deck
  - Construction = Fiber-Reinforced Polymer (FRP) I-Beams, stainless steel brackets, fibergrate floor
  - Deck Area = 8.92 m^2
  - Deck Dimensions = 365.7 x 243.8 cm Length x Width
  - Weight = 907.2 kg on land; 362.9 kg underwater
  - Ladder = 2.5 to 3.0 m Height

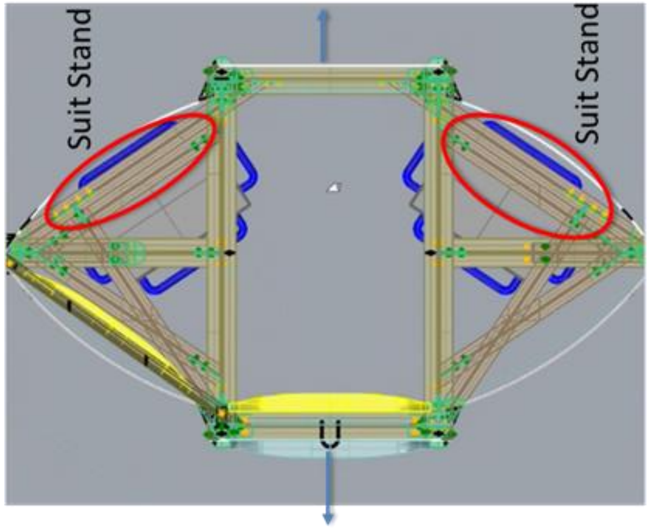
Rendering cargo lander mockup



SEATEST 6 cargo lander mockup

2.3.3 Conceptual Airlock

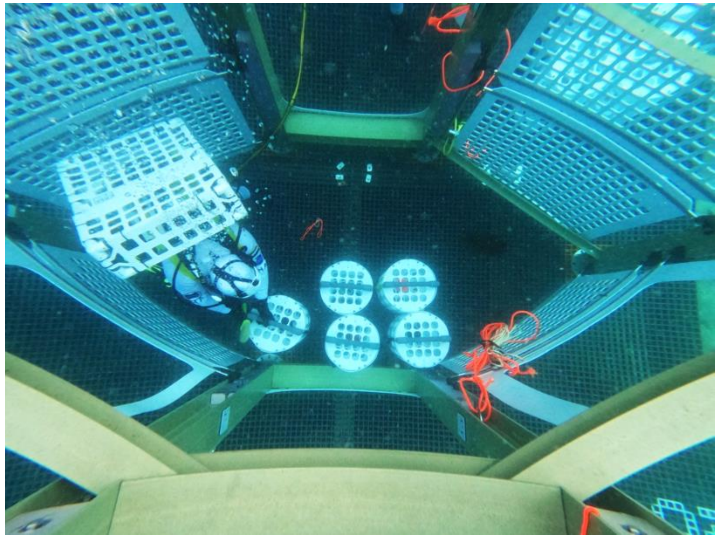
- Construction = FRP I-Beams, Kydex panels, Stainless steel brackets
- Dimensions = 383.3 x 201.7 cm Length x Width
- Internal Volume = 9.5 m^3
- Hatch = 152.4 x 101.6 cm
- Weight = 907.2 kg on land; 362.9 kg underwater



Rendering of airlock top view

Airlock Rendering

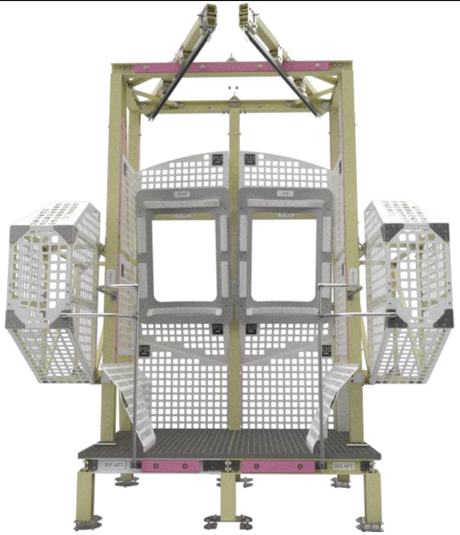
Airlock mockup



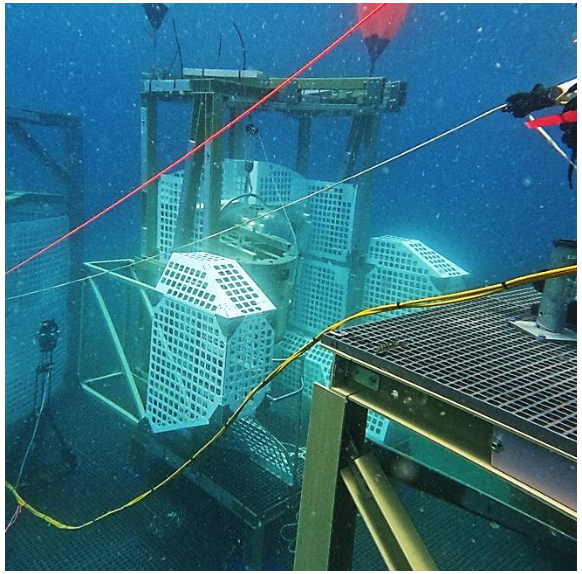
SEATEST 6 airlock top view

2.3.4 Conceptual Logistics Port (Pressurized Rover Aft Deck)

- For MPLC operations
- Aft Deck
  - Construction = FRP I-Beams, stainless steel brackets, Kydex panels, fibergrate floor
  - Dimensions = 191.6 x 375.9 x 202.8 cm (width x height x depth)
  - Weight = ~ 11,339.8 kgf on land; 498.9 kgf underwater



Rendering of aft deck mockup



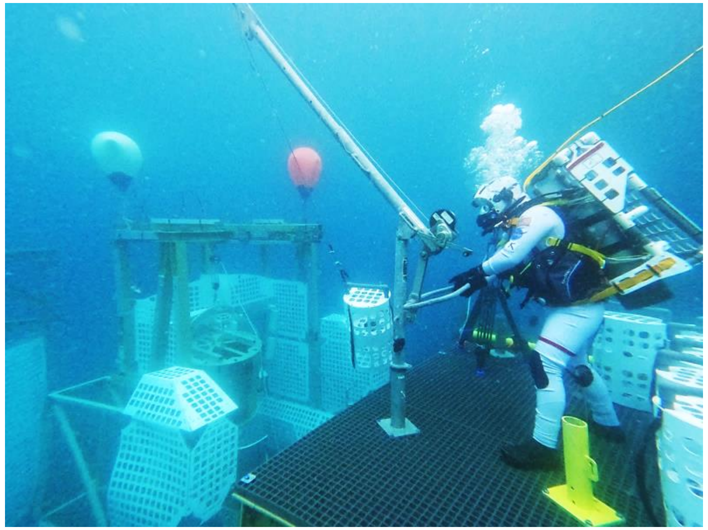
SEATEST 6 aft deck mockup

2.3.5 Conceptual Offloading Concepts

Two offloading concepts were tested: davit system and zipline system:

- Davit Construction = Stainless Steel
  - Fully extended arm = 153.6 cm
  - Height from Lander Deck = 247.2 cm
  - Lift Below Deck Height = 8.02 to 9.7 m
  - Cable is galvanized aircraft cable at 6 mm diameter
    - Total length = 13.7 m
  - Arm Load Rating = 300 kg
  - Arm Rotation Range = 360º
  - Swivel hook, swaged ball fitting and quick disconnect

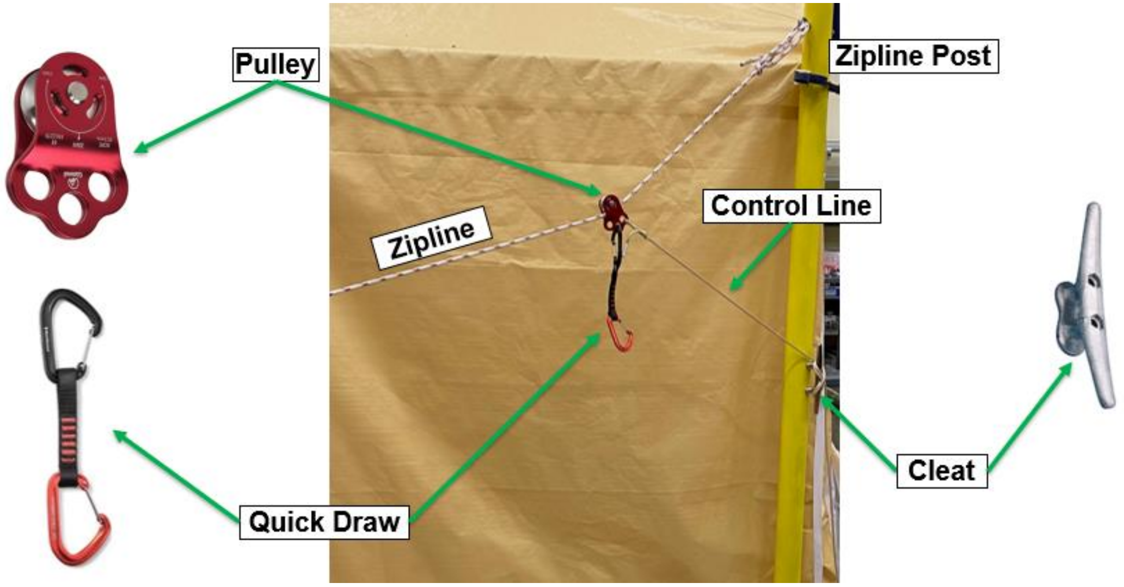
Rendering of davit



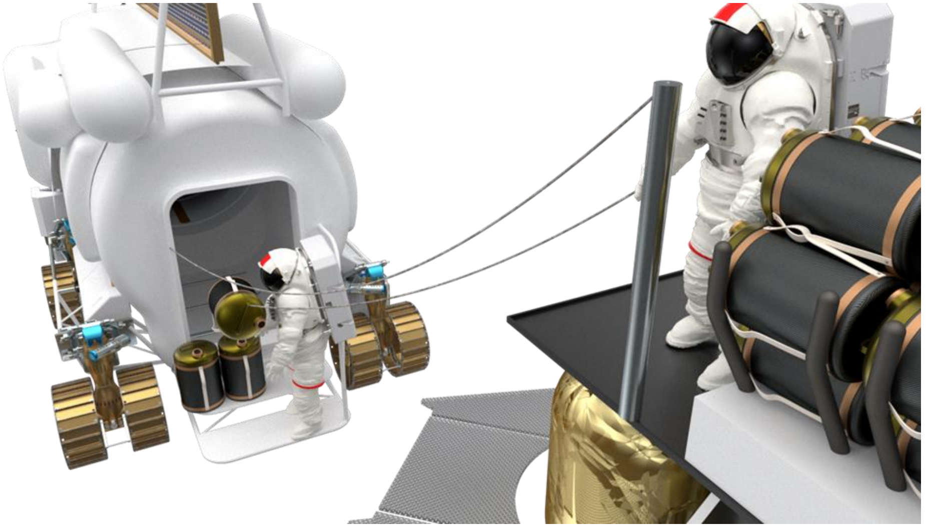
SEATEST 6 davit in use

2.3.5 Conceptual Offloading Concepts (cont.)

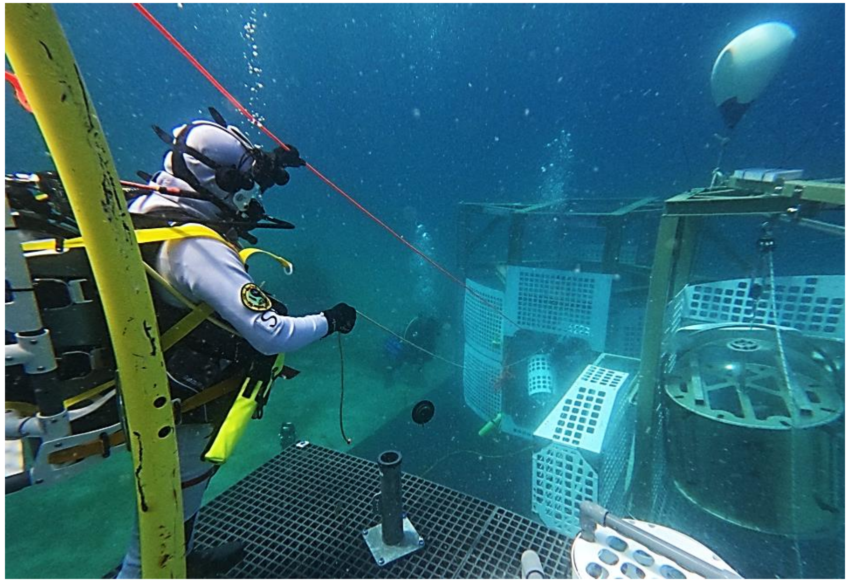
- Zipline System
  - Post Height from Lander Deck = 1.98 m
  - Rope is 11 mm static climbing rope



SEATEST 6 zipline system



Rendering of zipline



SEATEST 6 zipline in use

2.3.6 Conceptual Logistic Containers

- **Three concepts for pressurized logistic containers were evaluated: two small pressurized logistics containers (SPLCs), and one medium pressurized logistics container (MPLC)**

1.0 SPLC

- 1.0 Small Pressurized Logistics Container (SPLC)
- 1.0 CTBE
- Crew handling aids:
  - 1 hard handrail on top
  - 3 soft goods straps along length
- Mass: 38 kg

2.0 SPLC

- 2.0 Small Pressurized Logistics Container (SPLC)
- 2.0 CTBE
- Crew handling aids:
  - 2 soft goods straps along top and bottom circumference
  - 2 crew carry requirement
- Mass: 75 kg

MPLC

- Medium Pressurized Logistics Container (MPLC)
- 14-16 CTBE
- Docks to Transfer port
- Requires use of offloading system
- Crew handling aids:
  - 2 handrails
  - Lifting hoop
- Mass: 435 kg

- **The total number of containers included at ST6 was determined by estimating the number of containers of each type that could fit in the airlock while still leaving room for 2 suited crewmembers to ingress, close the hatch behind them, and doff their suits**
  - Consideration given to handling difficulties of each size container; e.g., a ground-rule dictated the 2.0 SPLC as too heavy/awkward for a single suited crewmember to lift/carry

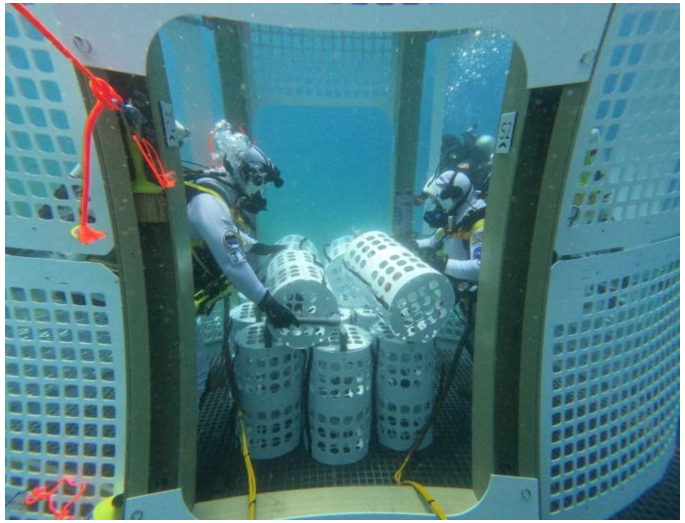
2.3.6 Conceptual Logistic Containers (cont.)

1.0 CTBE SPLC (can be carried by one crewmember)

- Construction = Kydex
- Capability = 1 CTBE
- Pressurized Volume = 0.05 m^3
- Dimensions = 58.2 cm height, 36.6 cm diameter
- Reference Weight = Lunar equivalent 6.5 kgf
- Under Water Weight = ~6.5 kgf

Rendering of a 1.0 SPLC (left) and mockup (right)

Crewmember carrying a 1.0 SPLC



1.0 SPLCs stacked in the A/L

2.3.6 Conceptual Logistic Containers (cont.)

2.0 CTBE SPLC – two crew carry the larger 2.0 SPLCs together

- Construction = Kydex
- Capability = 2 CTBE
- Pressurized Volume = 0.098 m^3
- Dimensions = 45.7 cm height, 55.9 cm diameter
- Reference Weight = Lunar equivalent 12.5 kgf
- Under Water Weight = ~11 kgf

Rendering of two crew carrying a 2.0 SPLC

Comparison of 1.0 and 2.0 CTBE SPLCs

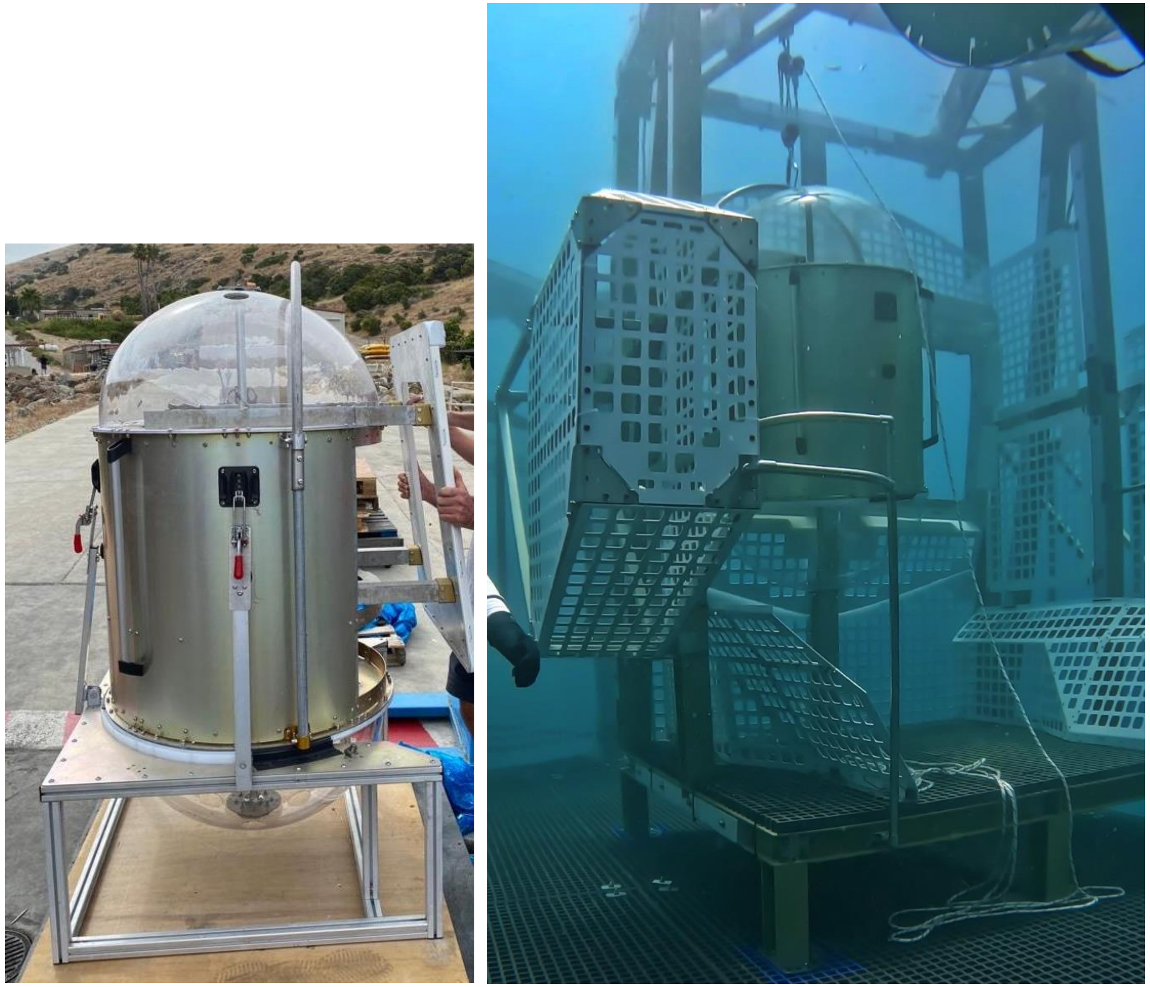
SEATEST test subjects moving a 2.0 SPLC

2.3.6 Conceptual Logistic Containers (cont.)

Medium Pressurized Logistic Container (MPLC)

- Construction = 6061 aluminum, acrylic end domes
- Capability = 14-16 CTBE
- Internal Volume = 1.3 m^3
- Dimensions = 160 x 80 cm
- Weight = 81.6 kg on land; 72.6 kg underwater

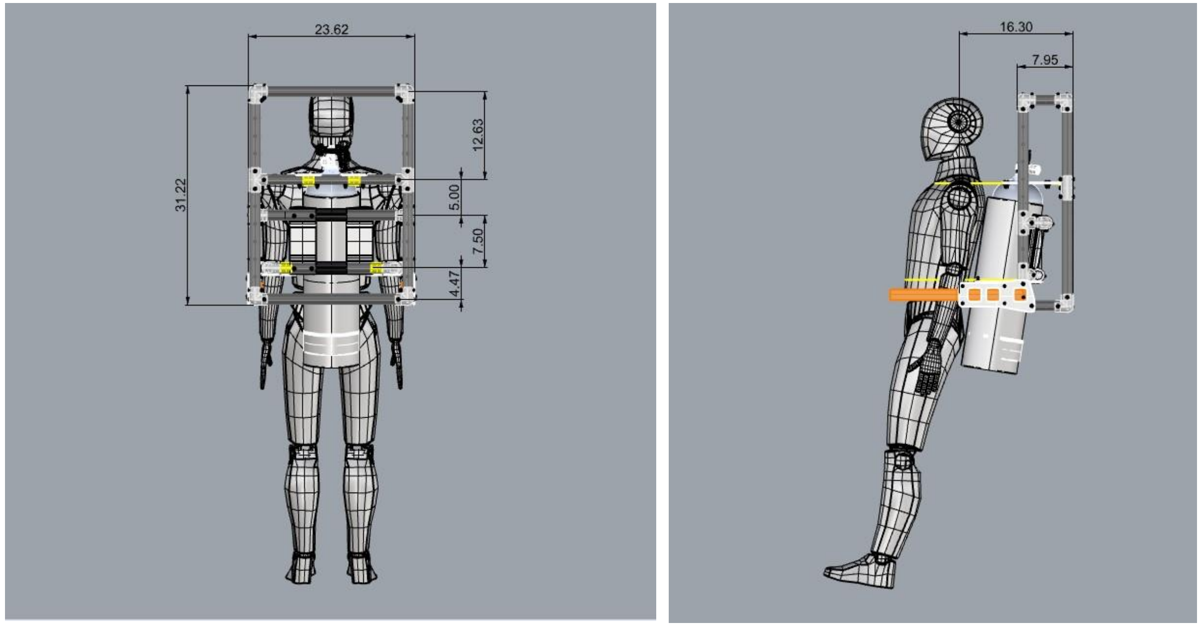
MPLC mockup rendering



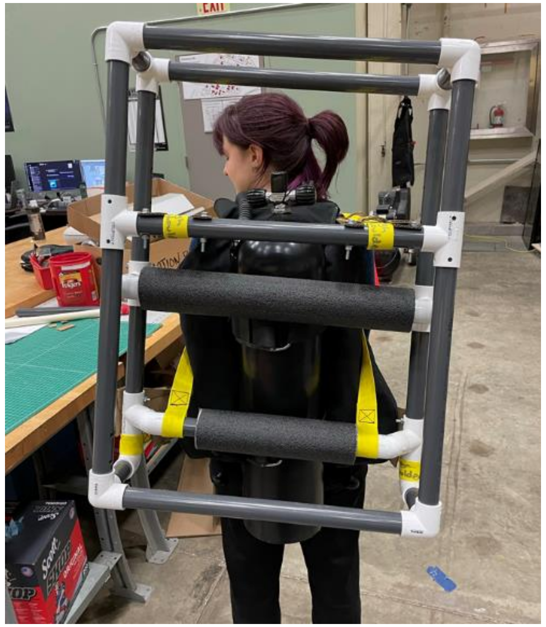
SEATEST 6 MPLC mockup

2.3.7 Portable Life Support System (PLSS) Mockup

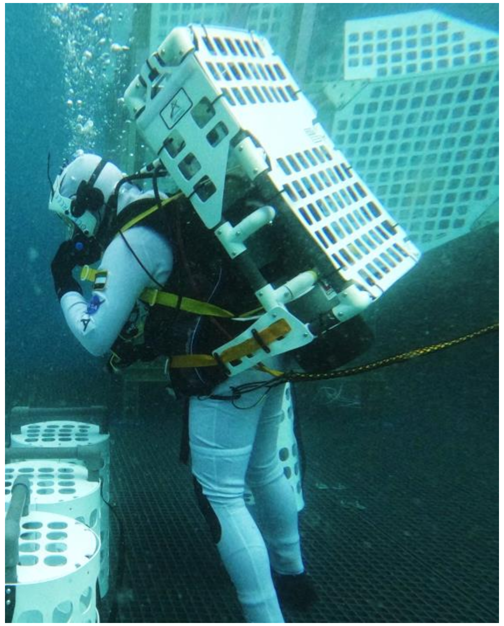
- PLSS Mockup that are donned over air tanks to increase test fidelity
  - Construction = Polyvinyl Chloride (PVC), Kydex, Polypropylene straps
  - Dimensions = 79.3 x 59.9 x 20.2 cm
  - Weight = 9.07 kg on land; 3.17 kg underwater



The PLSS mockup for Sea Test Six (Dimensions shown are in inches)



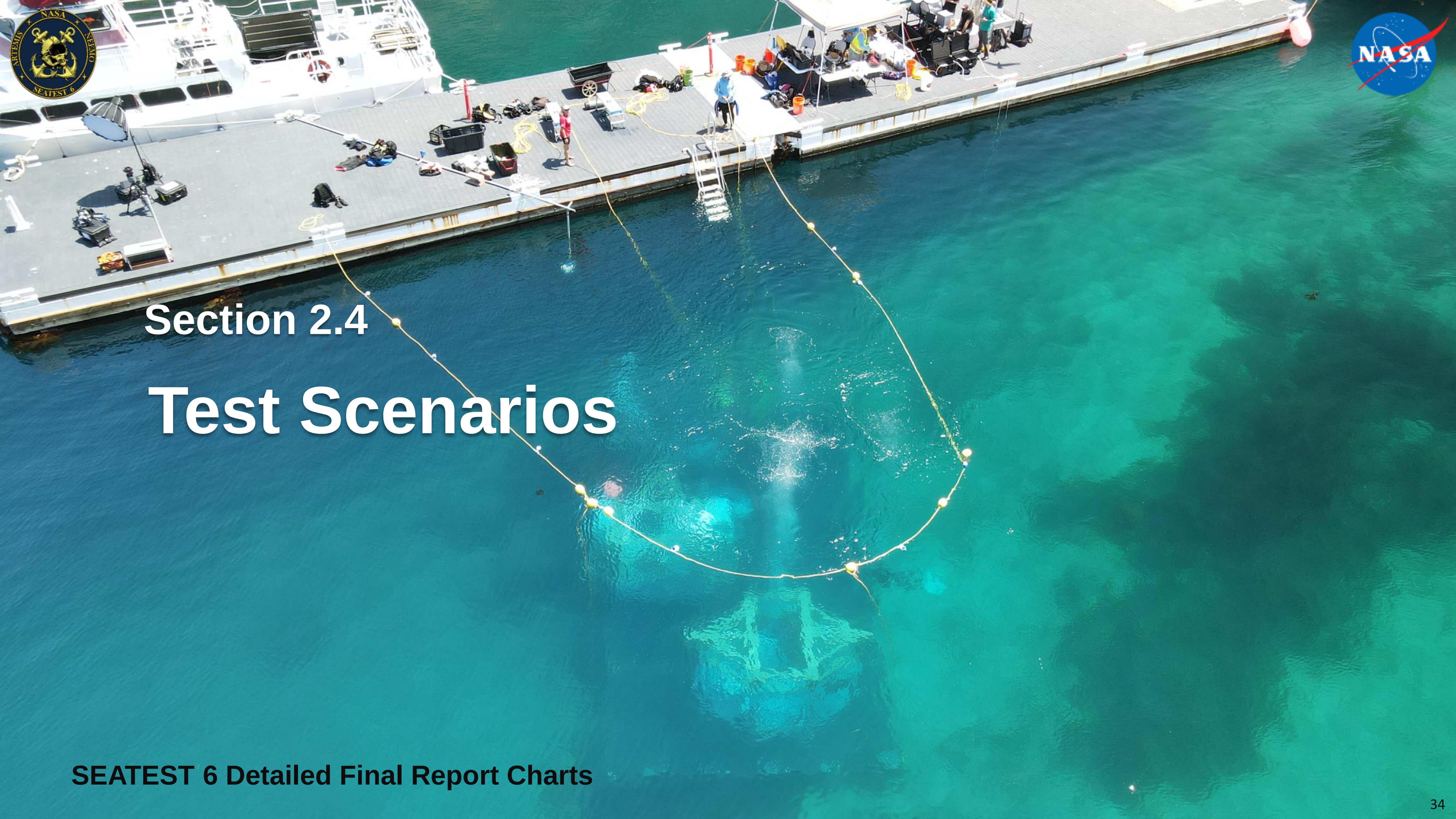
The PLSS mockup being tested on air tank



SEATEST 6 PLSS mockup

Section 2.4

Test Scenarios



SEATEST 6 Detailed Final Report Charts

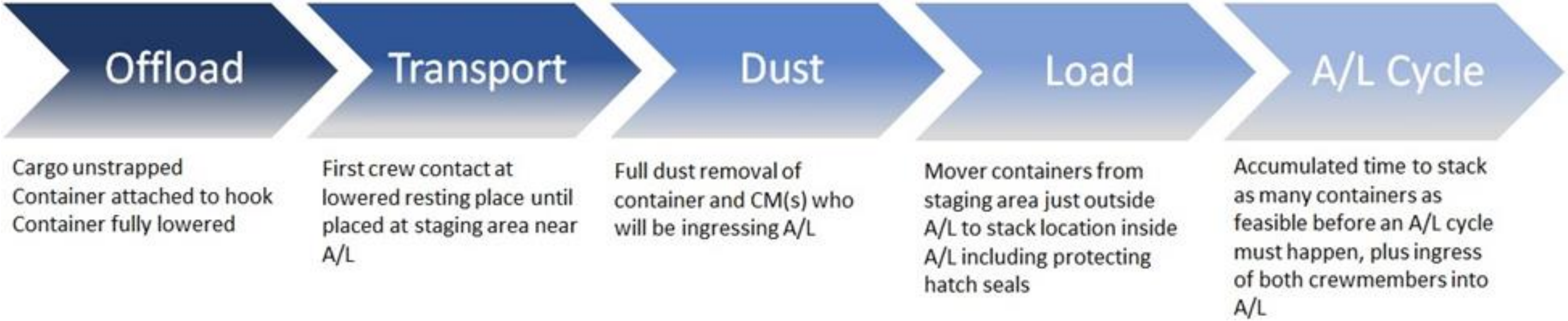
2.4.1 Study Design

Study designed to understand the EVA manual logistics transfer ConOps and time requirements using notional point design solutions:

- **Two conceptual offloading methods:**
  - Davit
  - Zipline system
- **Evaluation of three sizes of logistic containers:**
  - 1.0 CTBE SPLC
  - 2.0 CTBE SPLC
  - ~14-16 CTBE MPLC
- **Choreography of SPLC placement in the airlock to leave room for necessary ops: e.g., ingress, hatch closure, suit doffing**
  - The number of containers used for the test was determined by estimating the number of containers of each type could fit in the airlock, while leaving room for those critical ops
  - Consideration given to handling difficulties of each size container; e.g., a ground-rule dictated the 2.0 SPLC as too heavy/awkward for a single suited crewmember to lift/carry
- **Dust removal protocols were included for an understanding of the overall impact to transfer ops**

2.4.1 Study Design (cont.)

Off-Loading Flow for Davit and Zipline



2.4.1 Study Design (cont.)

MPLC Flow

Offload → Transport → Berth

- **Offload**: Remove cradle restraints, attach davit hook to lifting hoop, offload with davit and position near PR
- **Transport**: Transfer the load from the davit to the PR rail system
- **Berth**: Slide MPLC on Rail to berth to Logistic Port

Trash Reload Flow for Davit

Unload A/L → Transport → Load

- **Unload A/L**: Transfer all SPLCS out of the A/L
- **Transport**: Start of transport to final loading destination, until all containers area at the loading spot under the davit
- **Load**: Attaching the davit hook to SPLC(s), raising to the lander deck, unhooking and stacking in final disposal position

2.4.2 – Derivation of Assumptions

- The current assumption for a 2-crew, 14-day Pressurized Rover mission is that it will require 37.5 CTBE of pressurized cargo with a cabin volume of ~ 9.5 m^3
- Pre-mission testing was conducted to inform the SEATEST Assumptions that follow, and focused on two areas:
  1) How well a suited crewmember could handle SPLCs of different sizes
  2) Challenges of putting 37.5 CTBE in a volume of ~9.5 m^3
     - Both the SEATEST 6 Airlock mockup, and the mockup used in 1-g testing were ~ 9.5 m^3 in volume

Habitable Airlock mockup at JSC with 37.5 CTBE in soft bags; interior volume ~ 9.5 m^3

- Notes for (1)
  – Testing was done in 1-g in restrictive EXCON suits, with 1.0, 2.0 and 3.0 CTBE container sizes
  – Previous ARGOS push/pull test results were consulted
- Notes for (2)
  – Though soft CTBs were used in the testing shown, remember that these are a proxy for hard, pressurized SPLCs, which would both take more volume and could not be packed as efficiently as shown. 37.5 CTBE ends up taking up about half the usable volume, even without accounting for the 2 spacesuits (not shown) and crewmembers
  – When the SPLCs are unpacked, it results in taking up TWICE the volume (the rigid SPLCs + the soft goods that were inside them)

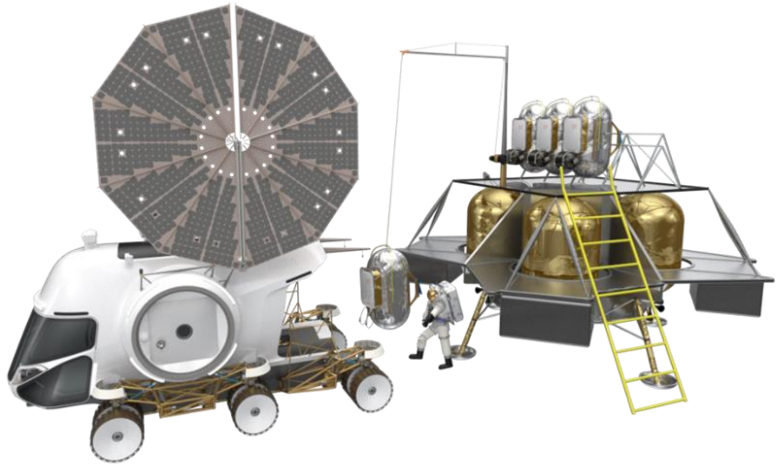
Suited limitations in handling different container sizes

2.4.3 Test Assumptions

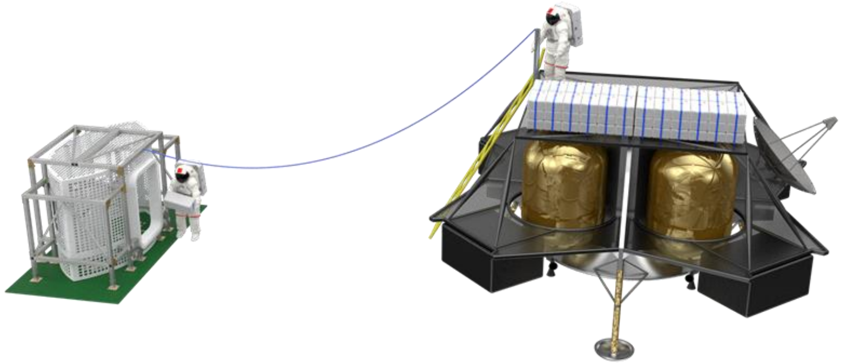
1. Pressurized logistics containers carry food, clothing, spares, medical supplies, etc. and portable water in contingency water containers (CWC)
2. The manifest for a 14-day PR mission was assumed, which requires 37.5 CTBE of pressurized logistics (See Appendix F for details)
3. Container assumptions were:

	1 CTBE	2 CTBE	MPLC
Lunar wt., Full (kgf)	7	14	77
Lunar wt., Empty (kgf)	2	5	25
Number of Containers	38	19	3

4. MPLCs are not manageable without load support
5. A single crewmember is required on the lander deck for all offloading methods with the other crewmember on the ground ready to “receive” the item
6. Any unloading operation should require no more than a single climb onto the lander deck by each crewmember
7. A single crewmember can lower the SPLC from the Zipline to the ground and unhook it



Artist concept of crew utilizing a davit to offload MPLCs to a pressurized rover logistic port



Artist concept of crew utilizing a zipline to transport SPLCs to a crewmember at an airlock

2.4.3 Test Assumptions (cont.)

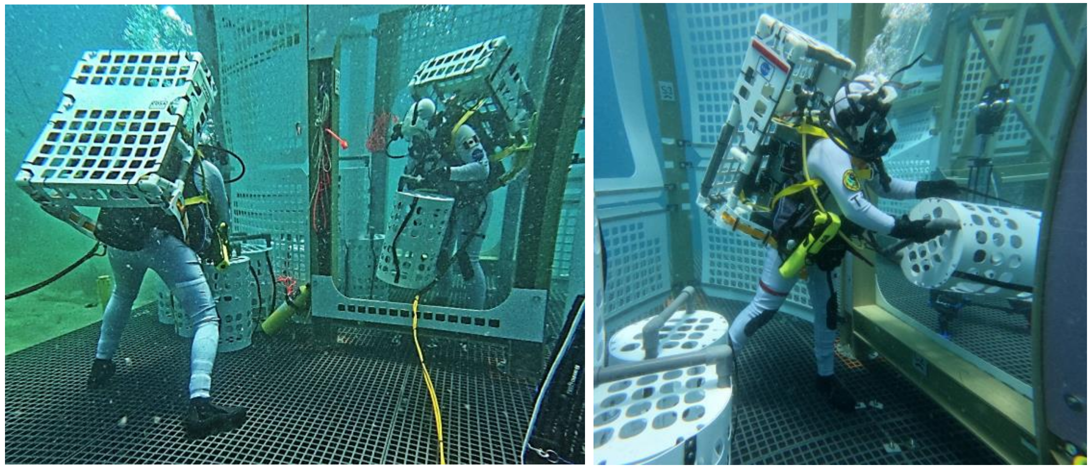
8. 1.0 SPLC can be carried and handed off into the airlock (A/L) by one crewmember

9. Both 1.0 and 2.0 SPLCs can be dragged *a few feet* to make room for unloading, but not any significant distance as a strategy. (We will not prescribe this distance, but will note what's required during testing)

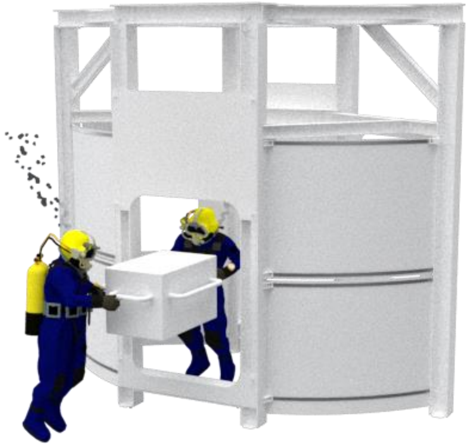
10. The thermal cover on the outside of the containers is strong enough to withstand dragging along the ground

11. Both 1.0 and 2.0 SPLCs can be dragged from the staging area outside the Airlock *across the seal protection* into the Airlock by a single crewmember

12. 2.0 SPLCs require two crewmembers to carry



EV1 carrying 1.0 SPLCs to A/L entry for hand-off to EV2 inside

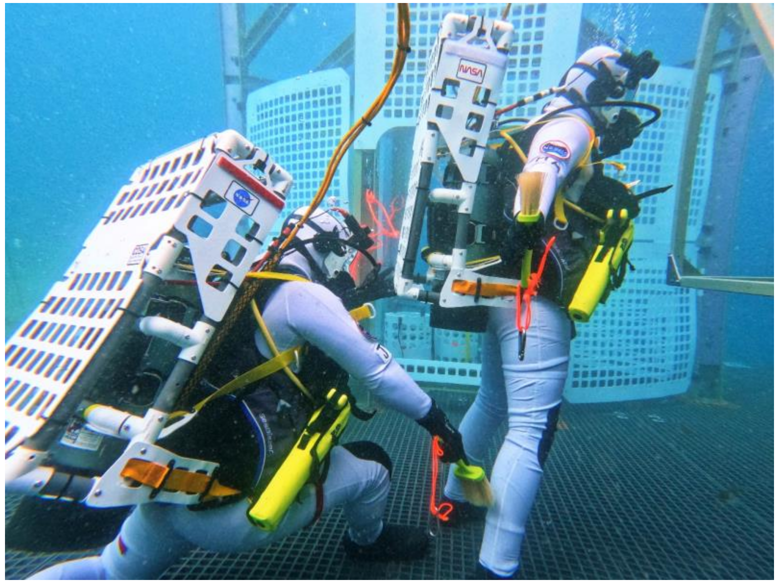


Rendered concept of two Crew carrying a 2.0 SPLC into A/L

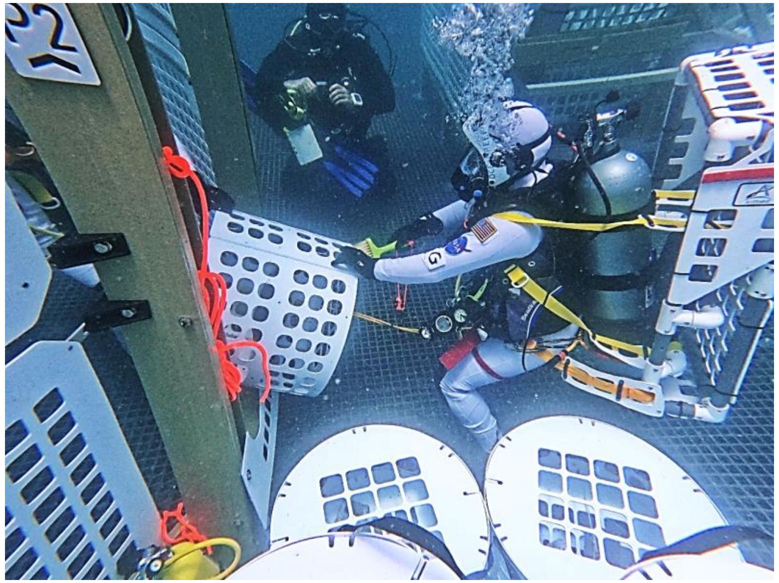
Crew carrying a 2.0 SPLC to A/L

2.4.3 Test Assumptions (cont.)

13. All SPLCs require two crewmembers to load them into the Airlock if not dragging across seal protection
14. All containers must be dusted prior to entering A/L, which can be accomplished by one person.
15. Each crewmember must be thoroughly brushed for dust by their buddy prior to entering the A/L.
16. Each crewmember will be inspected by their buddy as “clean” before entering A/L



Crew dusting each other



Crewmember dusting a 2.0 SPLC

2.4.4 Test Scenario Details

- **Planned Test Scenarios**

Davit	1. 1.0 CTBE SPLC Transfer to Staging Area using Davit
	2. 2.0 CTBE SPLC Transfer to Staging Area using Davit
	3. 2.0 CTBE SPLC Reload using Davit (raising from surface back to lander deck)
Zipline	4. 1.0 CTBE SPLC Transfer to Staging Area using Zipline
	5. 1.0 CTBE SPLC Transfer to Airlock using Zipline
	6. 2.0 CTBE SPLC Transfer to Airlock using Zipline
A/L	7. Airlock Egress Choreography with 2.0 CTBE SPLCs
	8. Airlock Ingress Choreography with 1.0 CTBE SPLCs
	9. Airlock Ingress Choreography with 2.0 CTBE SPLCs*
MPLC	10. MPLC*

ST6 Mockups seen from dock

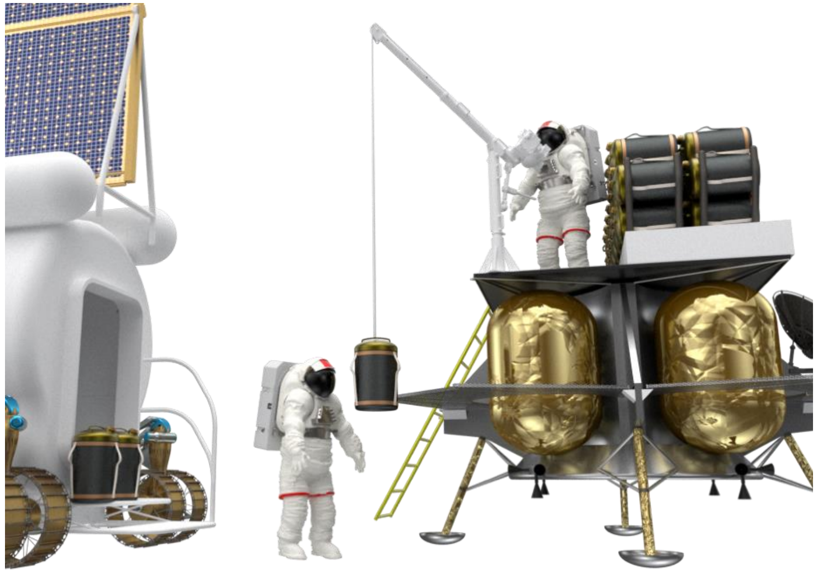
* Was not tested as the test was terminated early due to circumstances beyond the control of the test team (3 key participants became ill)

Scenario 1: 1.0 SPLC Transfer to Staging Area using Davit

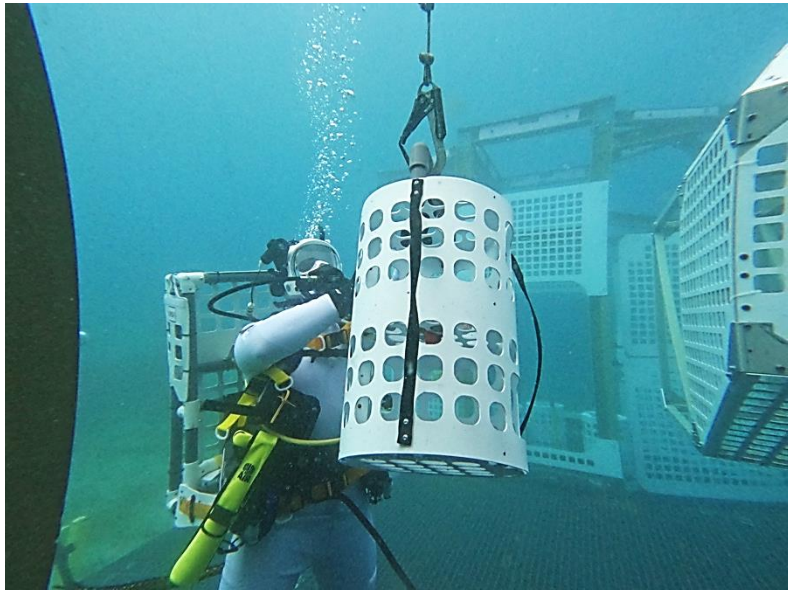
Container: 1.0 SPLC

- ✓ EV1 lowers 1.0 SPLC to lunar surface using Davit, EV2 unhooks and hand-carries SPLC to staging area for pre-staging. After SPLCs are transferred, perform dust mitigation and stow SPLCs inside airlock.

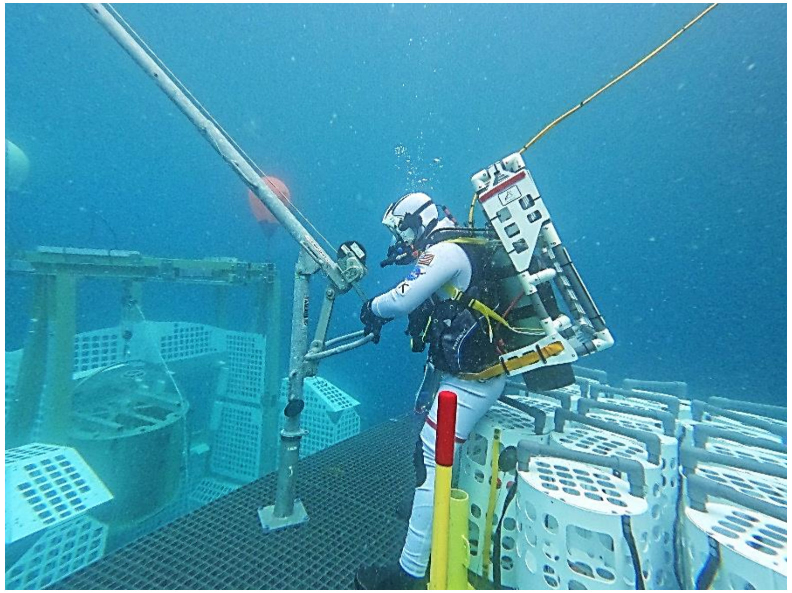
Note: 1.0 CTBE SPLCs can be hand carried by a single crewmember.



Rendering of davit offload of 1.0 SPLC. (artist concept only)



Receiving a 1.0 SPLC from the davit



Transfer of 1.0 SPLC from lander deck to lunar surface via davit

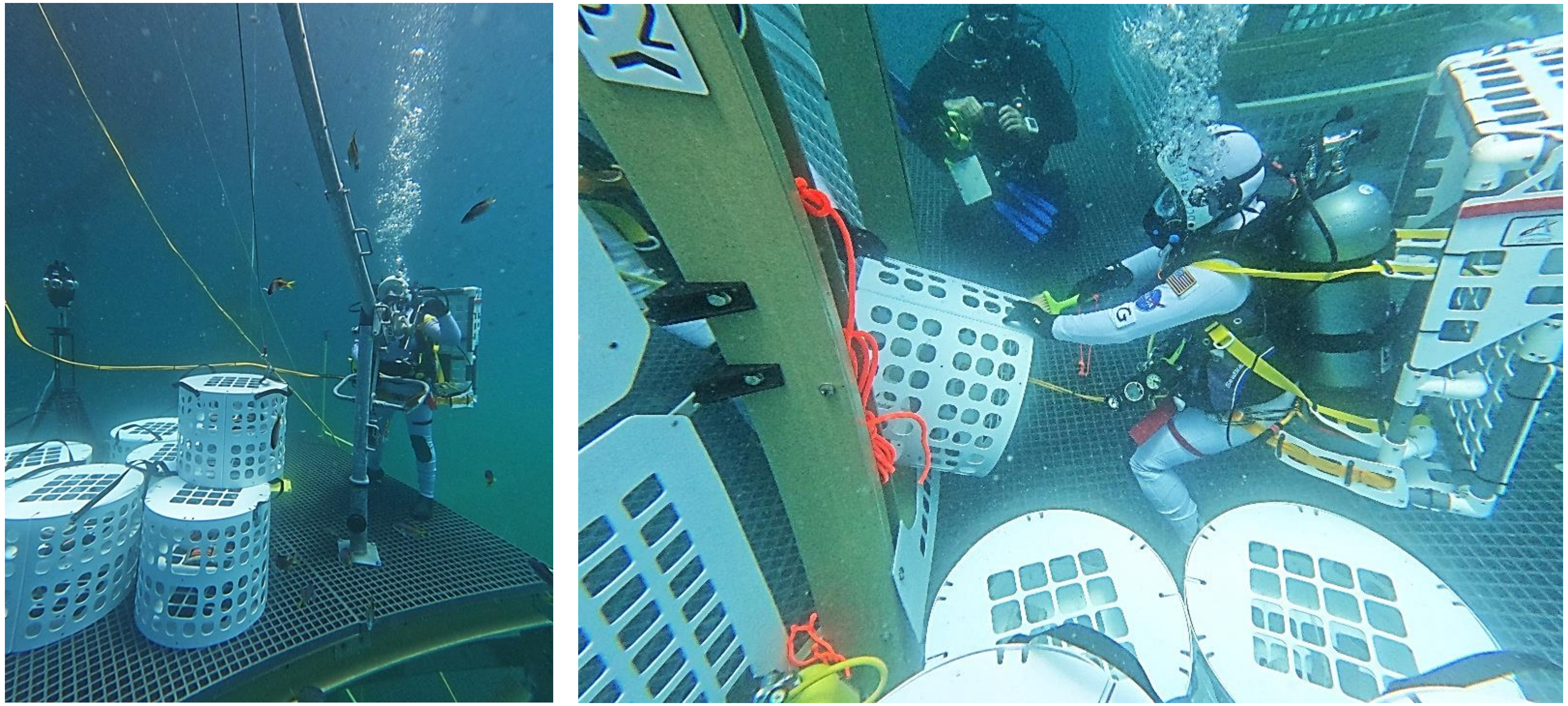
Scenario 2: 2.0 SPLC Transfer to Staging Area using Davit

Container: 2.0 SPLC

- ✓ EV1 lowers 2.0 SPLC to lunar surface using davit, EV2 unhooks and drags SPLC away from landing zone. After SPLCs are offloaded, EV1 and EV2 hand-carry to airlock for dust mitigation and stowing.

Note: 2.0 CTBE SPLCs require both crewmembers to hand carry.

Rendering of davit offload of 1.0 SPLC.
(artist concept only)



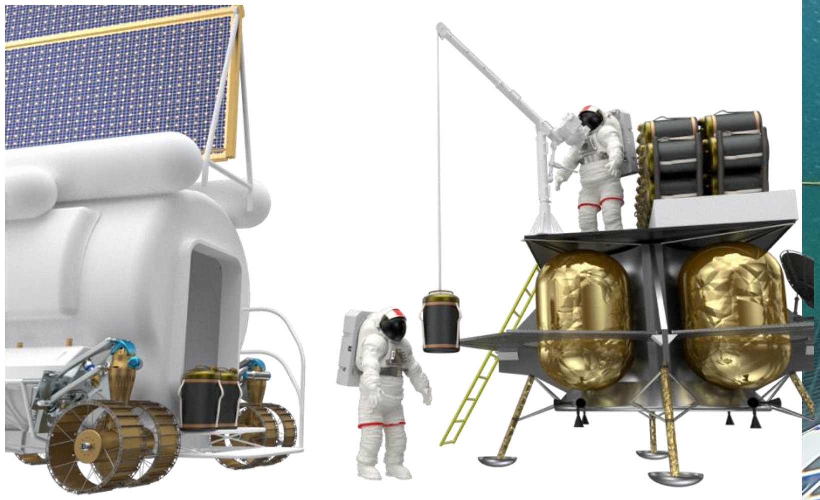
Transfer of 2.0 SPLC from lander deck to lunar surface via davit

Scenario 3: 2.0 SPLC Reload using Davit

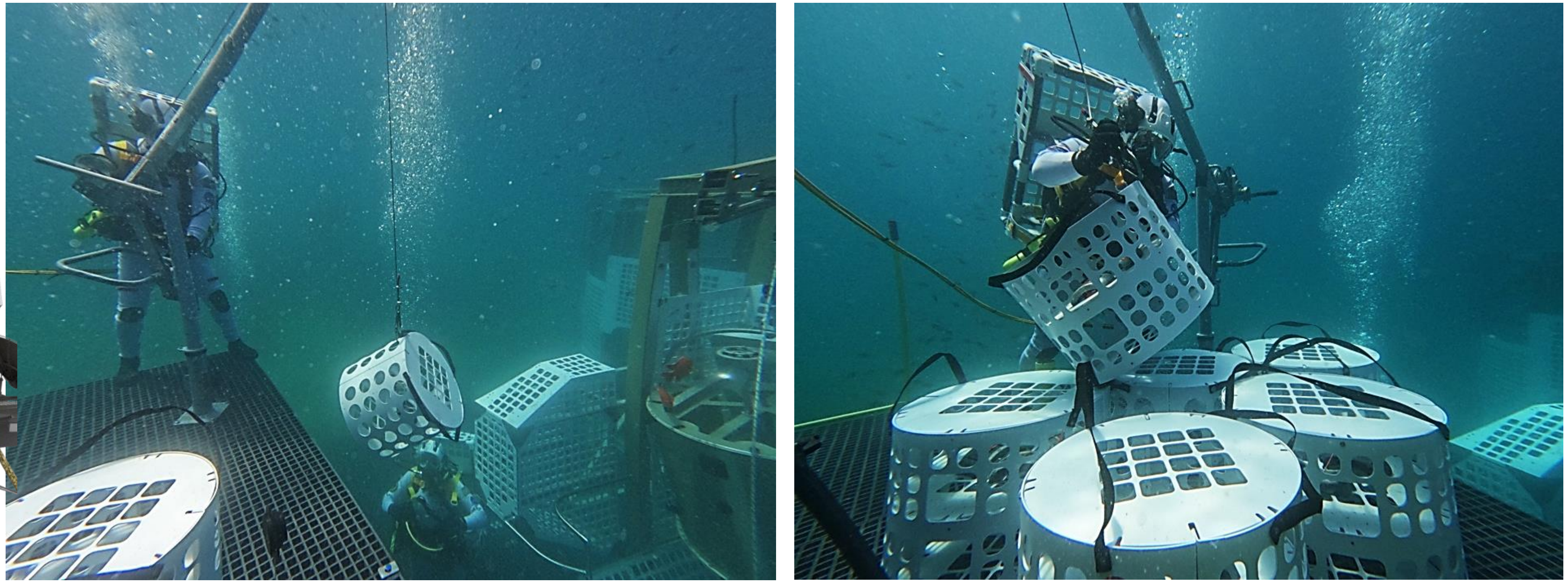
Container: 2.0 SPLC

✓ EV1 and EV2 hand-carry SPLCs from airlock to staging area. EV2 hooks SPLCs to davit, EV1 raises to lander deck and stages.

Note: This is the empty container/trash case



Rendering of davit offload of 1.0 SPLC. (artist concept only)



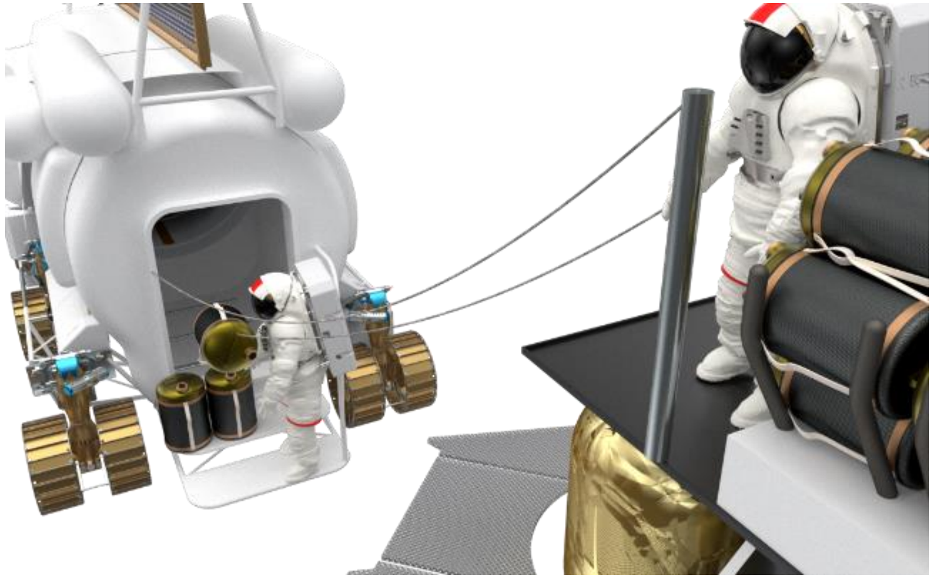
2.0 SPLC Reload to lander deck via davit

Scenario 4: 1.0 SPLC Transfer to Staging Area using Zipline

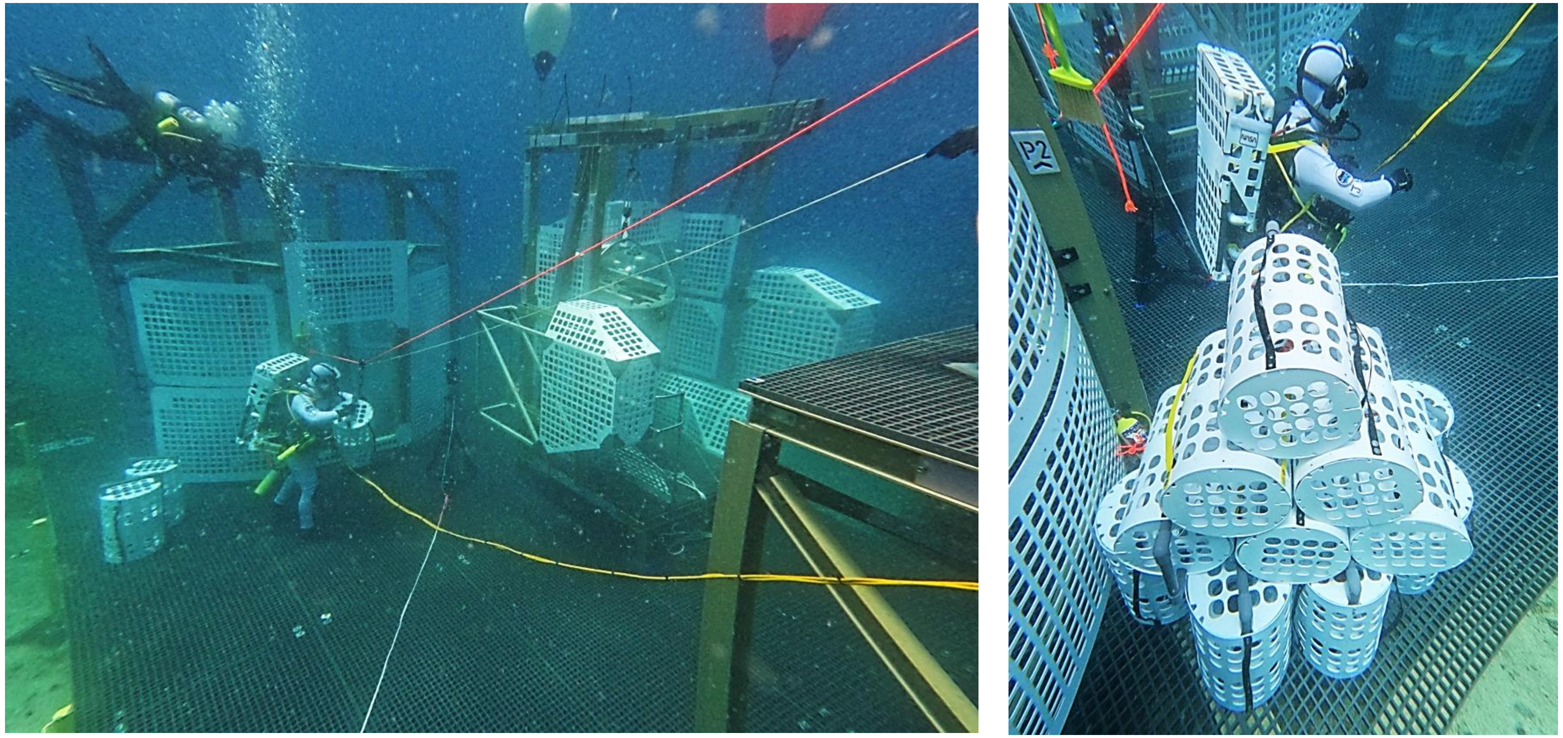
Container: 1.0 SPLC

✓ EV1 lowers 1.0 SPLC to lunar surface using zipline, EV2 unhooks and arranges SPLC in staging area for pre-staging. After SPLCs are transferred, perform dust mitigation and stow SPLCs inside airlock.

Note: This case transfers SPLCs to the outside of the A/L, where they require subsequent dusting before transfer into the A/L



Rendering of zipline transfer to staging area (artist concept only)



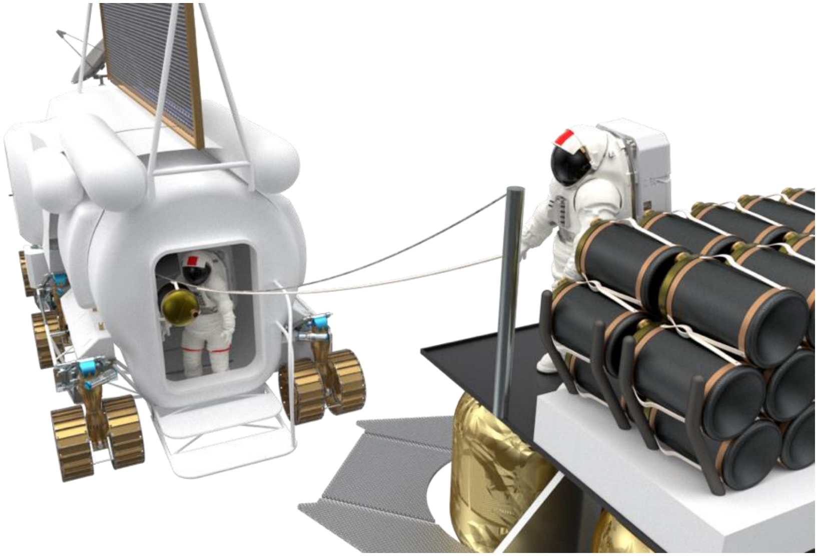
1.0 SPLC transfer to staging area via zipline

Scenario 5: 1.0 SPLC Transfer to Airlock using Zipline

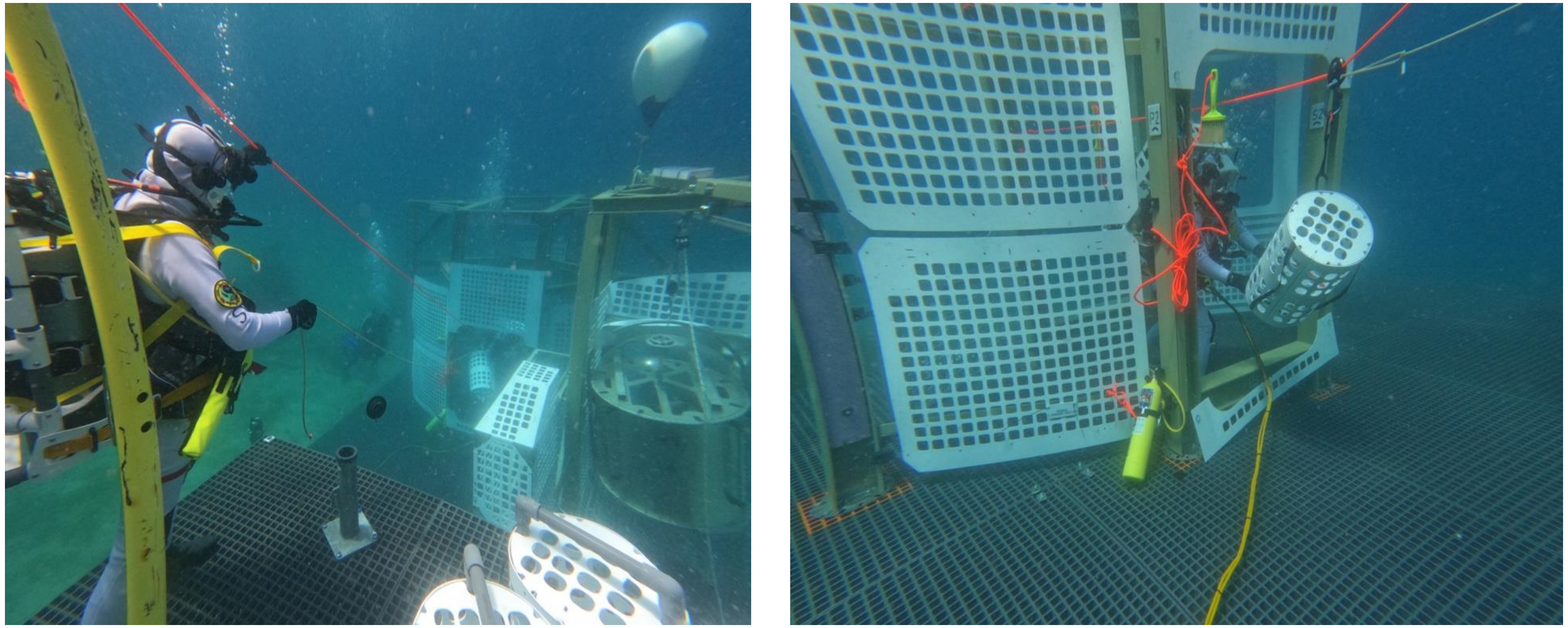
Container: 1.0 SPLC

- ✓ EV1 lowers 1.0 SPLC to lunar surface using zipline, EV2 unhooks and configures SPLCs inside A/L. After SPLCs are offloaded, EV1 is dusted and ingresses airlock.

Note: Zipline method straight into the A/L requires no container dusting steps (only crewmember)



Rendering of zipline transfer into airlock.
(artist concept only)



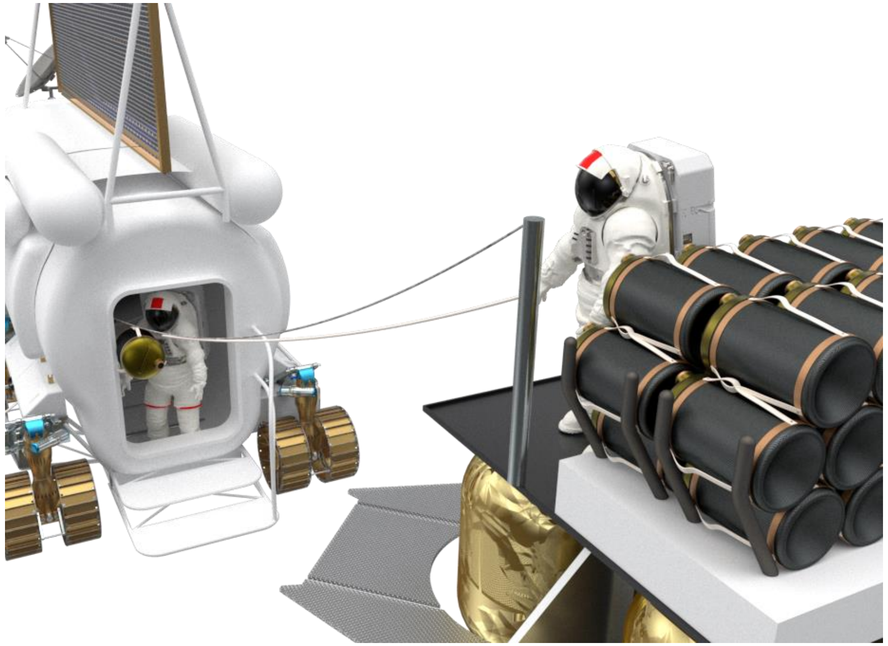
1.0 SPLC transfer to airlock via zipline

Scenario 6: 2.0 SPLC Transfer to Airlock using Zipline

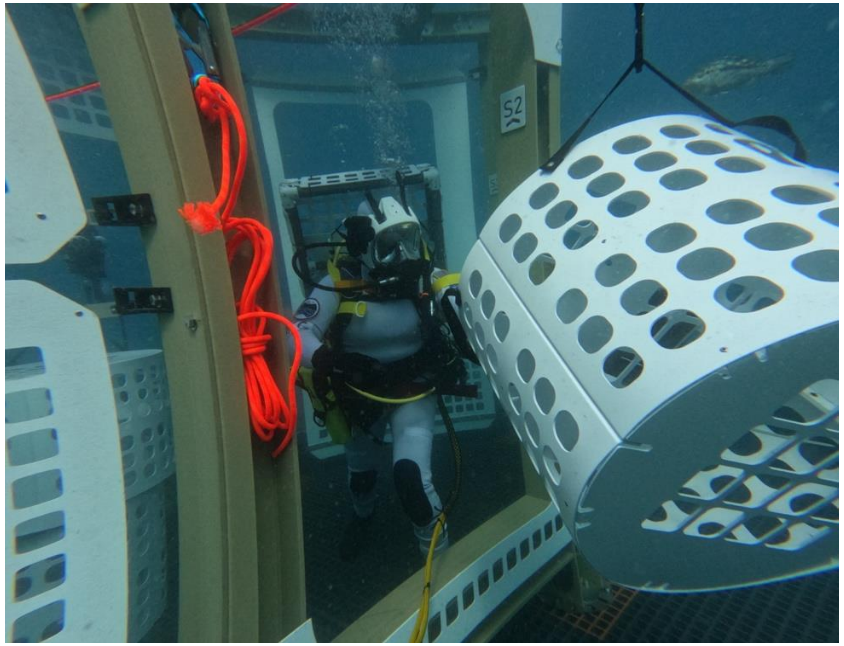
Container: 2.0 SPLC

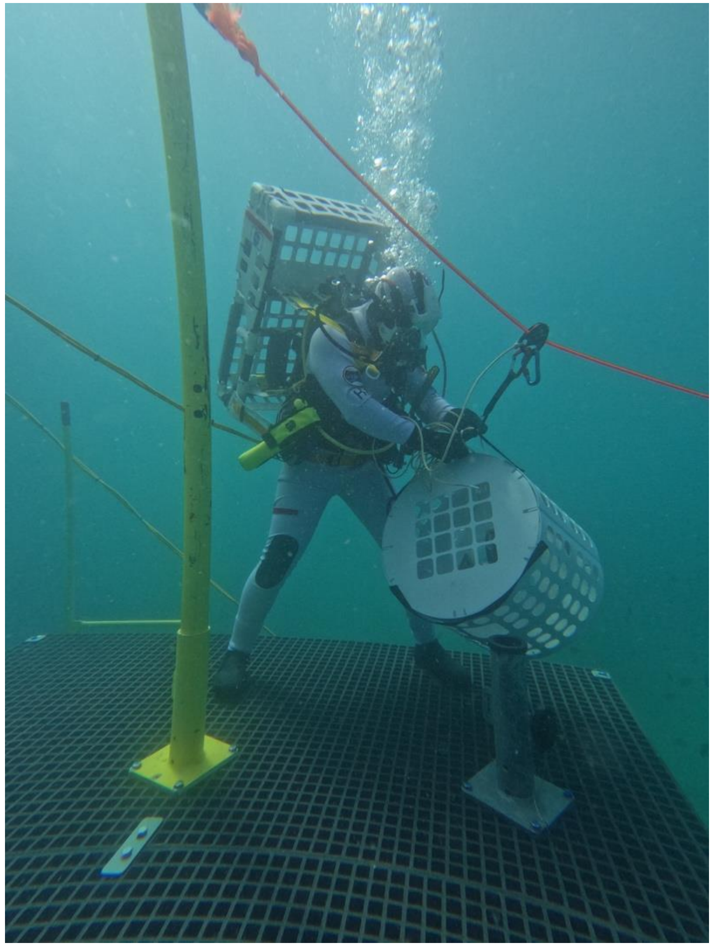
✓ EV1 lowers 2.0 SPLC to lunar surface using zipline, EV2 unhooks and configures SPLCs inside A/L. After SPLCs are offloaded, EV1 is dusted and ingresses A/L.

Note: Zipline method straight into the A/L requires no container dusting steps (only crewmember)



Rendering of zipline transfer into airlock (artist concept only)





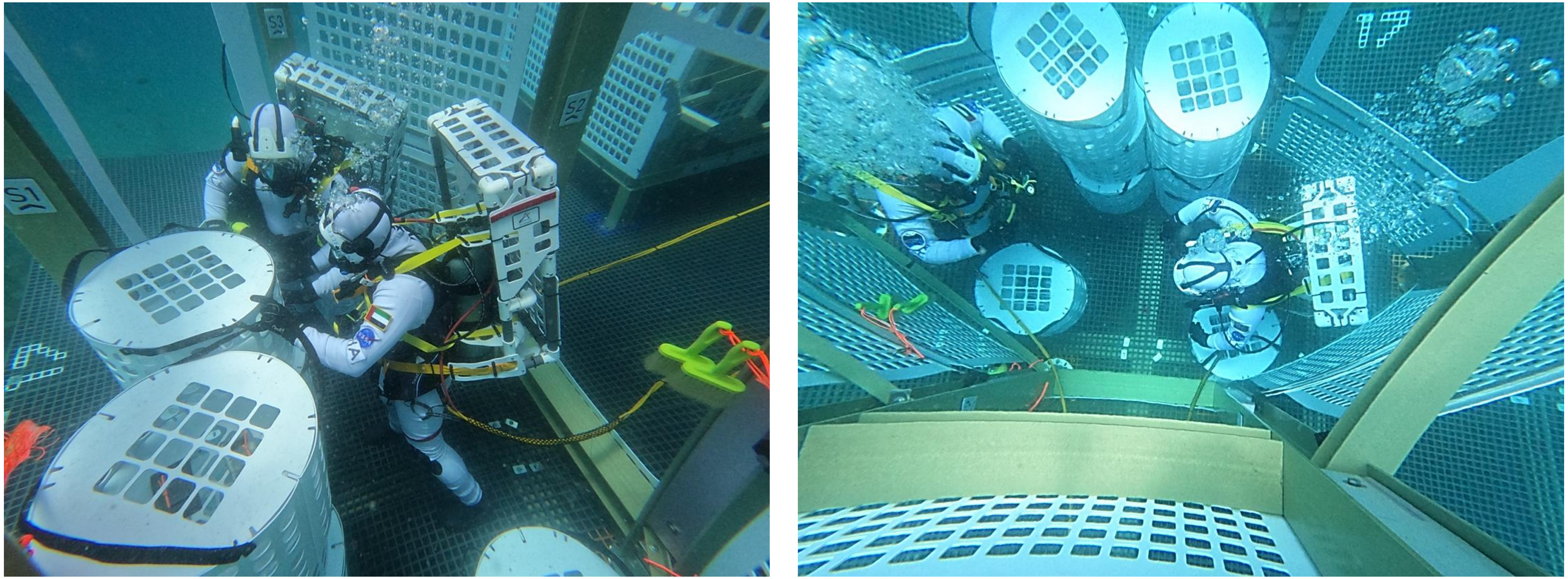
2.0 SPLC transfer to airlock via zipline

Scenario 7: Airlock Egress Choreography with 2.0 SPLCs

Container: 2.0 SPLC

- ✓ Both crewmembers enter the A/L, filled with containers to be disposed of, from the hab. SPLCs are rearranged to allow both crewmembers to don suits. EV1 and EV1 reorganize SPLCs to clear path to A/L hatch for egress. All SPLCs are transported outside the hab.

Note: 2.0 SPLCs require two crewmembers to lift.



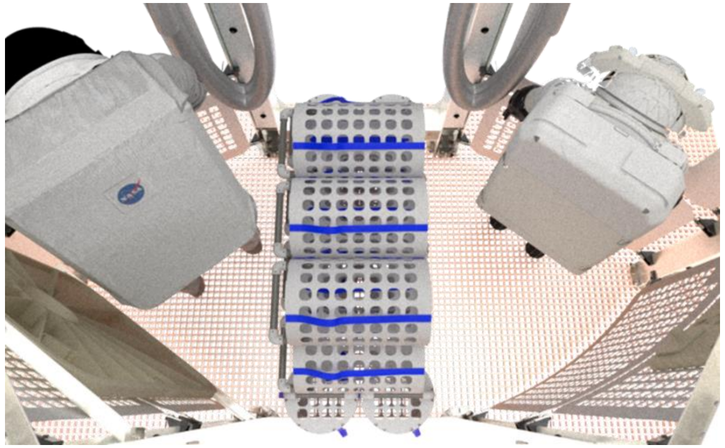
Airlock choreography for egress with 2.0 SPLCs

Scenario 8: Airlock Ingress Choreography with 1.0 SPLCs

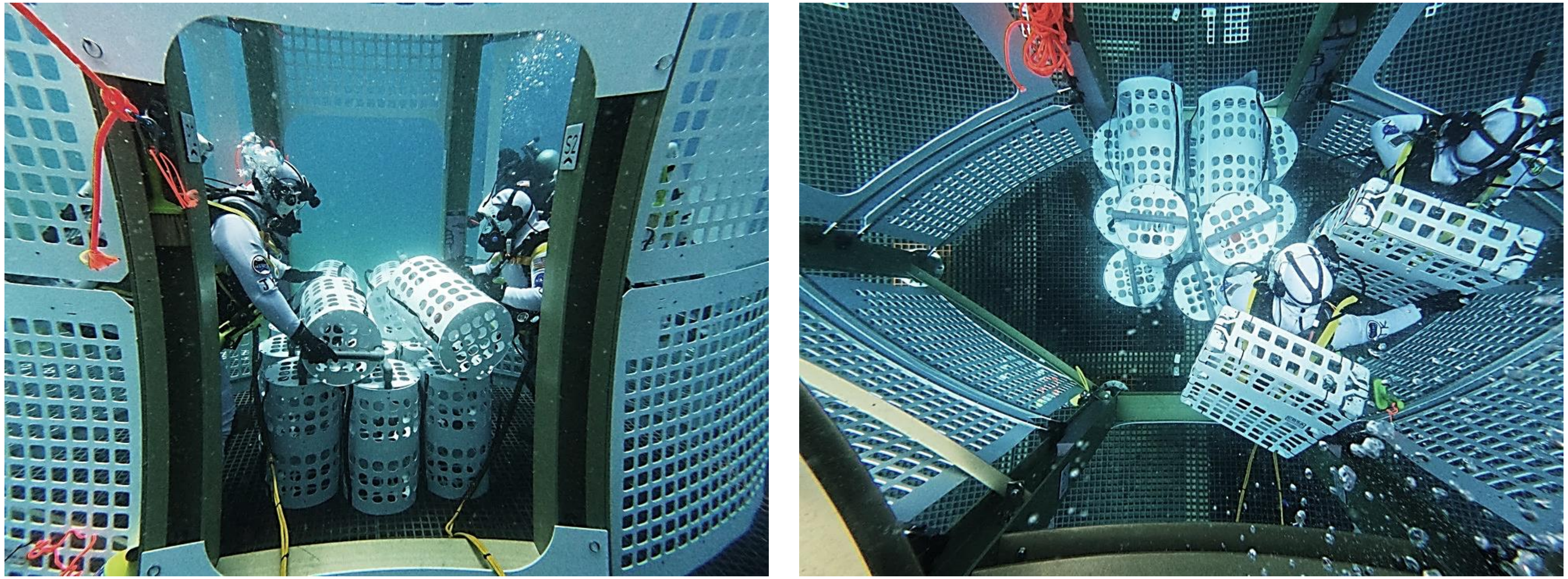
<u>Container: 1.0 SPLC</u>

✓ EV1 & EV2 fill A/L with as many SPLCs as they can fit, while maintaining room for both to ingress. EV1 & EV2 reorganize SPLCs such that EV1 can doff suit with assistance from EV2. EV1 & EV2 reorganize SPLCs such that EV2 can doff suit with assistance. Both crewmembers reorganize SPLCs to clear a path to A/L hatch for Habitat ingress.

Note: 1.0 SPLCs can be lifted by a single suited crewmember.



Rendering of airlock with crew & 1.0 SPLCs (artist concept only)



Airlock choreography for ingress with 1.0 SPLCs

Section 2.5

Data Collection

2.5.1 Data Collection

- **Objective and subjective data were collected from Crewmembers playing the role of an Artemis crew during each scenario (objective) and after each test day (subjective)**

  - **Objective data:** task timing and collisions/hang-up events recorded by two data collectors seated in MCC observing scenario runs in real-time:
    1. Event markers to record time durations of scenario subtasks (see slide 53 for subtask descriptions)
    2. Count of collision (“dings”)/hang-up events

    Footage and raw data from test scenarios is included in the test deliverables for future analysis/reference.
  - **Subjective data:** collected during consensus discussions among all crew at the end of each test day. Comments vocalized by crew in real-time during testing were recorded as field-notes when feasible to be used as “conversation starters” and “memory jogs” during consensus discussions

Daily debrief and crew consensus discussion

2.5.2 Objective Data

Descriptions for each timing subtask event and for collision/"Dings" and "Hang-up" events.

Data Type	Objective Data	Data Description
Timing (hh:mm:ss)	Climb/Descending Ladder	Amount of time it takes a crewmember to climb/descend the cargo lander ladder
	Lander Deck	Amount of time the crewmember is physically on the lander deck from the point of first step onto the deck to the last step off the deck
	Offloading	Amount of time to offload all logistic containers
	Transport	Time moving the logistic containers from the feet of the cargo lander to the staging area at the Airlock
	Staging	Amount of time it takes a crewmember(s) to stack the logistic containers at the staging area
	Dusting Ops	Amount of time it takes a crewmember(s) to dust off all logistic containers and themselves
	Loading in A/L	The amount of time in takes two crewmembers to stow all the logistic containers into the Airlock, ingress the Airlock and close the Airlock Hatch
	Total Task Time	Amount of time for the entire end-to-end logistics operations from first step up on the ladder to closing the Airlock hatch
	AL Choreography Clearing EV 1 suit stand	Amount of time to reconfigure AL and logistics containers to clear EV1 suit stand for doffing
	AL Choreography Clearing EV 2 suit stand	Amount of time to reconfigure AL and logistics containers to clear EV2 suit stand for doffing
	AL Choreography Total Task Time	Amount of time for entire reconfiguration of logistic containers to clear suit don/doff stands. Timing starts when crew starts reconfigure of logistic containers to going to internal hatch
"Hang-ups"	Overall Offloading Zone Area	Any areas within the overall offloading zone where the crew got hung up and burned unnecessary time
"Dings"	Airlock Hatch	Amount and location of any collisions on the Airlock hatch with logistic containers, PLSSs, or human body parts

2.5.3 Subjective Data: Simulation Quality

- **Simulation quality ratings were collected to reflect the extent to which the simulation itself allowed for meaningful evaluation of the logistic offloading and transfer operations**
  - Justifications for why a particular simulation quality numerical rating was chosen were provided to explain what the simulation quality limitations were and what could have been done (if anything) to improve the simulation quality
  - A simulation quality rating of 4 or 5 indicates the hummus simulation quality was too poor to enable meaningful evaluation of the test objectives

Scale Rating	Criteria
1	Simulation quality (e.g. hardware, software, procedures, comm., environment) presented either zero problems or only minor ones that had no impact to the validity of test data.
2	Some simulation limitations or anomalies encountered, but minimal impact to the validity of test
3	Simulation limitations or anomalies made test data marginally adequate to provide meaningful evaluation of test objectives (please describe).
4	Significant simulation limitations or anomalies precluded meaningful evaluation of major test objectives (please describe).
5	Major simulation limitations or anomalies precluded meaningful evaluation of all test objectives (please describe).

2.5.4 Subjective Data: Capability Assessment

- **Capability assessment ratings were used to reflect how mission enhancing (or not) each logistics transfer method was**
  - Justifications were provided for each numerical rating

Essential / Enabling		Significantly Enhancing		Moderately Enhancing		Marginally Enhancing		Little or No Enhancement	
Impossible or highly inadvisable to perform mission without capability		Capabilities are likely to significantly enhance one or more aspects of the mission		Capabilities likely to moderately enhance one or more aspects of the mission or significantly enhance the mission on rare occasions.		Capabilities are only marginally useful or useful only on very rare occasions		Capabilities are not useful under any reasonably foreseeable circumstances.	
1	2	3	4	5	6	7	8	9	10

2.5.5 Subjective Data: Acceptability

- **Acceptability ratings were used to describe how acceptable or unacceptable a task (or portion of a task) was for each scenario**
  - For numerical ratings of 3 or higher, comments were solicited regarding specific desired/warranted/ required improvements, and/or minor/moderate/significant deficiencies

Totally Acceptable		Acceptable		Borderline		Unacceptable		Totally Unacceptable	
No improvements necessary and/or No deficiencies		Minor improvements desired and/or Minor deficiencies		Improvements warranted and/or Moderate deficiencies		Improvements required and/or Unacceptable deficiencies		Major improvements required and/or Totally unacceptable deficiencies	
1	2	3	4	5	6	7	8	9	10

2.5.6 Subjective Data: Additional Notes

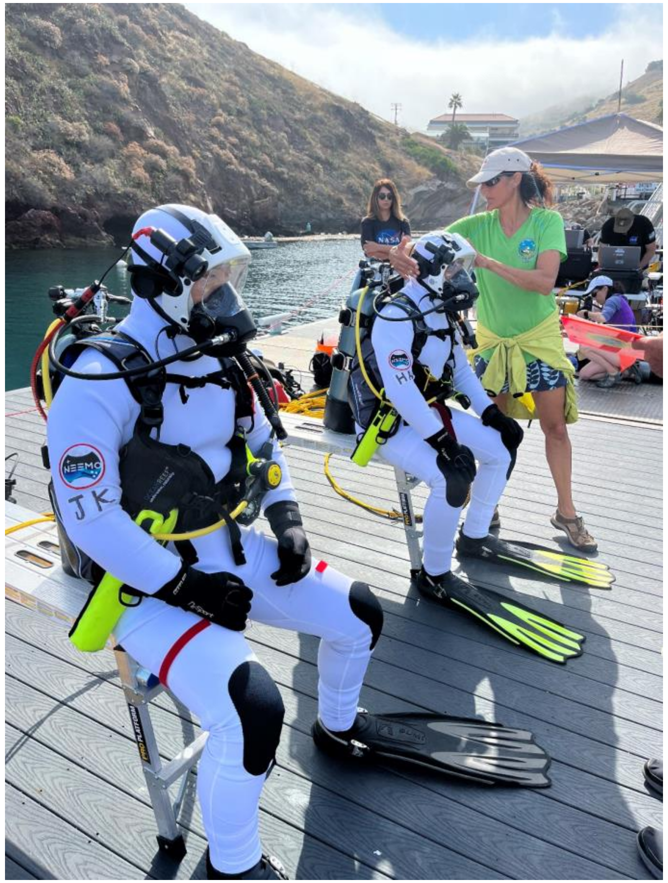
- It is possible for a capability to be highly mission enhancing, while being unacceptable due to the way it was implemented
  - As a hypothetical example, a zipline might be found to be mission enhancing for offloading cargo quickly and efficiently from a raised lander deck with minimal crew effort, while simultaneously being found to be unacceptable from an implementation standpoint and in need of improvement before it could be considered an acceptable solution (e.g., no room for the crew to stand on the lander deck, they couldn't reach the upper connection point, etc.)
- Conversely, it is also possible that capabilities have been included that are fully acceptable as implemented, yet provide little to no mission enhancement
- It is important to assess simulation quality, capability assessment, and acceptability when evaluating ConOps and capabilities, as each metric addresses unique features important to the design decision making process
  - Without adequate simulation quality, corresponding capability assessment and acceptability data hold little merit
  - Capability assessment ratings can help prioritize limited resources to implement and improve upon those capabilities that have the potential to provide the highest level of mission enhancement
  - Acceptability ratings help bin the level of criticality w.r.t. recommended improvements, e.g., required vs. desired
    - Required (i.e., "I can't do this task without this improvement")
    - Desired (i.e., "This would be nice to have, but I can manage OK without it")

Section 2.6

Test Execution

2.6.1 Test Team Training and Qualifications

- **Test Subject Crew**
  - Open Water SCUBA cert
  - American Academy of Underwater Sciences (AAUS) qualification
  - Full Face Mask Training
- **Topside Divers**
  - Open Water SCUBA cert
  - Aquarius Reef Base “Working Diver” qual
  - AAUS qualification
  - Full Face Mask Training
  - Previous NASA Extreme Environment Mission Operations (NEEMO) diving experience
- **Other Training**
  - Fam and mission briefings at JSC
  - Deck fam with hardware
- **Mission Specific Dive Training**
  - Familiarization with Neptune III Full Face Mask
  - Undersea familiarization with logistics mockups
  - End-to-end engineering dry runs
  - Mission-config out of air Emergency drills



Crew about to utilize Neptune III Full Face Masks during tests

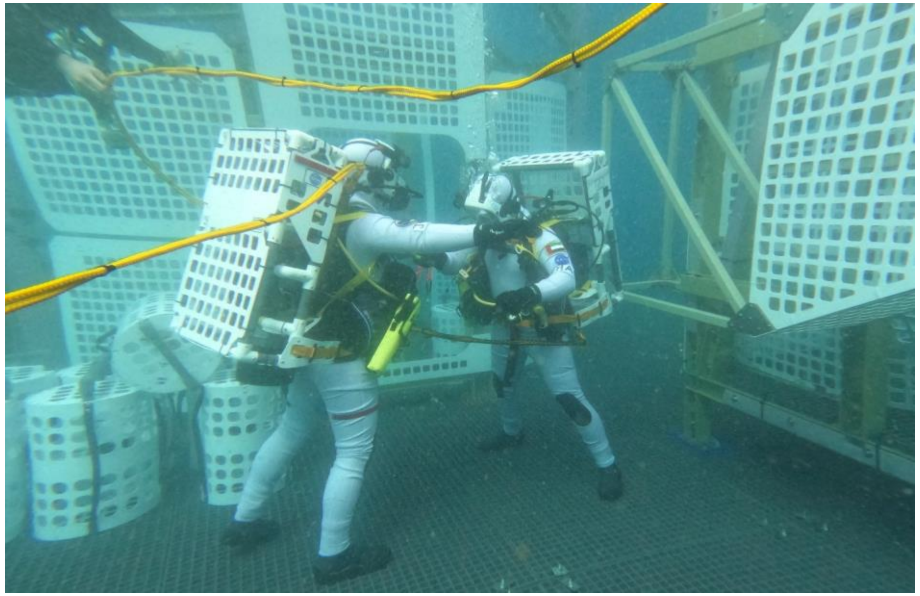
Crew getting AAUS qualification training

Topside diver tending comm umbilical

2.6.2 Diving ConOps: Test Scenario Execution

- **Crew**
  - Crews worked as a team of 2 for approximately 1 hour per scenario
  - Performed various cargo transfer scenarios as a 2-person team
    - Crewmembers not currently conducting the scenarios underwater observed from MCC so that all crew could participate in consensus discussions
  - 5 Crewmembers rotated through EV1, EV2, and MCC observation roles and experienced each scenario type (davit, zipline, airlock)
  - 4 test scenarios tested per day
- **Support divers**
  - One support diver buddied with one Crewmember, with primary role of ops support
  - Also provided configuration support (e.g., PLSS and extra weight donning for partial-g config), communication umbilical management, and photo documentation
  - Re-configured hardware between dives

Crewmember & Stakeholders observing operations from MCC



Support Divers providing ops support

2.6.3 MCC/Crew Comm Protocol

- Crewmembers referred to as EV1/EV2
- CapCom referred to as MCC
- CapCom relayed procedure steps to crew and managed scenario timeline during run
- Crew would speak "aloud" to provide rationale for their techniques and approaches
- Thermal/Tank Pressure/Glove checks every ~10 mins (similar to ISS EVA Glove checks)
- When interacting with suspended or unsecured loads:
  - Overcommunication was encouraged.
  - Explicit with diver locations and who has eyes-on vs. who has control of load.
  - Verified diver locations prior to motion

2.6.4 Minimum Success Criteria

1. **Mockup Deployment**
   - ✓ a. Deck
   - ✓ b. Lander
   - ✓ c. A/L
   - ✓ d. Supplemental (Davit, zipline pole, containers)
2. **Comm Setup**
   - ✓ a. Verify good internet connection/Wi-Fi at Dock and MCC
   - ✓ b. Verify Diver comm box dockside
     - ✓ i. Both Diver cams and SA cam
     - ✓ ii. 2-way voice to all divers
   - ✓ c. Verify capability to record all video and audio
   - ✓ d. Verify alternate comm method between dock and MCC (walkie talkies?)
3. **Training**
   - ✓ a. All support and Test Subject divers complete all elements of training to qualify to support the mission
   - ✓ b. Crew fam dive with no objectives, using full comm setup
   - ✓ c. Mission config, Test Subject out-of-air emergency drills
4. **Dry Runs**
   - ✓ a. 1 day of Dry Runs with the assembled mockups
     - ✓ i. Exercise of zipline system in offloading direction
     - ✓ ii. Exercise of davit system, both offloading and loading
     - ✓ iii. Demo or reconfiguration of Zipline Pole, Davit, and container weights
     - ✓ iv. End-to-End comm check with MCC
     - ✓ v. Crew opportunity to see all assembled hardware
5. **Test runs (in priority order)**
   - ✓ a. 1.0 SPLCs with Davit
   - ✓ b. 1.0 SPLC with Zipline to A/L
   - c. 2.0 Ingress A/L Choreography
   - ✓ d. 2.0 Egress A/L Choreography
   - ✓ e. 2.0 SPLCs with Davit
6. **Mockup Retrieval**
   - ✓ a. All pieces of the mockups retrieved from the sea floor and put in local storage
7. **Crew Data**
   - ✓ a. Crew ratings from each run captured
   - ✓ b. Crew consensus captured for the entire mission
8. **Mission Statuses**
   - ✓ a. Email status to Dive Safety Board (DSB) every other day
   - b. 3 management status reports
     - ✓ i. After training/setup
     - ii. Mid test week
     - ✓ iii. Post mission
9. **Mission Data capture**
   - ✓ a. All video, audio, and still photo data captured and copied to return to Houston

All minimum success criteria completed*

* Test duration was not long enough to necessitate a mid test week status (8.b.ii.)

2.6.5 Additional Objectives to meet Full Mission Success

1. **Mockup Deployment**
   - ✓ a. PR aft deck mockup
2. **Comm Setup**
   - ✓ a. Verify connectivity between Diver Comm box and MCC
     - ✓ i. Both Diver cams and SA cam viewable in MCC
     - ✓ ii. 2-way voice with divers 1 and 2
     - iii. Diver 3 can hear MCC
3. **Dry Runs**
   - ✓ a. 2nd day of Dry Runs with the assembled mockups – opportunity for crew to familiarize themselves with the mockups and transfer hardware
4. **Test runs (in priority order)**
   - ✓ a. 1.0 SPLC Zipline to Staging Area
   - ✓ b. 1.0 A/L Choreography
   - ✓ c. 2.0 Zipline to A/L
5. **Lowest Priority test runs**
   - ✓ a. 2.0 Reload with Davit
   - b. MPLC with Davit
6. **Dealer's choice test runs (as determined by the team, in the event an opportunistic scenario is deemed of higher value than the pre-determined ones)**

Section 3.0

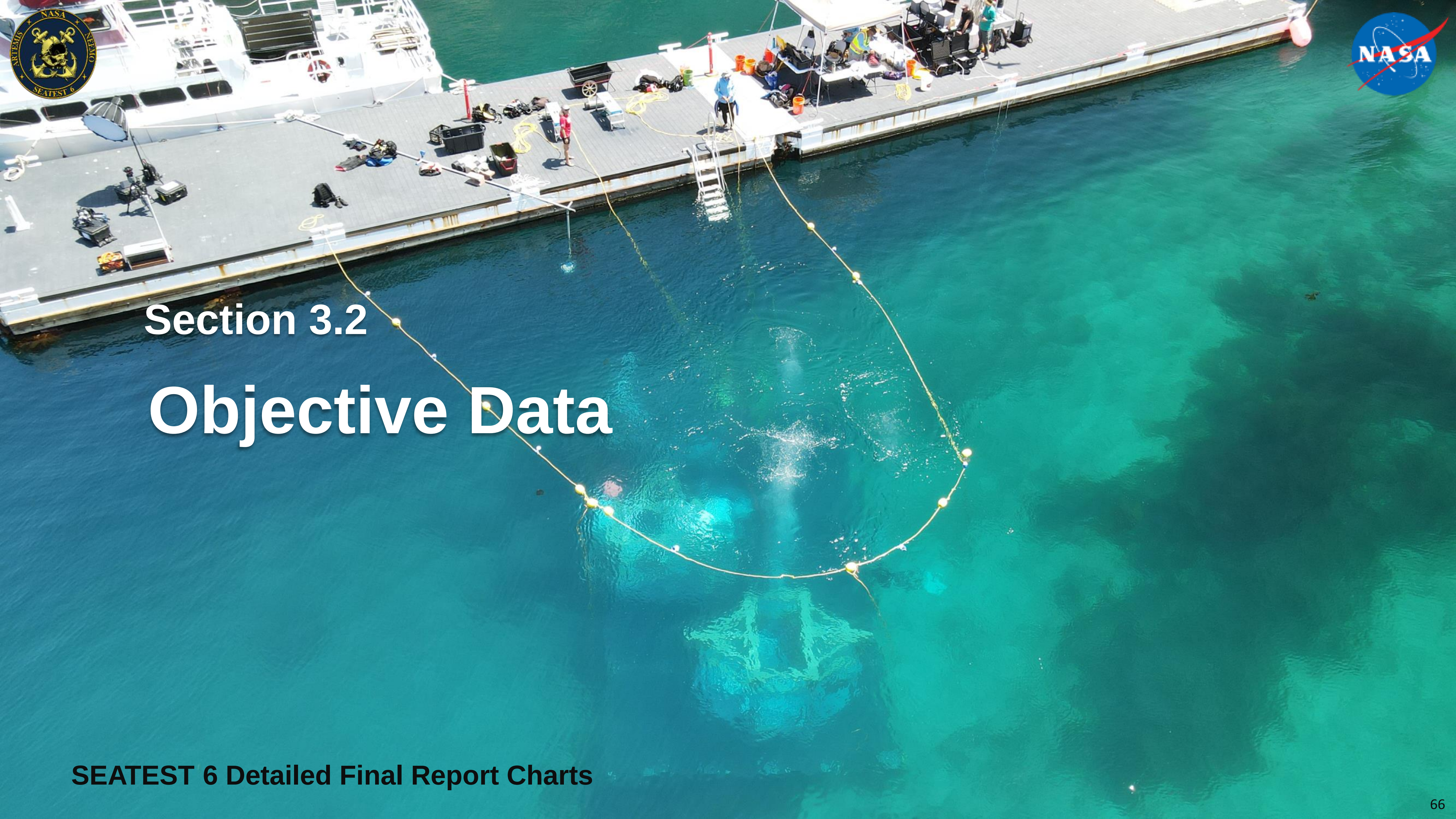
Results

3.1 Results Overview

- **8 of the 10 Planned test scenarios were accomplished**

Davit	1. 1.0 CTBE SPLC Transfer to Staging Area using Davit
Davit	2. 2.0 CTBE SPLC Transfer to Staging Area using Davit
Davit	3. 2.0 CTBE SPLC Reload using Davit (raising from surface back to lander deck)
Zipline	4. 1.0 CTBE SPLC Transfer to Staging Area using Zipline
Zipline	5. 1.0 CTBE SPLC Transfer to Airlock using Zipline
Zipline	6. 2.0 CTBE SPLC Transfer to Airlock using Zipline
A/L	7. Airlock Egress Choreography with 2.0 CTBE SPLCs
A/L	8. Airlock Ingress Choreography with 1.0 CTBE SPLCs
A/L	9. Airlock Ingress Choreography with 2.0 CTBE SPLCs
MPLC	10.MPLC

- The remaining 2 (with lowest priority) were not accomplished as the test was terminated early due to circumstances beyond the control of the test team (3 key participants became ill)
- All objective and subjective data outlined previously was collected on the accomplished scenarios
- Insights from debriefs, discussions and testing prior to the mission are also captured here



Section 3.2

Objective Data

SEATEST 6 Detailed Final Report Charts

3.2.1 Timing Results (Example)

MISSION DAY	*1*							
SCENARIO:	*1*							
DESCRIPTION:	*1.0 SPLC Transfer to Staging Area Using Davit*							
EV1								
EVENT MARKERS		**EVENT**			**TIME FORMAT: h:mm:ss**			
EVENT START	EVENT END		Clock Time Start	Clock Time Stop	Interval Start	Interval Stop	Δ t	NOTES:
CAPCOM "Go"	End of last scenario task	Task Total	9:20:49	9:47:53	0:00:00	0:27:04	0:27:04	
First foot on first step	Foot on deck	Climb Ladder	9:21:49	9:22:11	0:01:00	0:01:22	0:00:22	
Foot on deck	Foot on ladder	Time on Lander Deck	9:22:07	9:39:18	0:01:18	0:18:29	0:17:11	
First contact with first container	EV2 remove hook from last container	Offloading Containers (Cumulative)	9:22:27	9:38:41	0:01:38	0:17:52	0:16:14	EV2 going to airlock with container (3 containers total in AL)
First contact with container	EV2 remove hook from container	Offload Container 1	9:22:27	9:23:49	0:01:38	0:03:00	0:01:22	standing on the side of davit while cranking wench
EV2 remove hook from container	EV1 contact with next container	Reset Davit	9:24:09	9:25:09	0:03:20	0:04:20	0:01:00	
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
First foot on ladder	Last foot off ladder	Descend Ladder	9:38:53	9:39:26	0:18:04	0:18:37	0:00:33	
First step of walk towards A/L	Reach A/L	Translate to Airlock	9:39:26	9:40:08	0:18:37	0:19:19	0:00:42	
First swipe brush	Last swipe of brush	Dust Ops - EV2	9:40:16	9:42:48	0:19:27	0:21:59	0:02:32	wants a longer brush when dusting off EV2
First swipe brush	Last swipe of brush	Dust Ops - Containers	9:43:54	9:47:42	0:23:05	0:26:53	0:03:48	7 containters in staging area (EV1 dusting container only while EV2 loading in container. EV1 dusting sides, bottom, and top)
Lift of first container	Last container contact and crew over ha	Staging in Airlock (handover to EV2)	9:44:16	9:47:44	0:23:27	0:26:55	0:03:28	offloaded 10 1.0 splcs total

Example table of objective timing data collected for EV1, representative for each scenario (grayed out boxes/break in table indicates similar data that is not shown). Similar tables were constructed for EV2. Full set of raw data provided separately upon request. Start/Stop event markers are included for each event. Clock Time Start/Stop indicate local task times (when available), Interval Start/Stop indicate event timing within the task timeline. Δt indicates the time duration of each subtask (hh:mm:ss). Notes were provided for added event context when appropriate.

3.2.1 Timing Results (Example) (cont.)

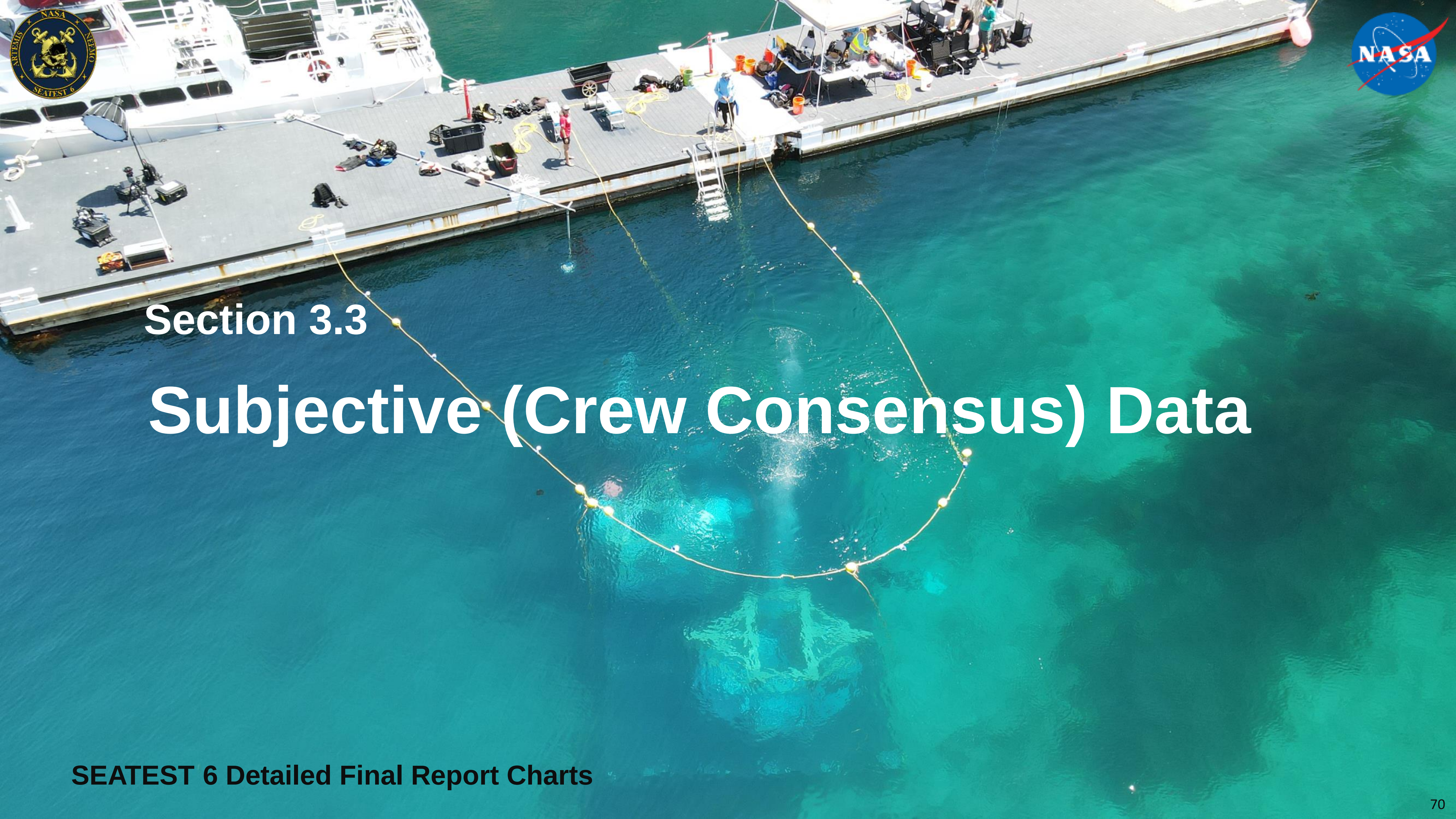
MISSION DAY	*1*								
SCENARIO:	*1*								
DESCRIPTION:	*1.0 SPLC Transfer to Staging Area Using Davit*								
EV2									
EVENT MARKERS		**EVENT**			**TIME FORMAT: h:mm:ss**				
EVENT START	EVENT END		Clock Time Start	Clock Time Stop	Interval Start	Interval Stop	Δ t	NOTES	
CAPCOM "Go"	End of last scenario task	Task Total	9:20:49	9:47:53	0:00:00	0:27:04	0:27:04		
EV1 climb ladder	First container contact for transfer	Wait for Transfer Start	9:21:42	9:23:47	0:00:53	0:02:58	0:02:05		
First contact with first container	Last contact with last container after transfer	Transfer Containers (Cumulative)	9:23:47	9:38:22	0:02:58	0:17:33	0:14:35	Deposit into A/L	
First contact with container	Last contact with container after transfer	Transfer Container 1	9:23:48	9:24:45	0:02:59	0:03:56	0:00:57	Deposit into A/L	
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	
First swipe of brush	Last swipe of brush	Dust Ops - EV1	9:39:42	9:41:40	0:18:53	0:20:51	0:01:58		
First swipe of brush	Last swipe of brush	Dust Ops - EV1 Brush EV2 Feet	9:44:01	9:44:11	0:23:12	0:23:22	0:00:10		
Ingress A/L	Last container down in A/L	Configure/Staging in Airlock (handover from EV	9:44:28	9:47:42	0:23:39	0:26:53	0:03:14		

Example table of objective timing data collected for EV2, representative for each scenario (grayed out boxes/break in table indicates similar data that is not shown). Full set of raw data provided separately upon request. Start/Stop event markers are included for each event. Clock Time Start/Stop indicate local task times (when available), Interval Start/Stop indicate event timing within the task timeline. Δt indicates the time duration of each subtask (hh:mm:ss). Notes were provided for added event context when appropriate.

3.2.2 Collisions Results

Lander Deck and Airlock Hatch Collision Data

Scenario Number	Scenario	Lander Deck	Hang ups in Offload Zone Area	Airlock Hatch			
				Top	Stbd Side	Port Side	Bottom
01	1.0 Davit	0	0	0	0	0	0
02	1.0 Zipline Airlock	11	0	0	0	0	0
03	1.0 Zipline Staging Area	1	1	0	0	0	0
04	1.0 Airlock Transfer Ops	0	0	0	0	0	0
05	2.0 Zipline Airlock	3	0	0	0	0	0
06	2.0 Reverse Davit (Reload)	0	0	0	0	0	3
07	2.0 Davit	0	0	0	0	0	0
08	2.0 Airlock Transfer Ops (Reverse)	0	0	0	0	0	1



Section 3.3

Subjective (Crew Consensus) Data

SEATEST 6 Detailed Final Report Charts

3.3.1 Simulation Quality Results

Simulation quality reflects the extent to which the simulation allows meaningful evaluation of test objectives

Scale Rating	Criteria
1	Simulation quality (e.g. hardware, software, procedures, comm., environment) presented either zero problems or only minor ones that had no impact to the validity of test data.
2	Some simulation limitations or anomalies encountered, but minimal impact to the validity of test
3	Simulation limitations or anomalies made test data marginally adequate to provide meaningful evaluation of test objectives (please describe).
4	Significant simulation limitations or anomalies precluded meaningful evaluation of major test objectives (please describe).
5	Major simulation limitations or anomalies precluded meaningful evaluation of all test objectives (please describe).

- **Q1. Rate the simulation quality of the environment as compared to expected lunar environment**
  - Rating: 3
  - Comments:
    - Slack in the zipline required a substantial change in how the crew preformed the task which was unrealistic
    - In davit operations with the 2.0 SPLC, crew was forced to the edge of the lander deck
    - Crew stability for the water resistance was unrealistic as this would not be felt in lunar gravity
- **Q2. Rate the simulation quality of the environment's ability to provoke relative operational considerations**
  - Rating: 2
  - Comments:
    - Simulation did provoke much thought into operational considerations, which continued in crew conversations into the evenings
    - Volume of suit beyond PLSS was a limiting factor, limited fidelity of airlock, lack of lunar simulation communications delay, ROM limitations
    - "This test environment does provoke relevant operational thought about how logistics transfer operations are preformed and give us the insight on how to interpret the tasks at this early stage."

Simulation quality was sufficient to support meaningful evaluation of all test objectives

3.3.2 Capability Results

Capability assessment ratings reflect the level of mission enhancement a capability might have

Essential / Enabling		Significantly Enhancing		Moderately Enhancing		Marginally Enhancing		Little or No Enhancement	
Impossible or highly inadvisable to perform mission without capability		Capabilities are likely to significantly enhance one or more aspects of the mission		Capabilities likely to moderately enhance one or more aspects of the mission or significantly enhance the mission on rare occasions.		Capabilities are only marginally useful or useful only on very rare occasions		Capabilities are not useful under any reasonably foreseeable circumstances.	
1	2	3	4	5	6	7	8	9	10

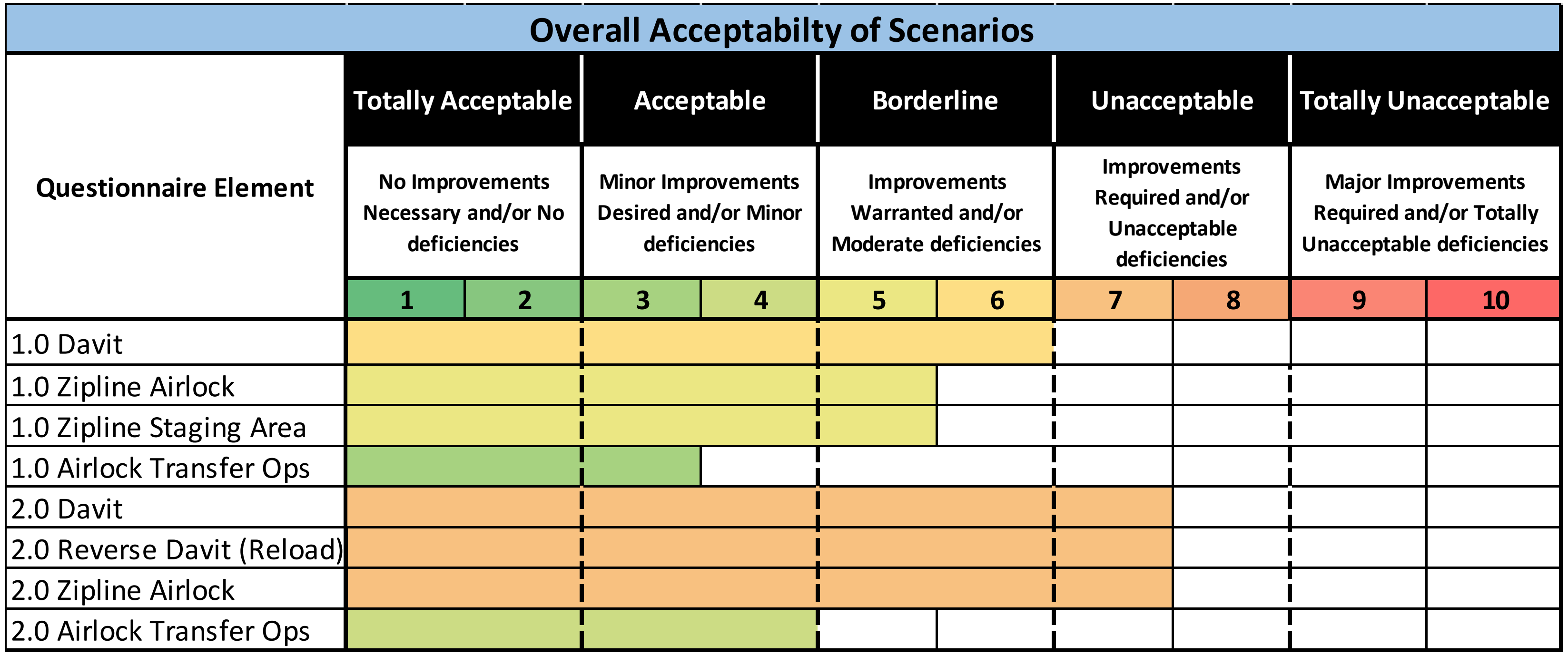
- **Q1: Provide Capability Assessment ratings and comments on the davit concept for unloading and reloading cargo logistics containers from and to the cargo logistics lander**
  - Rating: 2 (*essential and enabling*)
  - Comments:
    - Never had to physically lift container during offload process making it less fatiguing for suited crew
    - If logistics containers are located on a deck that is a significant height above the lunar surface (e.g., greater than ~2.5 m), something like davit is needed for safe logistics transfer

- **Q2: Provide Capability Assessment ratings and comments on the zipline concept for unloading and reloading cargo logistics containers from and to the cargo logistics lander**
  - Rating: 3 (*significantly enhancing*)
  - Comments:
    - Allowed for potential dust free transfer
      - Potential time savings
    - Perceived to be fastest, most efficient way to transfer cargo

The crew suggested that the most efficient means for logistics transfers could include a hybrid method using both a davit and zipline. For example, for larger payloads, the crew could use the davit as it has more mechanical advantage and makes the process easier for the crew, while the zipline could be used for smaller payloads that could be sent directly into the pressurized surface element.

3.3.3 Acceptability Results

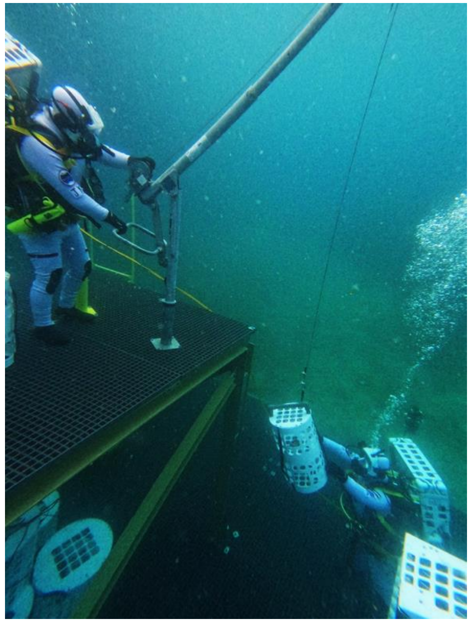
- **Acceptability describes how acceptable (or unacceptable) a task was (e.g., hand cranking a davit winch, attaching a container to a zipline, reconfiguring containers in airlock, etc.) in the given environment**
- **Overall Acceptability Rating Results:**
  - Airlock Transfer Operations for both the 1.0 and 2.0 containers were rated *acceptable* with only *minor deficiencies* and *minor improvements desired*
  - 1.0 Zipline Operations for both Airlock and Staging Area were rated *borderline* with *moderate deficiencies* and *improvements warranted*
  - 2.0 Davit, Reverse Davit (Reload), and Zipline Airlock were rated *unacceptable* with *unacceptable deficiencies* and *improvements required*



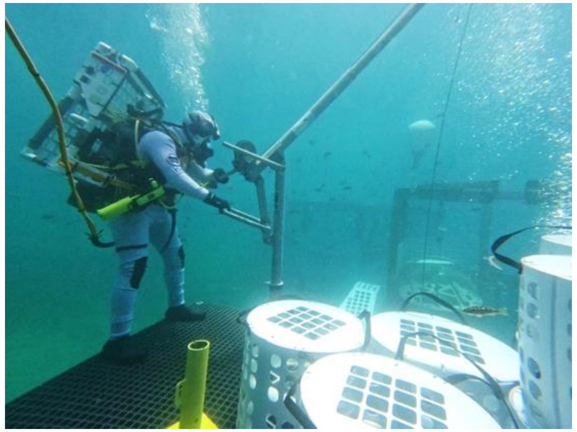
3.3.3 Acceptability Results (Davit Operations)

- **Davit Operations**
  - Scores were driven by the proximity of crewmember to the edge of the lander deck in the test configuration and dust mitigation issues
  - Crews liked the flexibility of the davit to pick up containers, so they did not have to handle them physically

- **Lander Deck**
  - With a significant lander deck height, a safety barrier is warranted around the deck perimeter *on a real lunar lander* as a visual or physical aid to orient the crew as to where the lander deck edge is located
  - The safety barrier should allow for continued offloading operations while restricting the crew to a safe area
  - Improvements required for crew safety barrier options *for a real lunar lander* included:
    - Rail
    - Tether
    - Strap Guard



Davit operation from lander deck

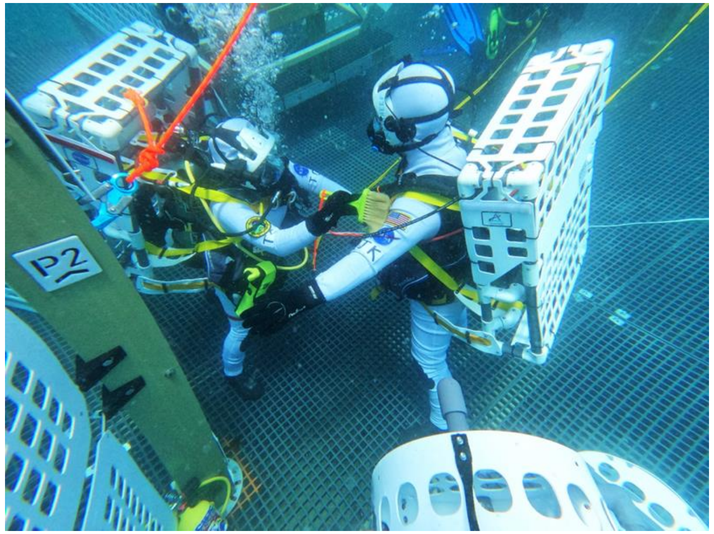


Davit operation from lander deck

3.3.3 Acceptability Results (Davit Operations, cont.)

- **Dusting Operations**
  - During the test, crew used a “paintbrush technique” (mobilizing the wrist in both flexion and extension). However, wrist mobility in the space suit is limited, so a similar flexion/extension motion will likely be infeasible.
  - Warranted design improvements:
    - A longer brush handle is required
    - Handrails on the exterior of the Airlock are required for stability of crew
    - Container stacking can also reduce dusting time (top containers don’t touch the regolith)

- **Lander Ladder**
  - Extended ladder handles allowed crew to develop an alternate method of swinging around the ladder handrail to get their feet on the first ladder rung for an easier descent strategy
  - Minor design improvements:
    - A slope to the ladder (~ 5 to 15 degrees) is required to better with suit weight distribution while a crewmember is ascending/descending the ladder



Dusting operations outside of Airlock

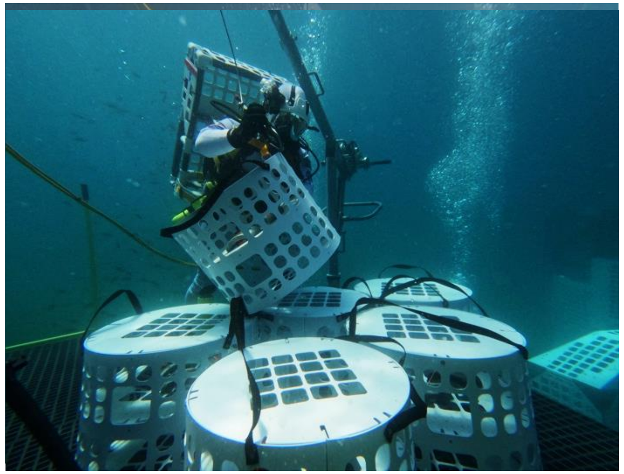

Swinging around ladder handrail in alternative descent strategy

3.3.3 Acceptability Results (Davit Operations, cont.)

- **Mechanisms**
  - Winch had significant issues with current design
    - Metabolic demands to manually operate a winch for loading/unloading was unacceptable
    - Current suit design would make this action very difficult to accomplish as the existing shoulder mobility capabilities are not conductive to this type of rotational motion
    - Additionally, it is hypothesized a significant increase in usage rate of time and oxygen can be expected as reflected in the increased amount of air used during the dive
  - Required design improvements:
    - Well developed motorized davit winch
    - Foot pedal similar to the ISS APFR (Articulating Portable Foot Restraint) for yawing operations
    - Arm pitch adjustment (~0 to 45 degrees) for maximized flexibility
    - Ratchet mechanism to prevent inadvertent movement in the opposite direction

- **Logistic Containers**
  - Minor Ops Considerations:
    - Efficient stacking on lander deck minimizes crew bending in a pressurized suit
    - Makes loading/unloading operations more efficient
    - Can reduce dusting operations time

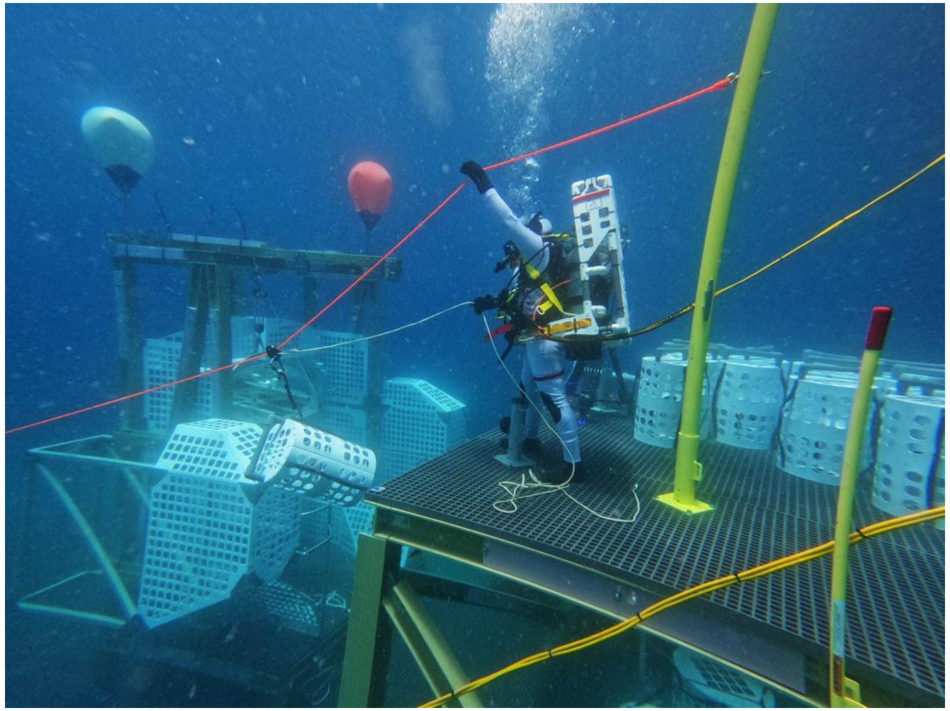
Davit winch operation



Stacking of 2.0 SPLCs on lander deck

3.3.3 Acceptability Results (Zipline Operations)

- **Zipline Operations**
  - Acceptability ranged from borderline (1.0 containers) to unacceptable (2.0 containers)
  - Loading and unloading was straight forward, easy and efficient
  - Warranted implementation for improvement:
    - Having a tauter zipline would have made this method more acceptable
- **Zipline**
  - Due to slack in the zipline, there were major operational inefficiencies with containers contacting the edge of the lander deck upon offloading
    - Mitigation of issue had crew using one hand to hold up zipline above their head which would be unrealistic in a space suit
  - Receiving end of zipline for incoming containers requires adjustment for different angles and distances
    - Test distance of 16 feet (4.89 meters) was considered as maximum range

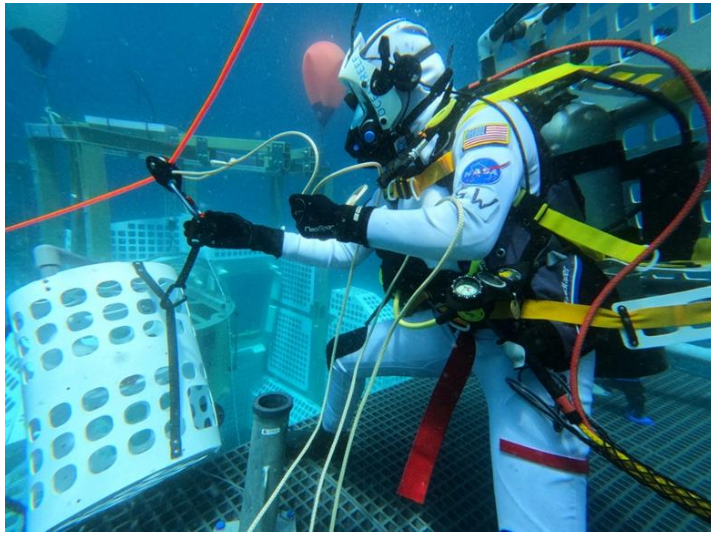


Zipline operation from lander deck – SPLC contact with lander deck during offload

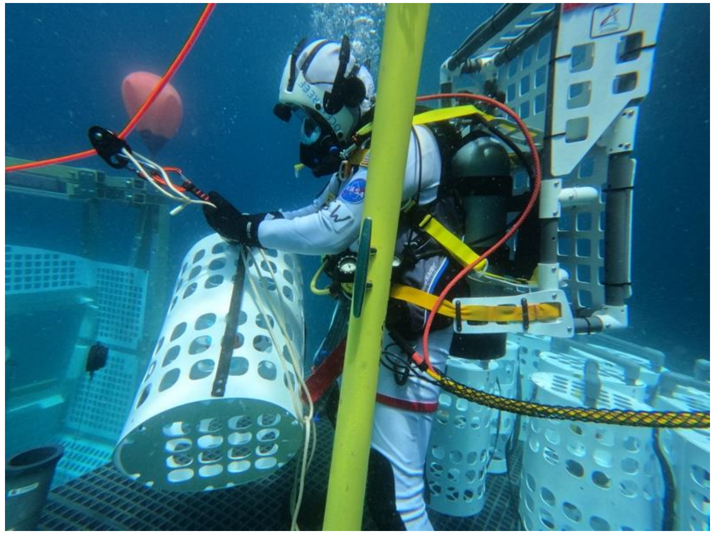
3.3.3 Acceptability Results (Zipline Operations, cont.)

- **Control Line**
  - Warranted design improvements:
    - Requires an improved slack management system
    - Control line requires at minimum an additional 10 feet (3.05 meters) of length of improve controllability

- **Zipline Hook**
  - Minor design improvements:
    - Requires hook design to hold multiple containers
    - Requires improve hook attachment so crew does not have to physically hold container while hooking to zipline
      - Suggested option: Bungee or retractable line system to bring hook to container



Excess control line slack during zipline operation



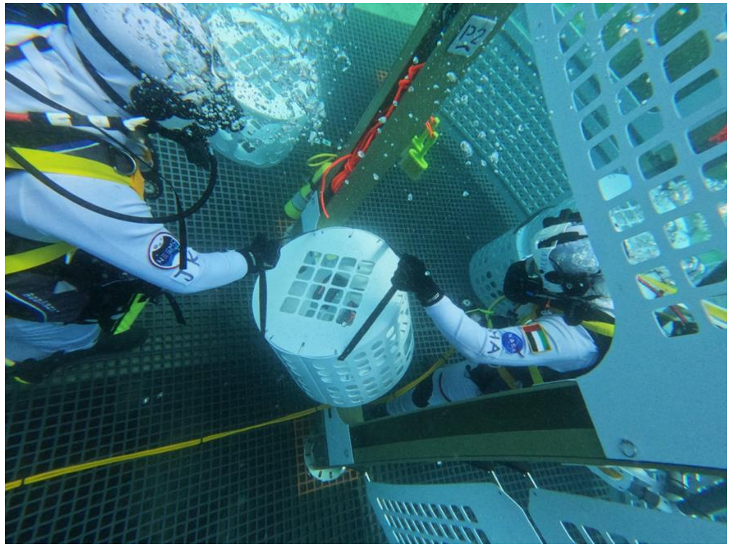
Crew holding container while implementing hook attachment

3.3.3 Acceptability Results (Zipline Operations, cont.)

- **Dust Operations**
  - Zipline eliminates dusting operations
  - Stacking containers reduces dusting time
  - Suggested implementation improvements:
    - More detailed procedures are required indicating order of dusting (i.e., top to sides to bottom) for when dusting is required, especially in staging area
  - Warranted dust mitigation options:
    - Tarp
    - Type of grating at entrance of the airlock or a “foot brush” to wipe off feet and equipment

- **Logistic Containers**
  - Height and size of 2.0 containers made it a challenge for crew to maneuver between the confines of the airlock hatch when including themselves and the container while maintaining awareness of the suit volume around their legs
  - Warranted design improvements:
    - Additional soft tether points with D-rings integrated on soft good handles at top and center of container for improved loading and balance
      - Minimizes reorientation requirements

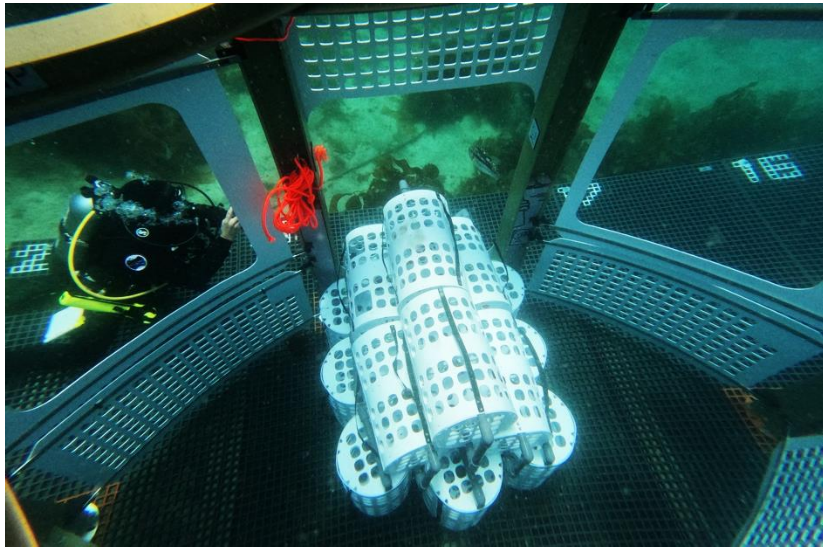
Zipline operation from lander deck



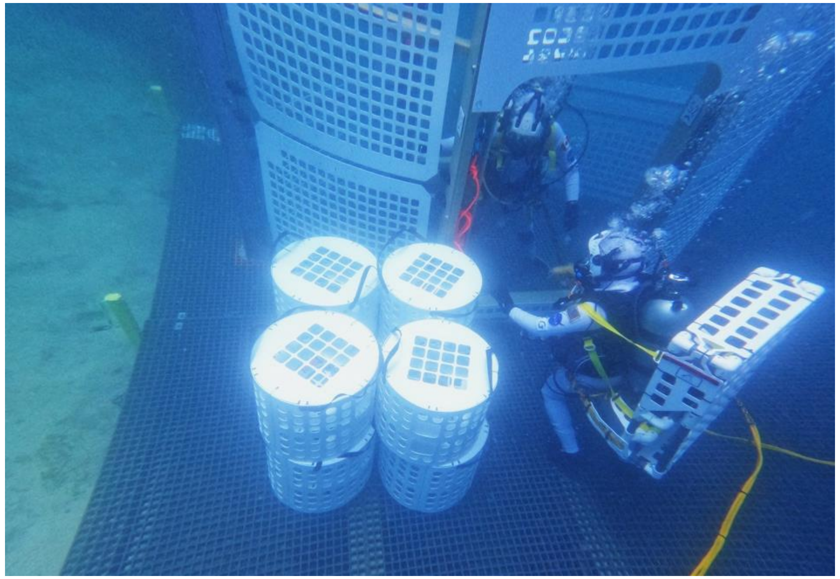
2.0 SPLC transfer into Airlock

3.3.3 Acceptability Results (Airlock Transfer Operations)

- **Airlock Transfer Operations**
  - Regardless of container size, airlock transfer operations were scored as acceptable with minor deficiencies and improvement
- **Stacking Strategies**
  - Stacking containers in center of airlock between the two-suit don/doff stands
    - Leaves enough space to walk around to access other crewmember
  - When accessing other don/doff stand, it was observed that crew did move approximately half of the containers to the opposite side and against the wall of the airlock of the suit stand for improved access
  - Stacking Strategies:
    - 1.0 containers (total of 15) stacking consensus was one vertical and two rows horizontal
    - 2.0 containers (total of 8) stacking consensus was a 4 by 2 matrix design
      - 4 containers on the bottom in a row of 2 with 4 containers on top
    - If a 3 high container stack was implemented, it was two rows of three stacked vertically
  - Stacking two high was within the suit work envelop
  - Regardless of stacking strategy, a way to secure the containers is desired
    - Minor importments:
      - “Lego type” capability on container to snap into place
      - Hand hold notch or retractable hand hold
      - Outside Airlock, containers can be stacked in a holding device like logs
  - To minimize hatch seal damage a fulcrum over the airlock hatch protector would be desired for larger loads



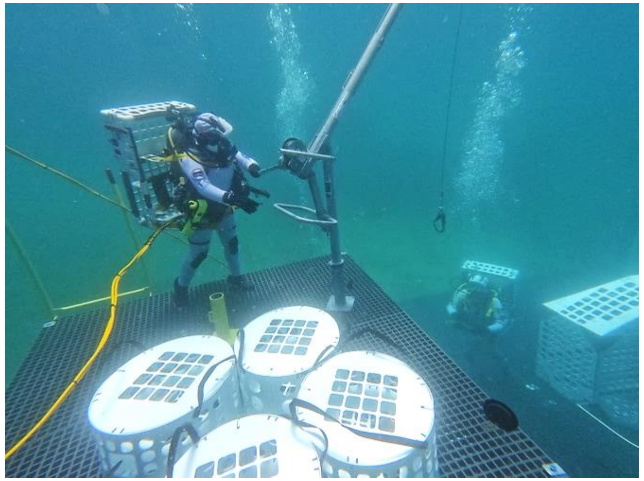
Crew consensus 1.0 SPLC stacking method



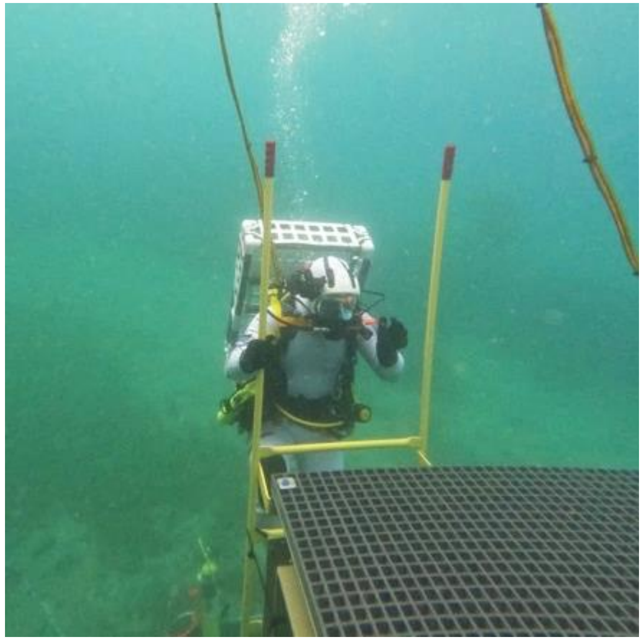
Crew consensus 2.0 SPLC stacking method

3.3.4 Crew Debrief Comments

- **Cargo Logistic Lander Configurations**
  - Safety
    - A railing or safety mechanism is required around the perimeter of the lander deck restricting crew to a safe area while continually loading/unloading logistics
    - Options
      - Rail
      - Strap Guard
      - Tether
  - Ladder
    - Extended ladder handrails aided crewmember in finding the ladder rung and descend the ladder
    - Adding a slope to the ladder of approximately 5 to 15 degrees aides in suited weight distribution for crewmember
  - Mechanisms
    - Concept of davit winch to lift and lower payloads or various sizes and mass is a valuable concept; however, current design required more design iteration
      - Metabolic demands are unacceptable with manually operating the current winch design
        - Current suit shoulder design does not have the capability for this type of rotational action that is required for winch operations
        - Time and consumables were observed at increased levels as reflected by SCUBA tank usage
      - Ability to offset payloads closer or father from davit is useful
        - Options
          - Make pitch of davit adjustable
          - Telescoping davit arm
      - Yawing capability of davit is very important
        - Options
          - Pedal to lock/unlock davit yaw angle in place similar to APFR on Station



Davit operations near lander deck edge

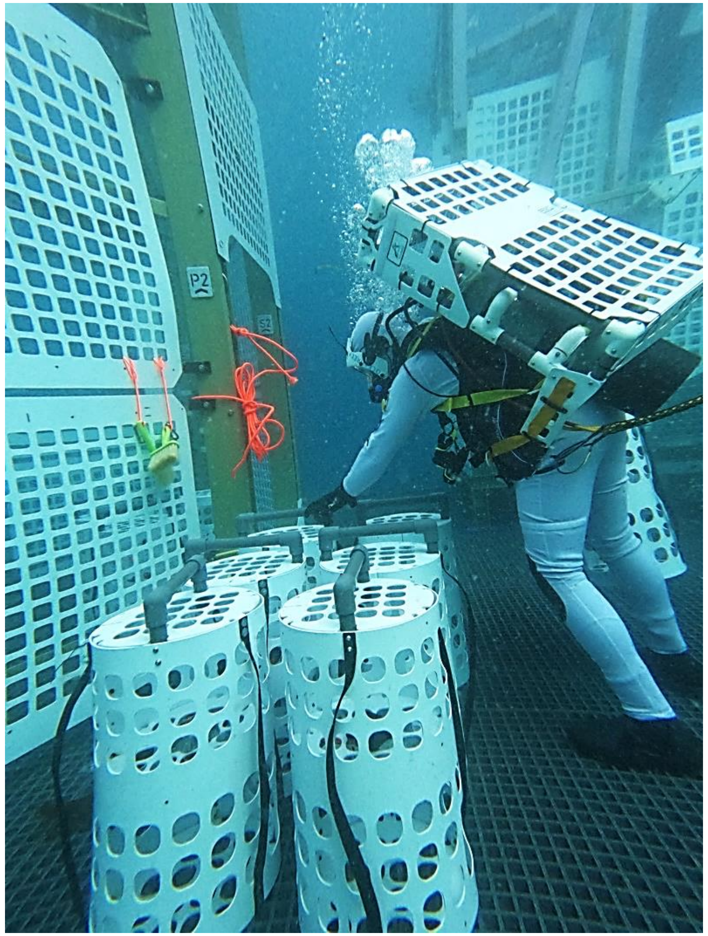


Extended ladder handrails

3.3.4 Crew Debrief Comments (cont.)

- **Dust Mitigation**
  - Dust mitigation with Zipline into Airlock was great
    - Need a method to raise and lower the airlock attach point to account for variable distances from lander platform to create correct angle for container to clear airlock hatch
  - Options for improved dust mitigation suggested in debrief (see slide 79)

- **Logistics Handling**
  - Fulcrum over Airlock hatch seal protector could be helpful to move large loads into and out of the airlock easily



Crew staging 1.0 SPLCs outside Airlock

3.3.4 Crew Debrief Comments (cont.)

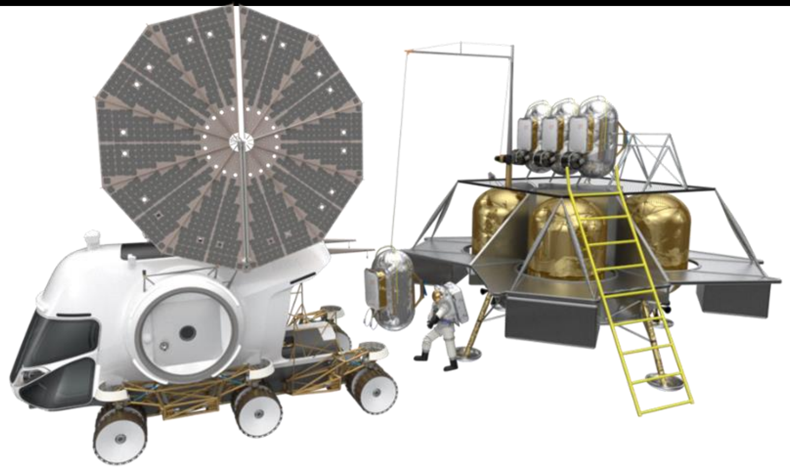
Recommendations for future SEATEST Analog Tests:

- **Better simulate spacesuit limitations**
  - Suggested options
    - More representative gloves, e.g., hockey glove
    - More representative boots, e.g., ski boot
    - A mobility restraint to simulate the motion envelope of a space suit would add fidelity to the simulation (i.e., a 3-D printed Hard Upper Torso (HUT) to simulate suited shoulder range-of-motion)
- **Better simulate the fall safety system on lander deck, as this would be essential to a real lunar environment**
  - One limitation of this underwater analog environment is the added stability provided by the water resistance giving the crew an unrealistic sense of safety on the lander platform
- **Increase crew weigh-out to better simulate lunar gravity for working on mockup**
- **Zipline position/height should be optimized to prevent lander deck contact, and ensure sufficient line tension and clearance through hatch**

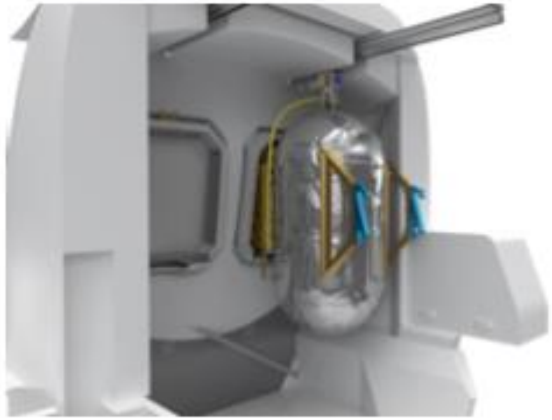
3.3.5 Crew Debrief on Container Relative Advantages

Although the test was shortened and the MPLC scenario wasn't run, it was discussed at length as a logistics concept by the crew. Key observations across the different concepts were:

- **In concept, the MPLC with transfer port is much preferred over the 1.0, 2.0 solutions**
  - EVA time required for each CTBE of pressurized cargo transferred should be much less than was seen for the smaller containers
  - Space is optimized with MPLC design because each attached MPLC adds temporary new volume, rather than taking up precious cabin volume
  - Dust mitigation is optimized with MPLC design (at most requiring logistics port seal dusting prior to berthing)
- **If MPLCs are not feasible, the size of 2.0 SPLCs seem preferable to 1.0s to minimize extra volume taken up by the containers.**



Artist concept of crew utilizing a davit to transport MPLCs to a pressurized rover logistic port

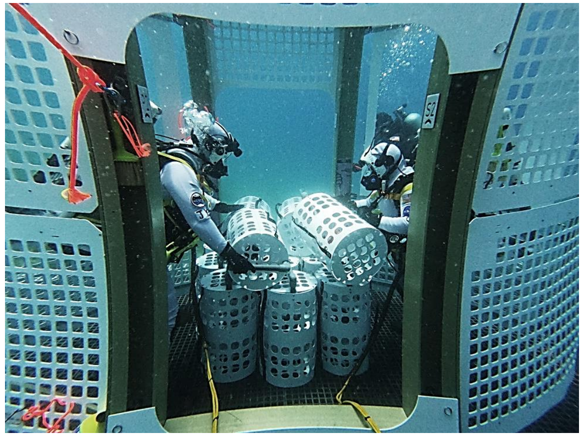


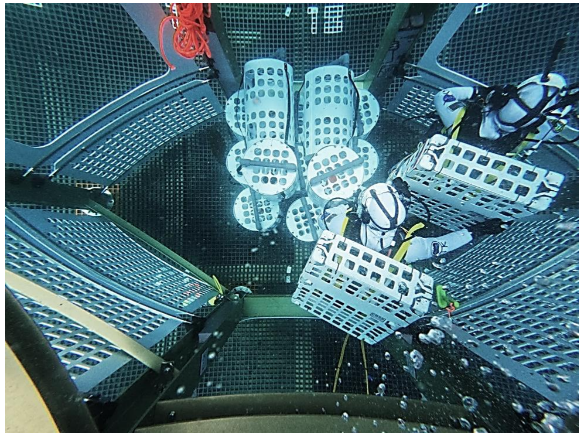
Artist concept of an MPLC connected to a logistics port on the aft end of a pressurized rover

Recommend that the team plan a future test for the MPLC unload and re-load scenarios

3.4 Discussion on Airlock Packing Limitations

- The Airlock mockup used for SEATEST 6 was ~ 9.5 m^3, which is ~ equal to the volume of the PR and the mockup used in 1-g pre-mission testing at JSC
- Due to suit restrictions and difficulty of handling SPLCs of different sizes either solo or with a buddy, estimations were also made on the number of SPLCs that could reasonably be stacked in the Airlock
- The number of SPLCs of each type used at SEATEST 6 was determined by estimating the number of containers of each type that could fit in the airlock, still leaving room for 2 suited crewmembers to ingress, close the hatch behind them, and doff their suits
- Once the Airlock is functionally full of SPLCs, an Airlock cycle must happen to bring them into the cabin
  - SEATEST 6 did NOT have 38 1.0s or 19 2.0s in play. Rather, the estimate based on pre-mission 1-g and CAD analysis was that 15 1.0s and 8 2.0s would be sufficient to fill the Airlock and require an airlock cycle
  - In the case of 15 1.0 SPLCs, it would require 3 airlock cycles (to get to 37.5 CTBE)
  - In the case of 8 2.0 SPLCs, it would also require 3 airlock cycles
  - Our ST6 crewmembers were able to find stacking strategies and preserve space to ingress, doff suits, etc. with 15 and 10 SPLCs respectively. Arguably they could have figured out how to cram a few more in, but only a few more at most without violating handling assumptions
- An Airlock cycle is functionally an EVA. You could try to do them all on the same day, but
  - It becomes increasingly harder to find space to store all the SPLCs in the cabin
  - SPLCs must be disposed of via EVA eventually – presumably full of trash
  - A strategy to recharge as needed, and combine the recharge/trash emptying on the same EVA may be most efficient
- SEATEST 6 only looked at a single airlock cycle for each container type
  - Once timing was understood to get one airlock cycle, the full impact could be extrapolated





Visualizing the airlock choreography challenge

Better understanding SPLC design, stackability, packing efficiency of containers, handling constraints while suited, etc. is important forward work

3.5 Expeditionary Training Benefits

- **The international astronauts involved unanimously thought SEATEST was a worthy addition to the Expeditionary Training they frequently receive (e.g., NOLS, CAVES, PANGAEA, Zero to Helo, D-RATS, etc.)**
- **Attributes that make it good Expeditionary Training included:**
  - Extreme environment mission operations with real risks demanding:
    - Critical and challenging training
    - Good buddymanship
    - High individual and team performance
  - Leadership/followership opportunities
  - Detailed procedures
  - "Detachment mentality" where the questions being answered are front and center for an extended period of time
  - Opportunity to learn from more experienced crew members
- **Crew comments included:**
  - *"There's a reason organizations like the service branches and NASA conduct training detachments away from home. It enables the team to be fully immersed with the tasks at hand, while forging the necessary tight-knit bonds that are required of all teams facing immense challenges, such as what we aim to do with Artemis."* – J. Kim
  - *"I get now why it makes sense to do these evaluations here (instead of in Houston). We were immersed in this exercise and evaluation, allowing us to have timely and thorough discussions and consensus building on forward logistics plans. Here we are at 7:00 at night still talking this, whereas at home we would have scattered by now as folks went to get the kids to soccer practice…"* – S. Williams
  - *"By performing these activities on an expedition, we benefit much more than we would by completing the evaluations independently. We are able to put our expeditionary behavior skills into practice, which is crucial for mission success."* – J. Sidey-Gibbons

Continuing discussions in the evening

Crew Dive Training

"When you have real-time operations that require a highly functioning team, risk management, and good decision making, you have the makings of good Expeditionary Training." – J. "Vegas" Kelly

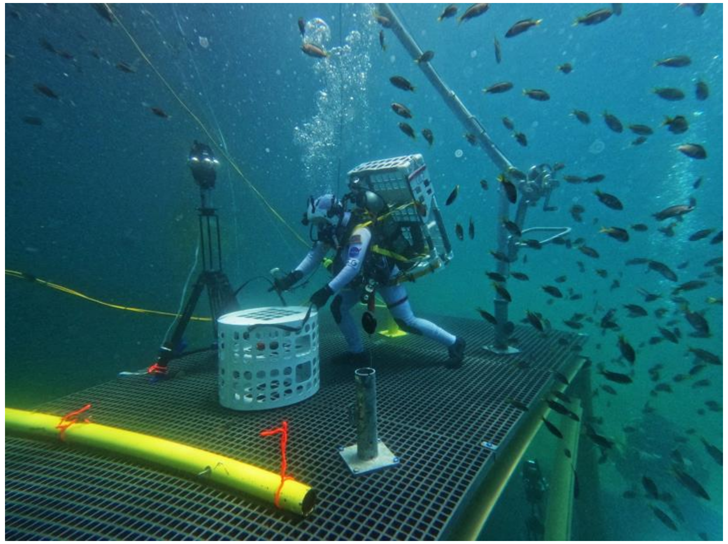
3.6 Other Activities

- **PAO objective of underwater 3D Virtual Reality (VR) video collected by Felix & Paul Studios (FPS)**
- **Setup consisted of:**
  - Topside divers positioned cameras on the lander deck and “lunar surface” (main deck) prior to the runs of the day, and removed them at the end of the day
  - The cameras were moved as required for optimal recording of the activities at hand throughout the dive day
  - The FPS team monitored camera footage in real time from the dock
  - A PAO Officer was present to support crew interviews with FPS

Dive supervisor/MCC communications area

Felix & Paul Studios interviewing crew (with NASA PAO supervision)

Felix & Paul Studios VR viewing (left) and 3D VR camera (right)



Felix & Paul Studios 3D VR camera capturing test footage

4.0

Conclusions

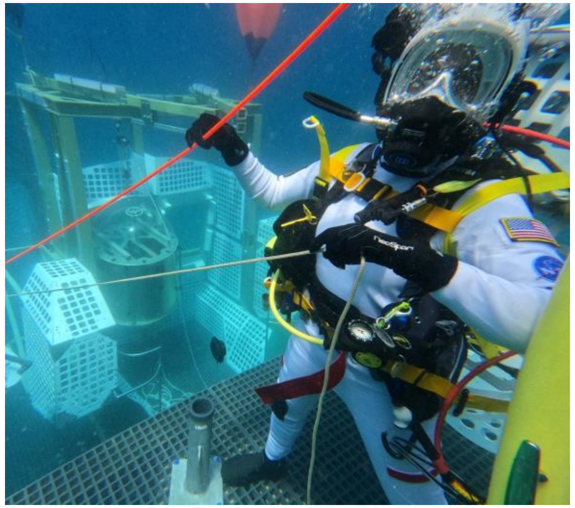
SEATEST 6 Detailed Final Report Charts

4.1 Key Takeaways – Specific to Logistics Transfer

- **Simulation quality was sufficient to support meaningful evaluation of all test objectives**
- **The two offloading transfer concepts presented both advantages and limitations**
  - Davit
    - The davit's flexibility allowed crew to pick up containers without physical interaction
    - Davit hardware components had limitations which can be solved mainly with winch improvements
  - Zipline
    - Proved to be the most efficient method of moving logistics containers to airlock
    - Has the potential to significantly reduce EVA dust mitigation required
- **A hybrid method combining the davit and zipline systems was proposed to increase efficiency**
  - Use a davit for larger payloads, because it has the mechanical advantage to make this easier for crew
  - Use the zipline for smaller, easier to handle payloads and send them straight into the pressurized element
- **Airlock Choreography**
  - Will be a significant issue and is highly dependent on airlock size and layout, as well as container size/dimensions/stackability/etc. Airlock choreography ease vs. difficulty will constrain how many EVAs are required to transfer an entire logistics manifest.
  - Crew identified several container stacking strategies and container securing options for future consideration
- **Plan a future test for the MPLC unload and re-load scenarios**
  - Given the potential advantages to this concept, it should be evaluated in future HITL testing

4.1 Key Takeaways – Specific to Logistics Transfer (cont.)

- **In concept, the MPLC with transfer port is much preferred over the 1.0, 2.0 solutions**
  - EVA time required for each CTBE of pressurized cargo transferred should be much less than was seen for the smaller containers
  - Space is optimized with MPLC design because each attached MPLC adds temporary new volume, rather than taking up precious cabin volume
  - Dust mitigation is optimized with MPLC design (at most requiring logistics port seal dusting prior to berthing)
- **If MPLCs are not feasible, the size of 2.0 SPLCs seem preferable to 1.0s to minimize extra volume taken up by the containers.**
- **EVA manual logistics transfer will be very challenging and time consuming**
- **For the current manifest for a 14-day mission, it's clear that 2-3 EVAs will be required to get all the supplies and corresponding trash into and out of the Pressurized Rover using Small Pressurized Logistics Containers**

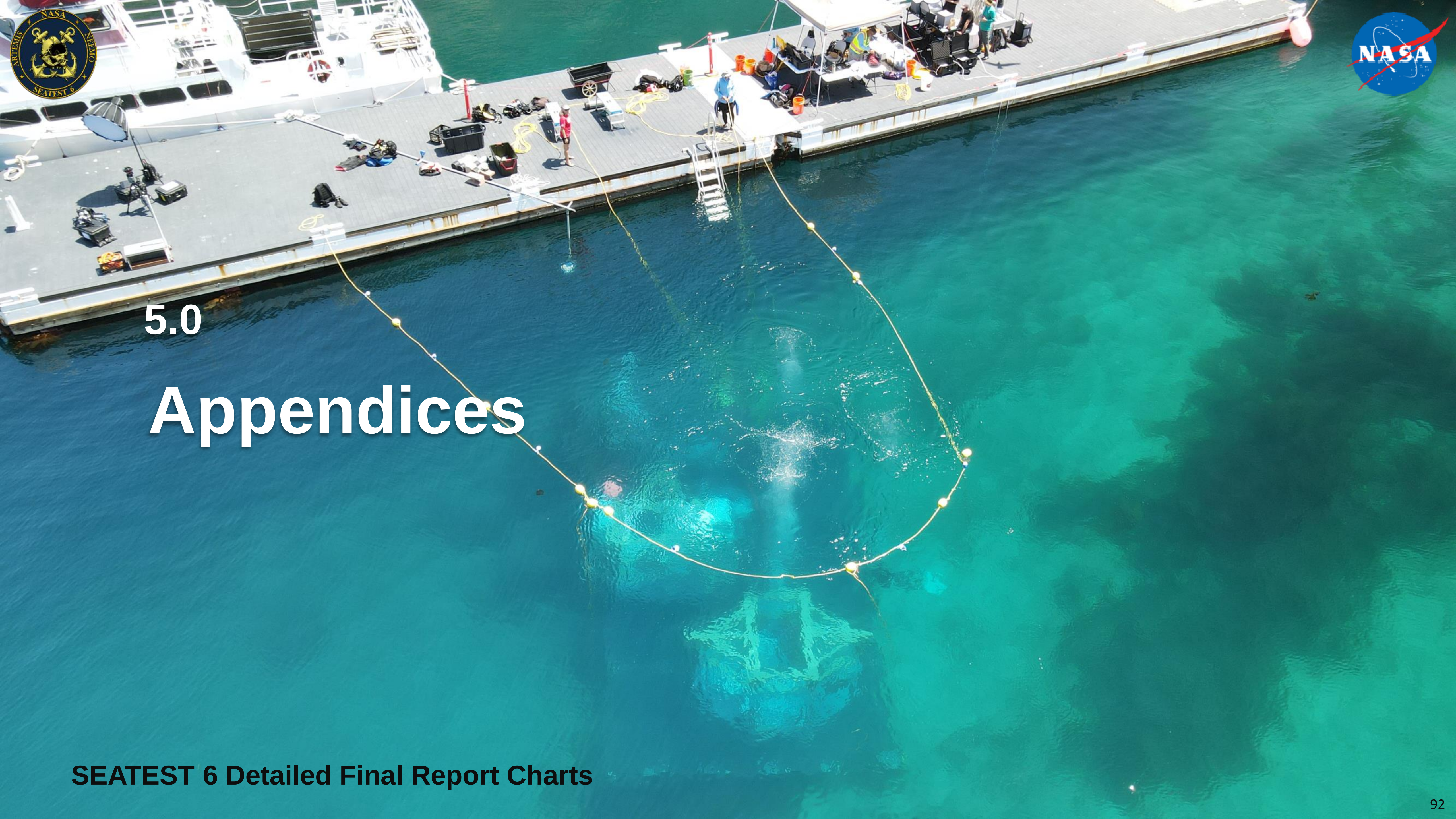


SEATEST 6 MPLC mockup berthed to PR logistics port mockup

- **Looking deeply at possible hardware and technique solutions uncovered many subsequent questions, e.g.**
  - What size container is reasonable for a single EV to carry?
  - What size container requires 2 EVs to carry?
  - At what size is it too big for even 2 EVs to carry?
  - Is dragging a container across the regolith feasible?
  - How many containers can reasonably fit in an airlock (or PR) and still have room for 2 suited crewmembers to ingress, pressurize, and assist each other in doffing suits?

4.2 Key Takeaways - General

- **Developing a SEATEST mission served as a forcing function to:**
  - Start an integration forum with all the primary stakeholders (Logistics, Cargo Lander, EVA, Dust, FOD) from multiple Artemis program offices
  - Identify POCs from each team for future work between teams
  - Build a common framework and vocabulary for discussing the challenges
- **The arbitrary but inflexible deadline ensured full team engagement and prioritization for a rapid test**
- **The SEATEST mission model proved that a small team with limited resources can rapidly plan, execute and document meaningful HITL test data (< 6 mos. from first concept briefing to final report)**
- **Having Logistics and Lander team stakeholders present during testing to witness results and discussions firsthand was very valuable**
- **The results documented in this report will immediately be fed forward to inform ongoing SAC 23 tasks, Architecture Definition Document (ADD), SAC24 tasks, and various ConOps Documents**



5.0

Appendices

SEATEST 6 Detailed Final Report Charts

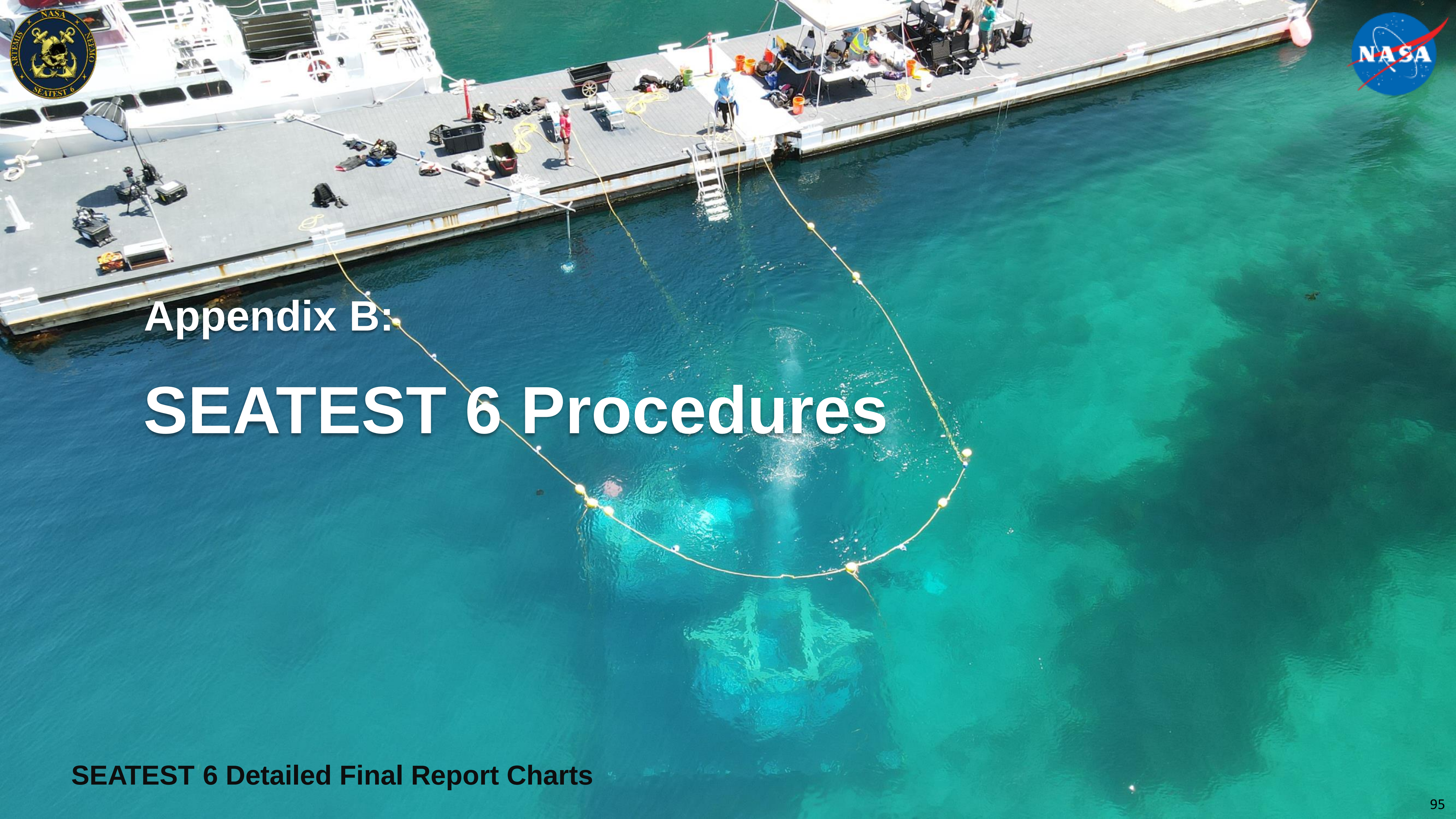
Appendix A:

SEATEST 6
Safety and Management Reviews

SEATEST 6 Detailed Final Report Charts

SEATEST 6 Safety and Management Reviews

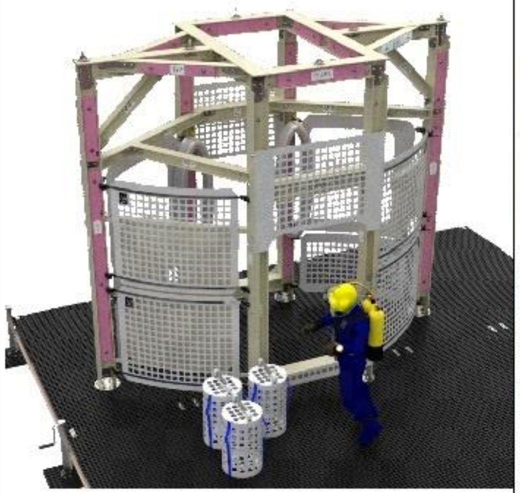
- Feb 16 – SAC 23 Planning TIM; brief of HITL objectives for FY23
- March 1 – Rev B updates of NEEMO Diving and Swimming and Dive Safety Manuals
- March 1 – NEEMO Dive Safety Board (DSB) approval
- March 22 – Brief to CB/Ops Training Branch; request for crew support
- March 15 – 1st brief to USC DSB
- April 19 – Received California Fish and Wildlife Permit
- May 31 – USC DSB and USC DSO Final approval
- June 1 – Mockup TRR (Chaired by SF3/W. Foley)
- June 8 – SEATEST 6 Integrated TrRR (Co-chaired by CB/S. Walker, XA/G. Nelson)
- June 16 – JSC DSB Review (Chaired by CX12/R. Erickson)
- July 10 – JSC DSB Approval
- July 10 – Integrated TrRR Approval



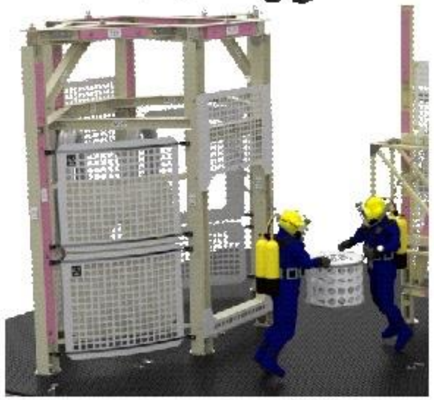
Appendix B:

SEATEST 6 Procedures

B.1 – 1.0 SPLC Transfer to Staging Area with Davit

IV/SSRMS	EV1	EV2
Scenario 2  	TRANSFER 1.0 SPLC FROM LANDER TO AIRLOCK **√Tank Pressure_________ / Thermal / Gloves** 1. Climb ladder and translate to davit worksite 2. Attach davit hook to hard handle of SPLC 3. Crank davit handle to lift SPLC and rotate clear of lander deck 4. **On EV2 GO**, lower SPLC to lunar surface 5. **On EV2 GO**, raise davit hook and repeat SPLC transfer 6. **√Tank Pressure_________ / Thermal / Gloves** Once SPLC transfer is complete: 7. Stow hook on davit and safe davit 8. Descend ladder and assist transferring SPLCs to Staging Area 9. **√Tank Pressure_________ / Thermal / Gloves** At Airlock: 10. Join EV2 and assist with dust ops of SPLCs 11. Get dusted by EV2 12. Dust EV2 13. Transfer SPLCs through Airlock hatch to EV2 14. Repeat until all SPLCs are transferred 15. Ingress Airlock and close simulated hatch 16. **√Tank Pressure_________ / Thermal / Gloves**	TRANSFER 1.0 SPLC FROM LANDER TO AIRLOCK **√Tank Pressure_________ / Thermal / Gloves** 1. Position to receive SPLCs at the base of Lander 2. When personnel are clear of SPLC lowering corridor, **give EV1 GO** to lower SPLC 3. **Give EV1 GO** to stop lowering SPLC when at lunar surface 4. Remove davit hook from SPLC and transfer to Airlock staging area 5. **Give EV1 GO** to raise davit hook 6. Repeat SPLC transfer 7. **√Tank Pressure_________ / Thermal / Gloves** At Airlock: 8. Start dust operations on SPLCs in stowage area 9. Dust EV1 10. Get dusted by EV1 11. Ingress airlock 12. Receive and stack SPLCs, while maintaining work volume for EV1 ingress 13. **√Tank Pressure_________ / Thermal / Gloves**

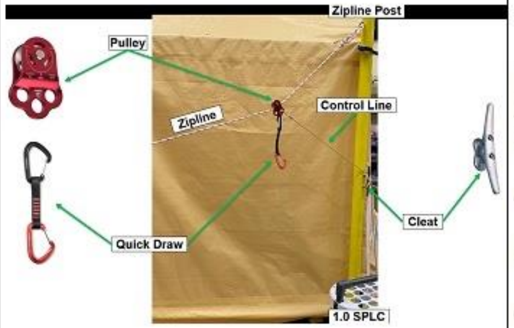
B.2 – 2.0 SPLC Transfer to Staging Area with Davit

IV/SSRMS	EV1	EV2
Scenario 3	TRANSFER 2.0 SPLC FROM LANDER TO AIRLOCK	TRANSFER 2.0 SPLC FROM LANDER TO AIRLOCK
  	**√Tank Pressure_________ / Thermal / Gloves**	**√Tank Pressure_________ / Thermal / Gloves**
	1. Climb ladder and translate to davit worksite 2. Attach davit hook to hard handle of SPLC 3. Crank davit handle to lift SPLC and rotate clear of lander deck 4. **On EV2 GO**, lower SPLC to lunar surface	1. Position to receive SPLCs at the base of Lander 2. When personnel are clear of SPLC lowering corridor, **give EV1 GO** to lower SPLC 3. **Give EV1 GO** to stop lowering SPLC when at lunar surface 4. Remove davit hook from SPLC and drag SPLC to Lander staging area
	5. **On EV2 GO**, raise davit hook and repeat SPLC transfer	5. **Give EV1 GO** to raise davit hook 6. Repeat SPLC transfer
	6. **√Tank Pressure_________ / Thermal / Gloves**	7. **√Tank Pressure_________ / Thermal / Gloves**
	Once SPLC transfer is complete: 7. Stow hook on davit and safe davit 8. Descend ladder 9. Transfer (2-crew carry) SPLCs from Lander staging area to Airlock staging area	8. Transfer (2-crew carry) SPLCs from Lander staging area to Airlock staging area
	10. **√Tank Pressure_________ / Thermal / Gloves**	9. **√Tank Pressure_________ / Thermal / Gloves**
	At Airlock: 11. Join EV2 and assist with dust ops of SPLCs 12. Get dusted by EV2 13. Dust EV2	At Airlock: 10. Start dust operations on SPLCs in stowage area 11. Dust EV1 12. Get dusted by EV1 13. Install hatch seal protection 14. Ingress airlock
	14. Push/pull SPLCs into Airlock	15. Push/pull SPLCs into airlock while maintaining work volume for EV1 ingress
	15. Ingress Airlock and assist EV2 to stack SPLCs 16. Stack SPLCs with EV2 assistance 17. Close simulated hatch	16. Drag SPLC out of hatchway 17. Stack SPLCs with EV1 assistance
	18. **√Tank Pressure_________ / Thermal / Gloves**	18. **√Tank Pressure_________ / Thermal / Gloves**

B.3 – 2.0 SPLC Reload with Davit

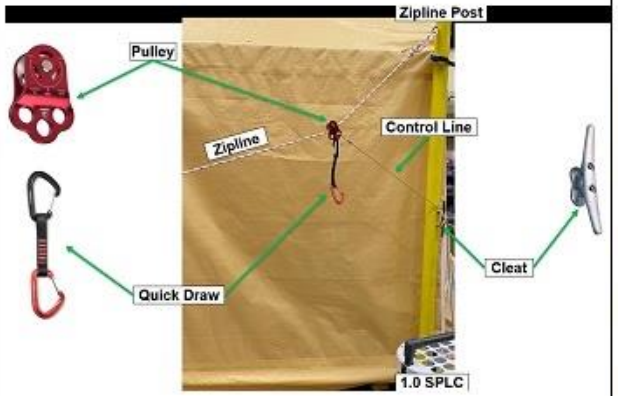
IV/SSRMS	EV1	EV2
Scenario 4 • Reverse with process with 2.0 SPLC only 	TRANSFER 2.0 SPLC FROM AIRLOCK TO LANDER **√Tank Pressure__________ / Thermal / Gloves** 1. Open Airlock hatch and install hatch seal cover 2. Jointly place first SPLC on floor of Airlock, leaving room for egress 3. Egress Airlock 4. Push/pull SPLCs through hatch 5. Drag SPLC to staging area clear of hatchway; repeat Note: EV1 may need to ingress A/L multiple times to assist unstacking SPLCs to ground level 6. **√Tank Pressure__________ / Thermal / Gloves** Once all SPLCs are in staging area: 7. Transfer (2-crew carry) SPLCs from Airlock staging area to Lander staging area 8. **√Tank Pressure__________ / Thermal / Gloves** After all SPLCs are transferred to Lander staging area: 9. Climb ladder and translate to davit worksite 10. Release davit hook and rotate davit to lower position 11. **On EV2 GO**, lower davit hook to lunar surface and slack line 12. Raise SPLC and rotate davit to stowage position 13. Lower SPLC to stowage position and slack line 14. Release davit hook and repeat Once all SPLCs are transferred: 15. Stow davit hook and safe davit 16. Descend ladder 17. **√Tank Pressure__________ / Thermal / Gloves**	TRANSFER 2.0 SPLC FROM AIRLOCK TO LANDER **√Tank Pressure__________ / Thermal / Gloves** 1. Jointly place first SPLC on floor of Airlock 2. Push/pull SPLCs through hatch 3. Repeat until all SPLCs are transferred out of airlock Note: EV1 may need to ingress A/L multiple times to assist unstacking SPLCs to ground level 4. **√Tank Pressure__________ / Thermal / Gloves** Once all SPLCs are in staging area: 5. Transfer (2-crew carry) SPLCs from Airlock staging area to Lander staging area 6. **√Tank Pressure__________ / Thermal / Gloves** After all SPLCs are transferred to Lander staging area: 7. Give EV1 GO to lower davit hook 8. Attach davit hook to SPLC and give EV1 GO to raise SPLC 9. Drag next SPLC to offloading zone and repeat until all SPLCs are transferred 10. **√Tank Pressure__________ / Thermal / Gloves**

B.4 – 2.0 SPLC Transfer to Staging Area with Zipline

IV/SSRMS	EV1	EV2
Scenario 5	ZIPLINE 2.0 SPLC FROM LANDER TO STAGING AREA	ZIPLINE 2.0 SPLC FROM LANDER TO STAGING AREA
	**√Tank Pressure_________ / Thermal / Gloves**	**√Tank Pressure_________ / Thermal / Gloves**
	1. Climb ladder and translate to zipline worksite 2. Raise SPLC and attach to zipline quick draw 3. While maintaining tension on load, release control line from cleat	1. Translate to Airlock staging area
	4. **On EV2 GO**, pay out slack to lower SPLC to Airlock	2. **Give EV1 GO** to lower SPLC 3. Lower SPLC to ground and unhook once line is slack
	5. **On EV2 GO**, haul on control line to reset quick draw back to loading position 6. Secure control line to cleat	4. **Give EV1 GO** to reset zipline
	7. **√Tank Pressure_________ / Thermal / Gloves**	5. **√Tank Pressure_________ / Thermal / Gloves**
	8. Retrieve next SPLC and repeat steps 2-6	6. Repeat until SPLCs are transferred
	When all SPLCs have been transferred: 9. Descend ladder and translate to Airlock	
	At Airlock: 10. Join EV2 and assist with dust ops of SPLCs 11. Get dusted by EV2 12. Dust EV2	At Airlock: 7. Start dust operations on SPLCs in stowage area 8. Dust EV1 9. Get dusted by EV1 10. Install hatch seal protection 11. Ingress airlock
	13. Push/pull SPLCs into Airlock	12. Push/pull SPLCs into airlock while maintaining work volume for EV1 ingress
	14. Ingress Airlock and assist EV2 to stack SPLCs 15. Stack SPLCs with EV2 assistance 16. Close simulated hatch	13. Drag SPLC out of hatchway 14. Stack SPLCs with EV1 assistance
	17. **√Tank Pressure_________ / Thermal / Gloves**	15. **√Tank Pressure_________ / Thermal / Gloves**

B.5 – 1.0 SPLC Transfer to Staging Area with Zipline

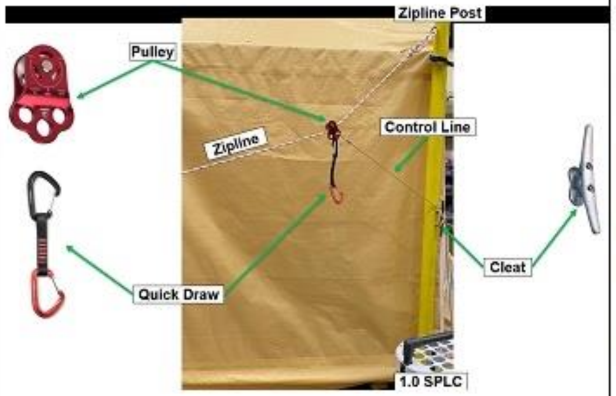
IV/SSRMS	EV1	EV2
Scenario 6	ZIPLINE 1.0 SPLC FROM LANDER TO STAGING AREA	ZIPLINE 1.0 SPLC FROM LANDER TO STAGING AREA
	√Tank Pressure_________ / Thermal / Gloves	**√Tank Pressure_________ / Thermal / Gloves**
	1. Climb ladder and translate to zipline worksite	1. Translate to Airlock staging area
	2. Raise SPLC and attach to zipline quick draw	
	3. While maintaining tension on load, release control line from cleat	
	4. **On EV2 GO**, pay out slack to lower SPLC to Airlock	2. **Give EV1 GO** to lower SPLC
		3. Lower SPLC to ground and unhook once line is slack
	5. **On EV2 GO**, haul on control line to reset quick draw back to loading position	4. **Give EV1 GO** to reset zipline
	6. Secure control line to cleat	
	7. **√Tank Pressure_________ / Thermal / Gloves**	5. **√Tank Pressure_________ / Thermal / Gloves**
	8. Retrieve next SPLC and repeat steps 2-6	6. Repeat until SPLCs are transferred
	When all SPLCs have been transferred:	
	9. Descend ladder and translate to Airlock	
	At Airlock:	At Airlock:
	10. Join EV2 and assist with dust ops of SPLCs	7. Start dust operations on SPLCs in stowage area
	11. Get dusted by EV2	8. Dust EV1
	12. Dust EV2	9. Get dusted by EV1
	13. Transfer SPLCs through Airlock hatch to EV2	10. Ingress airlock
	14. Repeat until all SPLCs are transferred	11. Receive and stack SPLCs while maintaining work volume for EV1 ingress
	15. Ingress Airlock and close simulated hatch	
	16. **√Tank Pressure_________ / Thermal / Gloves**	12. **√Tank Pressure_________ / Thermal / Gloves**



B.6 – 1.0 SPLC Transfer to Airlock with Zipline

IV/SSRMS

Scenario 7



EV1

ZIPLINE 1.0 SPLC FROM LANDER TO AIRLOCK

√Tank Pressure_________ / Thermal / Gloves

1. Translate to Airlock and perform dust operations on EV2
2. Translate to Lander
3. Climb ladder and translate to zipline worksite
4. Raise SPLC and attach to zipline quick draw
5. While maintaining tension on load, release control line from cleat
6. **On EV2 GO**, pay out slack to lower SPLC to Airlock
7. **On EV2 GO**, haul on control line to reset quick draw back to loading position
8. Secure control line to cleat
9. **√Tank Pressure_________ / Thermal / Gloves**
10. Retrieve next SPLC and repeat steps 2-6

When all SPLCs have been transferred:

11. Descend ladder and translate to Airlock

At Airlock:

12. Perform self-dust operations
13. Ingress Airlock and close simulated hatch
14. **√Tank Pressure_________ / Thermal / Gloves**

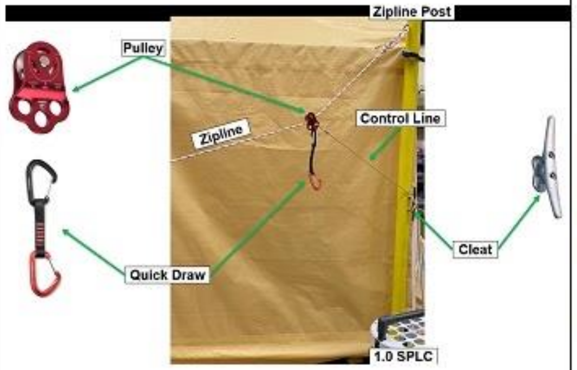
EV2

ZIPLINE 1.0 SPLC FROM LANDER TO AIRLOCK

√Tank Pressure_________ / Thermal / Gloves

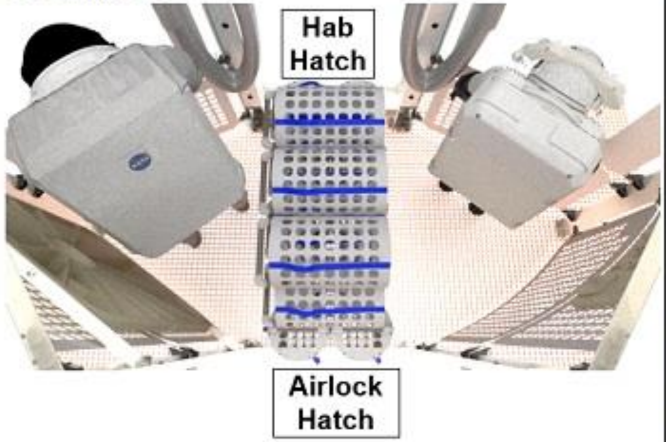
1. Translate to Airlock and get dusted by EV1
2. Ingress Airlock
3. Position to receive SPLCs
4. **Give EV1 GO** to lower SPLC
5. Lower SPLC to floor of airlock and unhook once line is slack
6. **Give EV1 GO** to reset zipline
7. Stack SPLCs while maintaining work volume for EV1 ingress
8. **√Tank Pressure_________ / Thermal / Gloves**
9. Repeat until SPLCs are transferred
10. **√Tank Pressure_________ / Thermal / Gloves**

B.7 – 2.0 SPLC Transfer to Airlock with Zipline

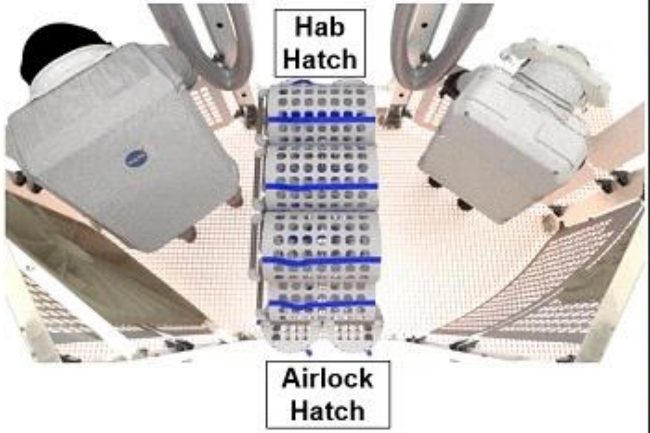


IV/SSRMS	EV1	EV2
Scenario 8	ZIPLINE 2.0 SPLC FROM LANDER TO AIRLOCK	ZIPLINE 2.0 SPLC FROM LANDER TO AIRLOCK
	√Tank Pressure_________ / Thermal / Gloves	**√Tank Pressure_________ / Thermal / Gloves**
	1. Translate to Airlock and perform dust operations on EV2	1. Translate to Airlock and get dusted by EV1
	2. Translate to Lander	2. Ingress Airlock
	3. Climb ladder and translate to zipline worksite	3. Position to receive SPLCs
	4. Raise SPLC and attach to zipline quick draw	
	5. While maintaining tension on load, release control line from cleat	
	6. **On EV2 GO**, pay out slack to lower SPLC to Airlock	4. **Give EV1 GO** to lower SPLC
		5. Lower SPLC to floor of airlock and unhook once line is slack
	7. **On EV2 GO**, haul on control line to reset quick draw back to loading position	6. **Give EV1 GO** to reset zipline
	8. Secure control line to cleat	7. Drag and stack SPLCs while maintaining work volume for EV1 ingress
	9. **√Tank Pressure_________ / Thermal / Gloves**	8. **√Tank Pressure_________ / Thermal / Gloves**
	10. Retrieve next SPLC and repeat steps 2-6	9. Repeat until SPLCs are transferred
	When all SPLCs have been transferred:	10. **√Tank Pressure_________ / Thermal / Gloves**
	11. Descend ladder and translate to Airlock	
	At Airlock:	
	12. Perform self-dust operations	
	13. Ingress Airlock	
	14. Assist with SPLC stacking as required	
	15. Close simulated hatch	
	16. **√Tank Pressure_________ / Thermal / Gloves**	

B.8 – Airlock Ingress Choreography with 1.0 & 2.0 SPLCs

IV/SSRMS	EV1	EV2
Scenario 9  	AIRLOCK CHOREOGRAPHY (INGRESS) **√Tank Pressure_________ / Thermal / Gloves** 1. Ingress Airlock 2. Attach suit umbilical 3. Start repress of Airlock 4. Reorganize SPLCs into center of airlock 5. **√Tank Pressure_________ / Thermal / Gloves** 6. Attach to donning stand 7. Doff suit 8. Reorganize logistic carriers for EV2 access to donning stand 9. Assist EV2 in doffing suit 10. Reorganize SPLCs to clear path to Hab hatch 11. **√Tank Pressure_________ / Thermal / Gloves**	AIRLOCK CHOREOGRAPHY (INGRESS) **√Tank Pressure_________ / Thermal / Gloves** 1. Ingress Airlock 2. Remove and stow hatch seal protection 3. Close hatch 4. Attach suit umbilical 5. Reorganize SPLCs to center of airlock for EV1 access to donning stand 6. **√Tank Pressure_________ / Thermal / Gloves** 7. Assist EV1 in doffing suit 8. Reorganize SPLCs for EV2 access to donning stand 9. Attach to donning stand 10. Doff suit 11. Reorganize SPLCs to clear path to Hab 12. **√Tank Pressure_________ / Thermal / Gloves**

B.9 – Airlock Egress Choreography with 2.0 SPLCs

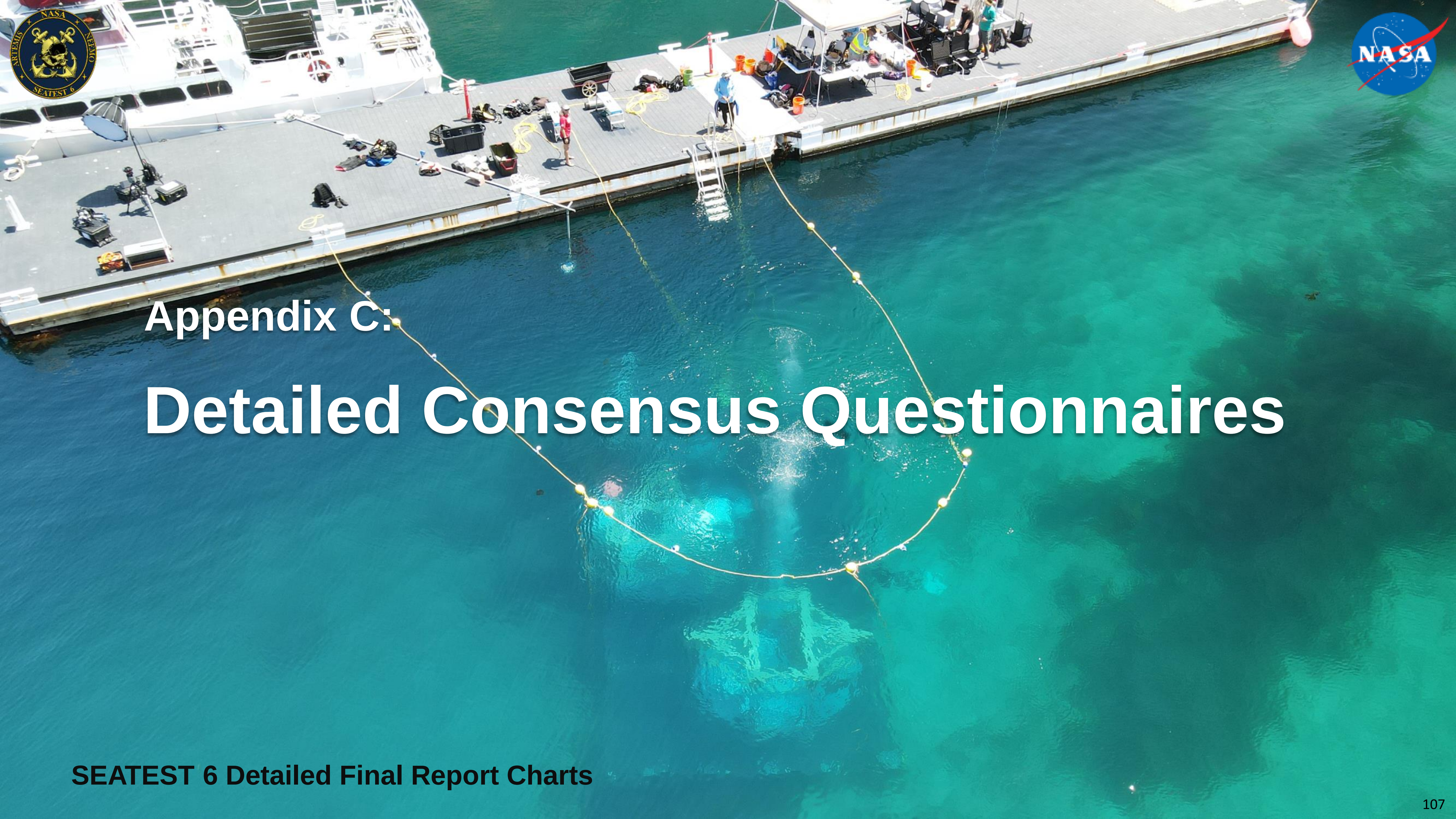
IV/SSRMS	EV1	EV2
Scenario 10	<u>AIRLOCK CHOREOGRAPHY (EGRESS)</u>	<u>AIRLOCK CHOREOGRAPHY IN REVERSE (EGRESS)</u>
 	**√Tank Pressure_________ / Thermal / Gloves** 1. Ingress Airlock (from Hab) 2. Unstow hatch seal protection and temp stow 3. Don suit 4. Attach umbilical 5. Egress donning stand 6. **√Tank Pressure_________ / Thermal / Gloves** 7. Reorganize SPLCs for EV2 access to donning stand 8. Assist EV2 in suit donning 9. Reorganize SPLCs to clear path to Airlock hatch Depress Airlock After depress complete: 10. Detach from umbilical 11. Open Airlock hatch 12. Egress Airlock 13. **√Tank Pressure_________ / Thermal / Gloves**	**√Tank Pressure_________ / Thermal / Gloves** 1. Ingress Airlock (from Hab) 2. Close Hab hatch 3. Assist EV1 in suit donning 4. **√Tank Pressure_________ / Thermal / Gloves** 5. Assist EV1 to reorganize SPLCs for EV2 access to donning stand 6. Don suit 7. Attach umbilical 8. Egress donning stand Depress Airlock After depress complete: 9. Retrieve hatch seal protection from temp stow location and install on Airlock hatch seal 10. Egress Airlock 11. **√Tank Pressure_________ / Thermal / Gloves**

B.11 – MPLC Transfer/Dock

IV/SSRMS	EV1	EV2
Scenario 1  	<u>TRANSFER MPLC FROM LANDER TO LOGISTICS PORT</u> **√Tank Pressure_________ / Thermal / Gloves** 1. Climb ladder and translate to MPLC worksite 2. Attach davit hook to **top portion** of MPLC lifting hoop 3. Crank davit line until taut (hook should rise to top of MPLC hoop) 4. Release launch locks (3) • Check launch bars are pulled away from MPLC 5. Lift MPLC via davit hand crank until clear from MPLC carrier 6. Rotate davit to move MPLC clear of lander deck 7. **On EV2 GO**, lower MPLC to EV2's discretion 8. **√Tank Pressure_________ / Thermal / Gloves** 9. **On EV2 GO**, release tension in davit line 10. Once EV2 has released davit hook, crank handle to reel hook back to davit 11. Safe davit 12. **√Tank Pressure_________ / Thermal / Gloves**	<u>TRANSFER MPLC FROM LANDER TO LOGISTICS PORT</u> **√Tank Pressure_________ / Thermal / Gloves** 1. Translate to Logistics Transfer Port aft deck 2. Dust logistics transfer port 3. Unstow aft deck hook 4. When personnel are clear of MPLC lowering corridor, **give EV1 GO** to lower MPLC. 5. **Give EV1 GO** to stop lowering MPLC when at desired height 6. Retrieve aft deck hook and attach to MPLC lifting hoop 7. Pull fall line until: • Centered under haul system • Line is taut • Clear of aft deck floor 8. Once MPLC load is transferred, **give EV1 GO** to release tension in davit line 9. Release EV1's davit hook 10. Raise MPLC to hard stop 11. Slide/push MPLC to port berthing position 12. Soft dock MPLC (magnets) Note: do **not** release aft deck hook 13. **√Tank Pressure_________ / Thermal / Gloves**

B.11 – MPLC Transfer/Dock (cont.)

IV/SSRMS	EV1	EV2
	TRANSFER MPLC FROM LOGISTICS PORT TO LANDER 13. Lower davit hook 14. **On EV2 GO**, tension davit line to transfer load 15. **On EV2 GO**, raise MPLC 16. Once MPLC is above MPLC cradle, rotate davit to reposition MPLC over cradle 17. Lower MPLC onto cradle and release tension in line (not fully) 18. Engage MPLC launch locks 19. Release davit hook; release remaining tension in davit line as required 20. Stow hook on davit and safe davit 21. **√Tank Pressure__________ / Thermal / Gloves**	TRANSFER MPLC FROM LOGISTICS PORT TO LANDER 14. Release MPLC from soft dock and slide to end of aft deck rail 15. Lower MPLC until davit hook can be attached (diver assist to release tension in fall line) 16. Attach davit hook to MPLC lifting hoop 17. **Give EV1 GO** to tension davit line 18. Release tension in haul system (diver assist) and remove aft deck hook 19. **Give EV1 GO** to raise MPLC; tend clear of any structure 20. When MPLC is clear, stow aft deck hook and lines 21. **√Tank Pressure__________ / Thermal / Gloves**



Appendix C:

Detailed Consensus Questionnaires

SEATEST 6 Detailed Final Report Charts

C.1 – Simulation Quality

Table 1D. *Crew Simulation Quality Questions*

Rate the simulation quality of the following elements:	
Q1	The environment as compared to expected lunar environment (1/6 g effects, mass management, offloading concept fidelity, etc.)
Q2	The environment's ability to p[provoke relevant operational considerations (dusting requirements, suit maneuverability, mechanism and system fidelity, etc.)
Q3	Additional comments are appreciated

C.2 – Capability

Table 1C. *Crew Capability for Transfer Operations*

Capability Questionnaire for Transfer Operations	
Provide a capability assessment rating and comments for the following transfer operation methods:	
Q1	The davit offloading concept
Q2	The zipline offloading concept
Q3	Additional comments are appreciated

C.3 – Acceptability

Table 1B. *Crew Questions for Davit*

Transfer Ops Using Davit	
Rate the overall acceptability of the following transfer operation elements:	
Q1	Using the Davit for transfer operations (reach, attachments, loading/unloading containers, davit handle, crank, hook, etc.)
Q2	The lander deck for transfer operations (deck volume, lander height, etc.)
Q3	The conceptual 1.0/2.0 SPLC container for use- with a davit (handrails, size, shape, connection points, etc.)
Q4	Size of Staging area
Q5	The number of crew for this transfer method
Q6	The conceptual dust migration procedures
Q7	The cargo packing (i.e., layout of SPLCs) on the lander deck for transfer operations
Q8	Overall acceptability of using this transfer method from end-to-end (including risk to crew) for 1.0 SPLCs
Q9	Additional comments

Table 2B. *Crew Questions for Reverse Davit (Reload)*

Transfer Ops Using A Davit for Reload	
Rate the overall acceptability of the following transfer operation elements:	
Q1	Using the Davit for transfer operations (reach, attachments, loading/unloading containers, davit handle, crank, hook, etc.)
Q2	The lander deck for transfer operations (deck volume, lander height, etc.)
Q3	The conceptual large SPLC container for use with a davit (handrails, size, shape, connection points, etc.,)
Q4	Transfer of SPLCs from A/L to staging area (below davit)
Q5	Size of Staging area (below the davit)
Q6	The number of crew for this transfer method
Q7	The cargo packing (i.e., layout of SPLCs) on the lander deck for transfer operations
Q8	Overall acceptability of using this transfer method from end-to-end (including risk to crew) for 2.0 SPLCs
Q9	Additional comments

C.3 – Acceptability (cont.)

Table 3B. *Crew Questions for Zipline and Staging Area*

Transfer Ops Using A Zipline and Staging Area	
Rate the overall acceptability of the following transfer operation elements:	
Q1	Using the zipline for transfer operation (reach, attachments, loading/unloading containers, quick draw, control line, pulley, zipline post, etc.)
Q2	The lander deck for transfer operations (deck volume, lander height, etc.)
Q3	The conceptual small SPLC container for use with a zipline (handrails, size, shape, connection points, etc.)
Q4	Size of Staging area
Q5	The number of crew for this transfer method
Q6	The conceptual dust migration procedures
Q7	The cargo packing (i.e., layout of SPLCs) on the lander deck for transfer operations
Q8	Overall acceptability of using this transfer method from end-to-end (including risk to crew) for 1.0 SPLCs
Q9	Additional comments

Table 4B. *Crew Questions for Zipline and Airlock*

Transfer Ops Using A Zipline and Airlock	
Rate the overall acceptability of the following transfer operation elements:	
Q1	Using the zipline for transfer operation (reach, attachments, loading/unloading containers, quick draw, control line, pulley, zipline post, etc.)
Q2	The lander deck for transfer operations (deck volume, lander height, etc.)
Q3	The conceptual 1.0/2.0 SPLC container for use with a zipline (handrails, size, shape, connection points, etc.)
Q4	The number of crew for this transfer method
Q5	Transfer of 1.0/2.0 SPLCs through the Airlock hatch (hatch opening, Airlock volume, disconnecting container, stacking containers, "dings" to hatch seals, etc.)
Q6	The conceptual dust migration procedures
Q7	The cargo packing (i.e., layout of SPLCs) on the lander deck for transfer operations
Q8	Overall acceptability of using this transfer method from end-to-end (including risk to crew) for 1.0 SPLCs
Q19	Additional comments

C.3 – Acceptability (cont.)

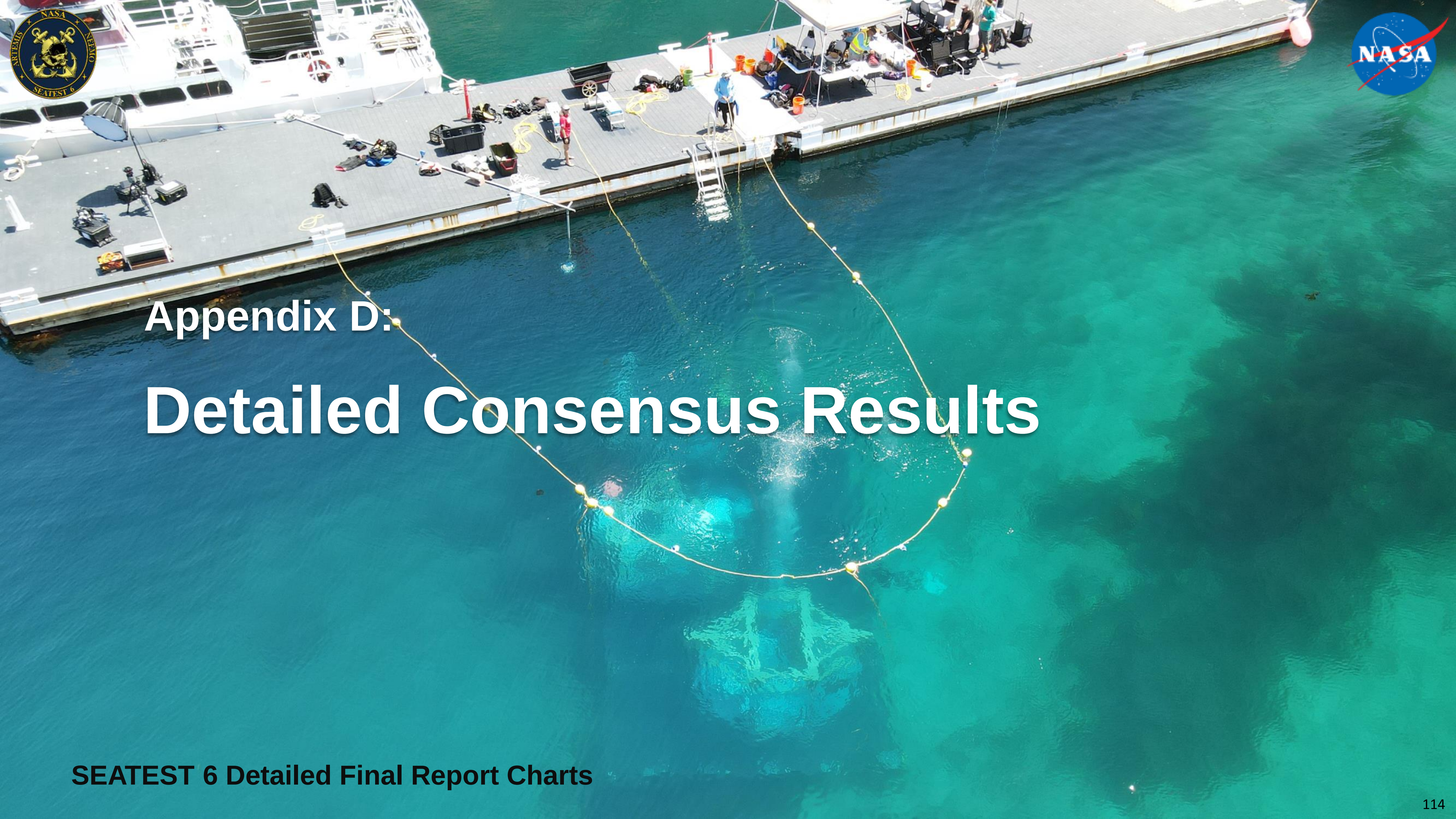
Table 5B. *Crew Questions for Airlock Ops*

Airlock Transfer Ops	
Rate the overall acceptability of the following transfer operation elements:	
Q1	Stacking the containers
Q2	Airlock container reconfiguration within the given airlock volume
Q3	Suit don/doff in the given airlock volume
Q4	Overall acceptability of using this transfer method from end-to-end (including risk to crew)
Q5	Additional comments

C.4 – Debrief

Table 1E. *Crew Debrief Questionnaire*

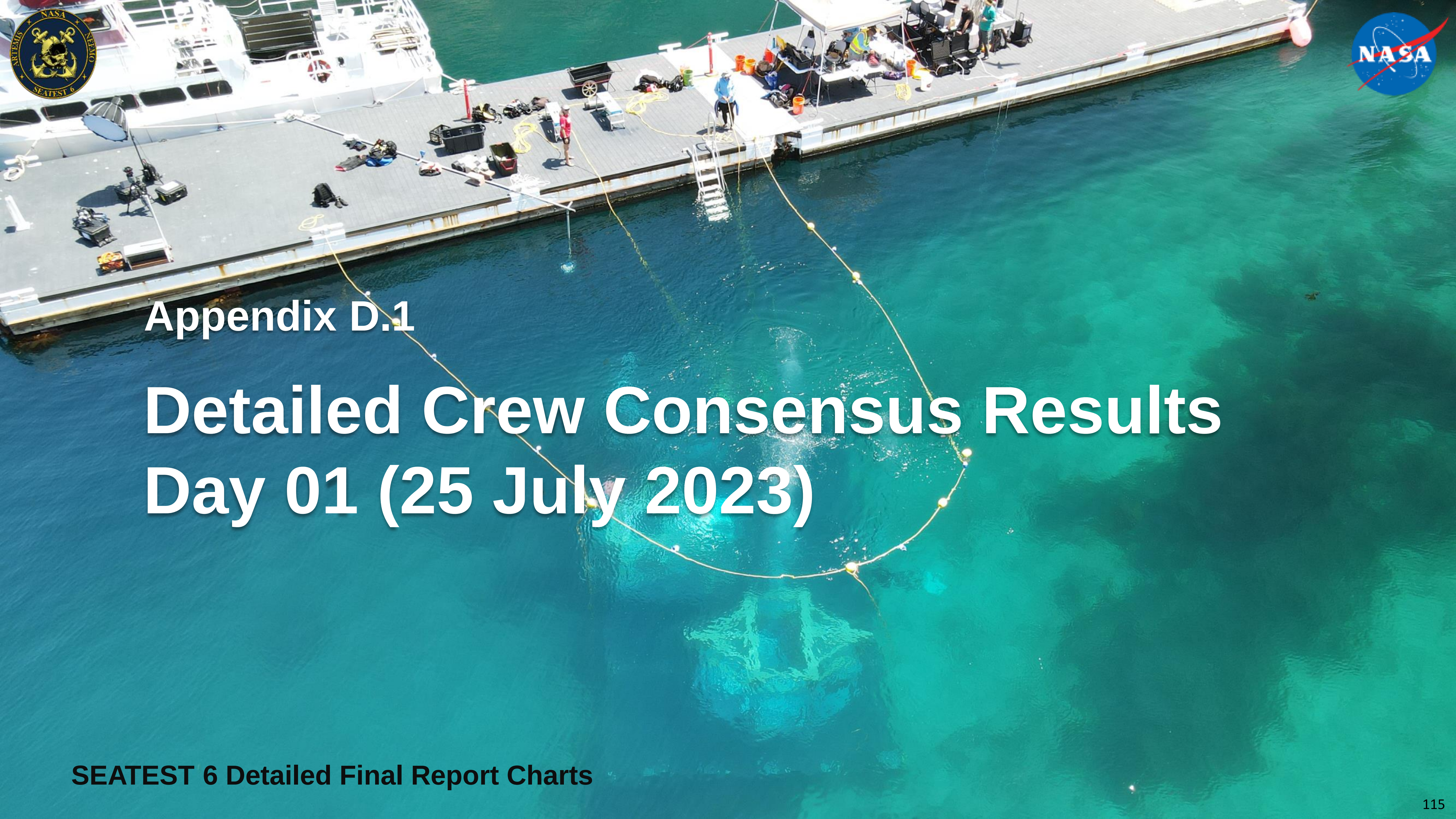
Crew Debrief Questionnaire	
Q1	Any other general thoughts on cargo logistics lander configurations (e.g., how logistics are packaged on a lander for offloading) and capabilities (e.g., specs for ladders, davits, winches, etc.)? E.g., can you envision lander details that are extremely prohibitive vs. extremely mission enhancing, etc.?
Q2	Any other general thoughts on dust mitigation strategies for logistic transfer ops?
Q3	What are your thoughts on the current logistics manifest for a 14-day rover mission for a crew of 2 (i.e., all 15 of the 1.0 SPLCs + 8 of the 2.0 SPLCs)? How do you propose we think about logistics for ~7 to 30-day surface mission (e.g., in pressurized rover and/or surface habitat)? What are your recommendations for determining (e.g., through analysis, testing + eval, etc.) what quantity of logistics is appropriate for these missions?
Q4	What are your concerns and recommendations w.r.t. our ability to simulate the lunar surface environment and Artemis mission operations in these SEATEST analog tests?
Q5	Any other feedback (e.g., for logistic handling)



Appendix D:

Detailed Consensus Results

SEATEST 6 Detailed Final Report Charts



Appendix D.1

Detailed Crew Consensus Results Day 01 (25 July 2023)

SEATEST 6 Detailed Final Report Charts

Day 01 Simulation Quality

SIMULATION QUALITY SCALE				
1	2	3	4	5
Simulation quality (e.g. hardware, software, procedures, comm., environment) presented either zero problems or only minor ones that had no impact to the validity of test data	Some simulation limitations or anomalies encountered, but minimal impact to the validity of test	Simulation limitations or anomalies made test data marginally adequate to provide meaningful evaluation of test objectives (please describe)	Significant simulation limitations or anomalies precluded meaningful evaluation of major test objectives (please describe)	Major simulation limitations or anomalies precluded meaningful evaluation of all test objectives (please describe)

- **Q1. The environment as compared to expected lunar environment (1/6g effects, mass management, offloading concept fidelity, etc.)**
- **Rating = 3**
- **Comments:**
  - The slack in the zipline required a substantial change to the method the crew member used to complete the scenario (one hand always tightening the slack on the zipline, meaning the control line is operated with one hand only).
  - Current management requires too much dexterity/tending (do we really want the cleat?).
  - Control line needs to be longer when the zip line is tethered at the forward side of the airlock (near the IV hatch) [approximately 10 feet more]
  - Recommend developing a way to simulate slack management in the zipline control line.

- **Q2. The environment's ability to provoke relevant operational considerations (dusting requirements, suit maneuverability, mechanism and system fidelity, etc.)**
- **Rating = 3**
- **Comments:**
  - Comm would be substantially different on a lunar mission (delay, call frequency, crew-to-crew calls).
  - Limited simulation of the volume of the suit beyond the PLSS. Water resistance allowed crewmembers to complete tasks unrealistically (and added comfort to operations on the lunar lander platform).
  - Limited fidelity of the airlock allowed for SLPCs to stick out open gaps in the mockup.
  - Range of motion limitations are not well simulated, which would be especially limiting during dusting operations.

Scenario 01 – 1.0 DAVIT (Acceptability)

Totally Acceptable		Acceptable		Borderline		Unacceptable		Totally Unacceptable	
No improvements necessary and/or No deficiencies		Minor improvements desired and/or Minor deficiencies		Improvements warranted and/or Moderate deficiencies		Improvements required and/or Unacceptable deficiencies		Major improvements required and/or Totally unacceptable deficiencies	
1	2	3	4	5	6	7	8	9	10

- **Q1. Using the Davit for transfer operations (reach, attachments, loading/unloading containers, davit handle, crank, hook, etc.):**
- **Rating = 7**
- **Comments:**
  - Davit crank operation required too much motion to be acceptable for the suit. Suggest this as a manual back up system (contingency only).
  - Crew member adjusted the crank length to allow for reasonable speed and torque. In doing so, back end of the crank handle extended toward the crewmember, creating a potential visor contact risk, requiring them to stand on the perpendicular side of the davit to the crank itself.
  - Electric motor for prime system would be ideal.
  - Although the task did not require it, additional recommendations include:
    - Pitch adjustments for the arm of the davit to maximize flexibility.
    - Change the hook design to enable multiple SPLCs.
    - Addition of clutch for efficient lowering.
    - Ratchet mechanism to prevent inadvertent movement in opposite direction.
    - Consider pedal/foot operated system to allow for hand free operation.

- **Q2. The lander deck for transfer operations (deck volume, lander height, etc.):**
- **Rating = 5**
- **Comments:**
  - Height of the lander is reasonable, but a safety mechanism needs to be in place (railing, tether, etc.).
  - Consider placement of the davit mount in proximity to zipline and edge of the lander to optimize for usability.
  - Flush davit mount would increase safety when davit is not installed. If safety (including fall and trip hazard) was not considered, rating would be 3.

- **Q3. The conceptual small SPLC container for use with a davit (handrails, size, shape, connection points, etc.):**
- **Rating = 4**
- **Comments:**
  - Crew member felt comfortable handling 1.0 SLPC and utilized the handle to stack SLPCs effectively.
  - Soft handles helpful for providing additional tether points allowing for various orientations during lowering.
  - Handles could be collapsible or all soft good handles if hard handle is not required for reorientation.
  - If volumetric trade is not too prohibitive, a change in shape would allow for better stacking.
  - Consider a mechanism which would allow SPLCs to interface with one another to facilitate stacking (base of SPLC fits the handle of the top of the SPLC so they fit together).
  - Attachment point for davit could center on the CG.

Scenario 01 – 1.0 DAVIT (Acceptability) cont.

Totally Acceptable		Acceptable		Borderline		Unacceptable		Totally Unacceptable	
No improvements necessary and/or No deficiencies		Minor improvements desired and/or Minor deficiencies		Improvements warranted and/or Moderate deficiencies		Improvements required and/or Unacceptable deficiencies		Major improvements required and/or Totally unacceptable deficiencies	
1	2	3	4	5	6	7	8	9	10

- **Q4. Size of staging area:**
- **Rating = 3**
- **Comments:**
  - Staging area should be sized to accommodate 15 stacked SPLCs (number could vary with operation).
  - Crew designated staging area to the port side of the A/L EV hatch.
  - Stacking strategies:
    - In staging area, stacking the SPLCs three high and two deep (pyramid configuration) worked well.
    - SPLCs could be stacked on their sides like a pile of logs if some side restraints were built in the staging area.
  - Stacked SPLCs require minimal dusting; however, crew height needs to be a consideration

- **Q5. The number of crew for this transfer method:**
- **Rating = 2**
- **Comments:**
  - Airlock volume is a limitation to number of crew.
  - For the as tested distance (16 feet) between the lander and the airlock/staging area is sufficient for two crew.
    - By the time one crewmember dropped off an SLPC at the airlock, the crew member on the lander had loaded another SLPC on the davit and was prepared to lower it.
  - If the two are further apart, an additional crew member on the lunar surface would improve the efficiency of the operation.

- **Q6. The conceptual dust migration procedures:**
- **Rating = 5**
- **Comments:**
  - In the suit, wrist mobility is limited so operations may be limited to one direction (as opposed to a "paintbrush" technique).
  - There needs to be a procedure for dusting, including order (top to bottom) and crew member movements.
  - A long handle brush would be helpful, along with handrails for single-footed stability during dusting.
  - Without a staging area, stacking SPLCs is preferred as stacking minimizes dusting.

- **Q7. The cargo packing (i.e., layout of SPLCs) on the lander deck for transfer operations**
- **Rating = 4**
- **Comments:**
  - Stacking is helpful on the lander platform and on the lunar surface during transfer.
  - Stacking minimizes crew member bending in the suit and improves dust mitigation.
  - Stacking also limits the need to travel on the lunar lander platform to retrieve SPLCs.
  - Ensuring the SLPCs interface with one another would minimize the potential for them to tumble.

Scenario 01 – 1.0 DAVIT (Acceptability) cont.

Totally Acceptable		Acceptable		Borderline		Unacceptable		Totally Unacceptable	
No improvements necessary and/or No deficiencies		Minor improvements desired and/or Minor deficiencies		Improvements warranted and/or Moderate deficiencies		Improvements required and/or Unacceptable deficiencies		Major improvements required and/or Totally unacceptable deficiencies	
1	2	3	4	5	6	7	8	9	10

- **Q8. Overall acceptability of using this transfer method from end-to-end (including risk to crew) for 1.0 SPLCs**
- **Rating = 6**
- **Comments:**
    - Low risk to crew member on the lunar surface as long as stacking is deliberate.
    - Some phases are acceptable, but the design of the davit used for this operation is not reasonable for a suited subject.
    - A more well-developed motorized davit would make this operational more acceptable.
    - If the davit and dust mitigation procedures were improved, acceptability would improve to a 3-4.

Scenario 02 – 1.0 ZIPLINE AIRLOCK (Acceptability)

Totally Acceptable		Acceptable		Borderline		Unacceptable		Totally Unacceptable	
No improvements necessary and/or No deficiencies		Minor improvements desired and/or Minor deficiencies		Improvements warranted and/or Moderate deficiencies		Improvements required and/or Unacceptable deficiencies		Major improvements required and/or Totally unacceptable deficiencies	
1	2	3	4	5	6	7	8	9	10

- **Q1. Using the zipline for transfer operation (reach, attachments, loading/unloading containers, quick draw, control line, pulley, zipline post, etc.)**
- **Rating = 5**
- **Comments:**
    - Loading and unloading was straight forward.
    - Zipline
        - Rope was slack which made this operation inefficient. A realistic zipline would be a taught wire.
        - To mitigate issue, crew had to hold one hand above their head to tighten the line, which is not reasonable considering suit mobility.
        - Control line needs to be longer with a slack management system (retractable or tended).
        - A brake mechanism for the control line would be ideal (magnetic or mechanical).
        - Improvement to the quick draw to facilitate loading would be beneficial, i.e., a retractable portion of the attachment.
    - The zipline attachment point and post
        - Were too close to the edge of the lunar lander platform.
        - Should be within the work envelope for most crew members, but should still allow for multiple container sizes, if possible.
        - Hook attachment should be changed to allow for multiple SPLCs on one zipline run.
        - SPLCs were loaded with the attachment to the soft good handle to allow the receiving crew member to grab the hard handle upon receiving the SPLC.
        - Crew member did not use the cleat to tie off the line when they had to retrieve SPLCs far from the zipline post (they held the control line in their hand).
    - Zipline in Airlock
        - The tie off (receiving end) of the zipline could be inside the A/L or outside the A/L without any difference to the position of the receiving crew member.
        - If zipline was tethered inside the airlock, receiving crew member retrieved the SPLC outside the hatch to prevent inadvertent contact with the hatch seals.
        - Enabled better control for the orientation for stacking in the airlock and minimized re-grips during that process.
        - For both the zipline airlock and zipline staging area, the receiving crew member can stand inside the airlock to enable stacking and minimize dusting.
        - To add extra stability for the receiving crew member both for SPLC retrieval and dusting, an internal handrail should be added near the EV hatch

Scenario 02 – 1.0 ZIPLINE AIRLOCK (Acceptability) cont.

Totally Acceptable		Acceptable		Borderline		Unacceptable		Totally Unacceptable	
No improvements necessary and/or No deficiencies		Minor improvements desired and/or Minor deficiencies		Improvements warranted and/or Moderate deficiencies		Improvements required and/or Unacceptable deficiencies		Major improvements required and/or Totally unacceptable deficiencies	
1	2	3	4	5	6	7	8	9	10

- **Q2. The lander deck for transfer operations (deck volume, lander height, etc.)**
- **Rating = 25**
- **Comments:**
  - Height of the lander is reasonable, but a safety mechanism needs to be in place (railing, tether, etc.).
  - Consider placement of the zipline mount in proximity to zipline and edge of the lander to optimize for usability.
  - Flush zipline mount would increase safety when davit is not installed. If safety (including fall and trip hazard) was not considered, rating would be 3.

- **Q3. The conceptual small SPLC container for use with a zipline (handrails, size, shape, connection points, etc.)**
- **Rating = 4**
- **Comments:**
  - Soft good handles were used with zip line hooks while handrail was used for controllability entering airlock.

- **Q4. The number of crew for this transfer method**
- **Rating = 2**
- **Comments:**
  - Unlike the DAVIT 1.0 the further away the HAB is from the logistics lander is less impact due to less walking.

- **Q5. Transfer of 1.0 SPLCs through the Airlock hatch (hatch opening, Airlock volume, disconnecting container, stacking containers, "dings" to hatch seals, etc.)**
- **Rating = 6**
- **Comments**
  - Crewmember inside airlock at the EV hatch and disconnected the container outside the hatch to protect the hatch seals and maintained a clean dust free environment for both crew and container.
  - Containers were reoriented into final configuration later to allow focus on clearing area to prep for next container.
  - Containers were staked in clean config for both crew ingress. handrail aided in control through airlock, addition recommended.
  - Mockup setup potentially limited container from smooth passage into airlock and required either detachment outside airlock or crew aid to pull into airlock.

Scenario 02 – 1.0 ZIPLINE AIRLOCK (Acceptability) cont.

Totally Acceptable		Acceptable		Borderline		Unacceptable		Totally Unacceptable	
No improvements necessary and/or No deficiencies		Minor improvements desired and/or Minor deficiencies		Improvements warranted and/or Moderate deficiencies		Improvements required and/or Unacceptable deficiencies		Major improvements required and/or Totally unacceptable deficiencies	
1	2	3	4	5	6	7	8	9	10

- **Q6. The conceptual dust migration procedures**
- **Rating = 5**
- **Comments**
    - Task didn't require container dust mitigation with this method.

- **Q7. The cargo packing (i.e., layout of SPLCs) on the lander deck for transfer operations**
- **Rating = 5**
- **Comments:**
    - Pre-staged with integrated line to handles for easy interface to connect to line (i.e., like a running clothesline).
    - "A dry cleaner feeder capability" instead of one at a time.

- **Q8. Overall acceptability of using this transfer method from end-to-end (including risk to crew) for 1.0 SPLCs**
- **Rating = 5**
- **Comments**
    - More acceptable than Davit but still needs improvement

Scenario 03 – 1.0 ZIPLINE STAGING AREA (Acceptability)

Totally Acceptable		Acceptable		Borderline		Unacceptable		Totally Unacceptable	
No improvements necessary and/or No deficiencies		Minor improvements desired and/or Minor deficiencies		Improvements warranted and/or Moderate deficiencies		Improvements required and/or Unacceptable deficiencies		Major improvements required and/or Totally unacceptable deficiencies	
1	2	3	4	5	6	7	8	9	10

- **Q1. Using the zipline for transfer operation (reach, attachments, loading/unloading containers, quick draw, control line, pulley, zipline post, etc.)**
- **Rating = 5**
- **Comments:**
  - Loading and unloading was straight forward.
  - Zipline
    - Rope was slack which made this operation inefficient. A realistic zipline would be a taught wire.
    - To mitigate issue, crew had to hold one hand above their head to tighten the line, which is not reasonable considering suit mobility.
    - Control line needs to be longer with a slack management system (retractable or tended).
    - A brake mechanism for the control line would be ideal (magnetic or mechanical).
    - Improvement to the quick draw to facilitate loading would be beneficial, i.e., a retractable portion of the attachment.
  - The zipline attachment point and post
    - Were too close to the edge of the lunar lander platform.
    - Should be within the work envelope for most crew members, but should still allow for multiple container sizes, if possible.
    - Hook attachment should be changed to allow for multiple SPLCs on one zipline run.
    - SPLCs were loaded with the attachment to the soft good handle to allow the receiving crew member to grab the hard handle upon receiving the SPLC.
    - Crew member did not use the cleat to tie off the line when they had to retrieve SPLCs far from the zipline post (they held the control line in their hand).
  - Zipline in Airlock
    - The tie off (receiving end) of the zipline could be inside the A/L or outside the A/L without any difference to the position of the receiving crew member.
    - If zipline was tethered inside the airlock, receiving crew member retrieved the SPLC outside the hatch to prevent inadvertent contact with the hatch seals.
    - Enabled better control for the orientation for stacking in the airlock and minimized re-grips during that process.
    - For both the zipline airlock and zipline staging area, the receiving crew member can stand inside the airlock to enable stacking and minimize dusting.
    - To add extra stability for the receiving crew member both for SPLC retrieval and dusting, an internal handrail should be added near the EV hatch

Scenario 03 – 1.0 ZIPLINE STAGING AREA (Acceptability) cont.

Totally Acceptable		Acceptable		Borderline		Unacceptable		Totally Unacceptable	
No improvements necessary and/or No deficiencies		Minor improvements desired and/or Minor deficiencies		Improvements warranted and/or Moderate deficiencies		Improvements required and/or Unacceptable deficiencies		Major improvements required and/or Totally unacceptable deficiencies	
1	2	3	4	5	6	7	8	9	10

- **Q2. The lander deck for transfer operations (deck volume, lander height, etc.)**
- **Rating = 5**
- **Comments:**
  - Height of the lander is reasonable, but a safety mechanism needs to be in place (railing, tether, etc.).
  - Consider placement of the davit mount in proximity to zipline and edge of the lander to optimize for usability.
  - Flush davit mount would increase safety when davit is not installed.
  - If safety (including fall and trip hazard) was not considered, rating would be 3.

- **Q3. The conceptual small SPLC container for use with a zipline (handrails, size, shape, connection points, etc.)**
- **Rating = 4**
- **Comments:**
  - Soft handles were used for controllability entering airlock.

- **Q4. Size of staging area**
- **Rating = 3**
- **Comments:**
  - Crew designated area to the port side of the A/L EV hatch.
  - In this staging area, stacking the SPLCs three high and two deep (pyramid configuration) worked well.
  - Crew member height is a consideration.
  - Stacked SPLCs require minimal dusting.
  - Should be sized to accommodate 15 stacked SPLCs (number could vary with operation).
  - SPLCs could be stacked on their sides like a pile of logs if some side restraints were built in the staging area.

- **Q5. The number of crew for this transfer method**
- **Rating = 2**
- **Comments:**
  - Unlike the DAVIT 1.0 the further away the HAB is from the logistics lander is less impact due to less walking.

Scenario 03 – 1.0 ZIPLINE STAGING AREA (Acceptability) cont.

Totally Acceptable		Acceptable		Borderline		Unacceptable		Totally Unacceptable	
No improvements necessary and/or No deficiencies		Minor improvements desired and/or Minor deficiencies		Improvements warranted and/or Moderate deficiencies		Improvements required and/or Unacceptable deficiencies		Major improvements required and/or Totally unacceptable deficiencies	
1	2	3	4	5	6	7	8	9	10

- **Q6. The conceptual dust migration procedures**
- **Rating = 5**
- **Comments:**
  - In the suit, wrist mobility is limited so operations may be limited to one direction (as opposed to a "paintbrush" technique).
  - There needs to be a procedure for dusting, including order (top to bottom) and crew member movements.
  - A long handle brush would be helpful, along with handrails for single-footed stability during dusting.
  - Without a staging area, stacking SPLCs is preferred as stacking minimizes dusting.
- **Q7. The cargo packing (i.e., layout of SPLCs) on the lander deck for transfer operations**
- **Rating = 5**
- **Comments:**
  - Stacking is helpful on the lander platform and on the lunar surface during transfer.
  - Stacking minimizes crew member bending in the suit and improves dust mitigation.
  - Stacking also limits the need to travel on the lunar lander platform to retrieve SPLCs.
  - Ensuring the SLPCs interface with one another would minimize the potential for them to tumble.
  - Plus, pre-staged with integrated line to handles for easy interface to connect to line (i.e., like a running clothesline).
  - "A dry cleaner feeder capability" instead of one at a time.

- **Q8. Overall acceptability of using this transfer method from end-to-end (including risk to crew) for 1.0 SPLCs**
- **Rating = 5**
- **Comments:**
  - More acceptable than Davit but still needs improvement

Scenario 04 – 1.0 AIRLOCK TRANSFER OPS (Acceptability)

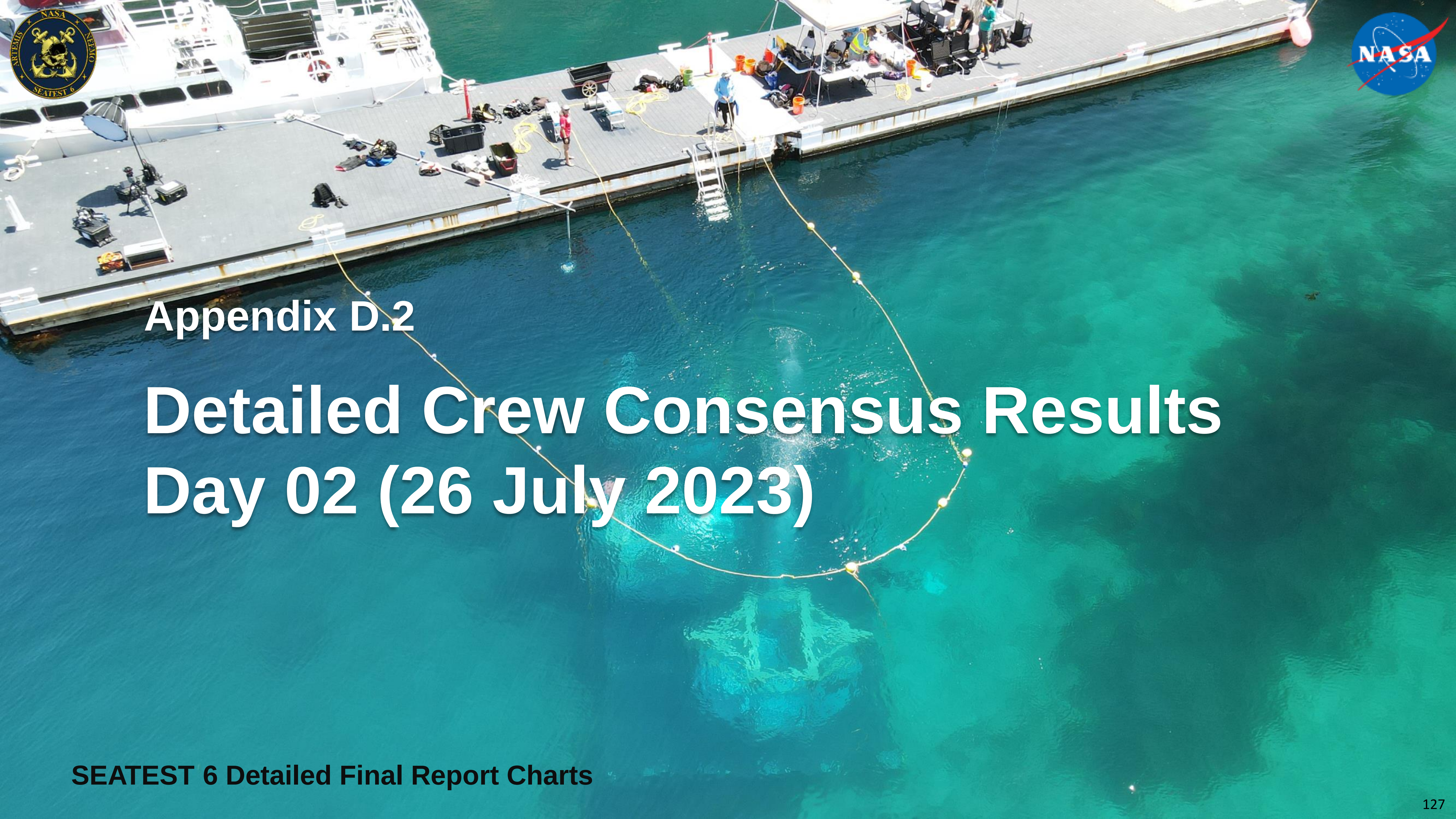
Totally Acceptable		Acceptable		Borderline		Unacceptable		Totally Unacceptable	
No improvements necessary and/or No deficiencies		Minor improvements desired and/or Minor deficiencies		Improvements warranted and/or Moderate deficiencies		Improvements required and/or Unacceptable deficiencies		Major improvements required and/or Totally unacceptable deficiencies	
1	2	3	4	5	6	7	8	9	10

- **Q1. Stacking the containers**
- **Rating = 4**
- **Comments:**
    - See comments from previous scenarios.
    - Summary:
        - 1) add "Lego type" capability to help stabilize stacking.
        - 2) potential handrail notch or retract handrail for easier stacking
        - 3) stacking like logs in airlock wont work unless have brackets to hold not rolling.
        - 4) could stack two vertical one horizontal
        - 5) can stack three high
        - 6) second row was in easy work envelope of 6) due to small space need capability to secure stack

- **Q2. Airlock container reconfiguration within the given airlock volume**
- **Rating = 3**
- **Comments:**
    - Stacking in airlock was centered between two crew don/doff stands with enough space to walk one way around to access other crew.
    - Stacked center/stbd.
    - Half of the containers needed to be moved around to access other side. 15 1.0 in airlock in this scenario

- **Q3. Suit don/doff in the given airlock volume**
- **Rating = 2**
- **Comments:**
    - Given airlock volume suit don doff volume was reasonable

- **Q4. Consensus Acceptability Ratings + Comments**
- **Overall acceptability of using this transfer method from end-to-end (including risk to crew)**
- **Rating = 3**
- **Comments:**
    - No comments



Appendix D.2

Detailed Crew Consensus Results Day 02 (26 July 2023)

SEATEST 6 Detailed Final Report Charts

Day 02 Simulation Quality

SIMULATION QUALITY SCALE				
1	2	3	4	5
Simulation quality (e.g. hardware, software, procedures, comm., environment) presented either zero problems or only minor ones that had no impact to the validity of test data	Some simulation limitations or anomalies encountered, but minimal impact to the validity of test	Simulation limitations or anomalies made test data marginally adequate to provide meaningful evaluation of test objectives (please describe)	Significant simulation limitations or anomalies precluded meaningful evaluation of major test objectives (please describe)	Major simulation limitations or anomalies precluded meaningful evaluation of all test objectives (please describe)

- **Q1. The environment as compared to expected lunar environment (1/6g effects, mass management, offloading concept fidelity, etc.)**
- **Rating = 3**
- **Comments:**
  - Slack in the zipline allowed the 2.0 SPLC to stay on the zipline directly into the airlock without contacting the hatch seals.
  - Larger containers forced crew members to the edge of the lunar lander platform, which is unrealistic given the additional stability from water resistance.

- **Q2. The environment's ability to provoke relevant operational considerations (dusting requirements, suit maneuverability, mechanism and system fidelity, etc.)**
- **Rating = 2**
- **Comments:**
  - Mechanisms
    - No simulated mechanism to lift 2.0 SPLC to the zipline hook.
  - System Fidelity
    - A/L simulations challenging with majority of hardware missing (SCUs, donning stands, hatches, etc.)
      - » Recommend the addition of umbilical, suit donning procedure, volumetric suit after doffing, dusting procedure
    - A/L height above the ground is low fidelity/unrealistic and can alter some of the test conclusions
  - Suit Maneuverability
    - Mobility of the wetsuit is not comparable to that in the xEMU. Kayak suit, shoulder limiter, 3D printed HUT, hockey gloves, ski boots all recommended additions for space suit simulations.
    - Height and size of the 2.0 SPLCs made it challenging to maneuver between them in the airlock while maintaining awareness of the suit volume around the legs. No simulation mockup of lower half of the suit, so it was more challenging to consider size/volume limitations in that region.

Scenario 05 – 2.0 ZIPLINE AIRLOCK (Acceptability)

Totally Acceptable		Acceptable		Borderline		Unacceptable		Totally Unacceptable	
No improvements necessary and/or No deficiencies		Minor improvements desired and/or Minor deficiencies		Improvements warranted and/or Moderate deficiencies		Improvements required and/or Unacceptable deficiencies		Major improvements required and/or Totally unacceptable deficiencies	
1	2	3	4	5	6	7	8	9	10

- **Q1. Using the zipline for transfer operation (reach, attachments, loading/unloading containers, quick draw, control line, pulley, zipline post, etc.)**
- **Rating = 7**
- **Comments:**
  - Attachment
    - Attachment of the 2.0 SPLCs to the zipline hook was challenging (sim limitation).
    - Bungee or RET system recommended to bring soft goods handle to zipline attachment point.
    - The end point of the zipline inside the airlock should be adjustable zenith/nadir in order to change the angle of the zipline.
      - » Accounts for a varying distance from lander to airlock while still ensuring payloads clear the hatch seal.
  - Mechanisms
    - Locking mechanism could reduce need for a hook swap
    - Longer control line and control line management system (Velcro, magnetic, or mechanical brake) required.
  - Loads and Containers
    - Additional soft tether point/d-ring integrated on a soft goods handle recommended at the center top of the SPLC such that the load may be balanced after attachment.
      - » Minimize reorientation requirements once the SPLC reaches the lunar surface/lander deck.

- **Q2. The lander deck for transfer operations (deck volume, lander height, etc.):**
- **Rating = 5**
- **Comments:**
  - Height of the lander is reasonable, but a safety mechanism needs to be in place (railing, tether, etc.).
  - Consider placement of the davit mount in proximity to zipline and edge of the lander to optimize for usability.
  - Flush davit mount would increase safety when davit is not installed. If safety (including fall and trip hazard) was not considered, rating would be 3.

- **Q3. The conceptual large SPLC container for use with a davit (handrails, size, shape, connection points, etc.):**
- **Rating = 6**
- **Comments:**
  - See question 1 for additional comments on tether point and handrail recommendations.

Scenario 05 – 2.0 ZIPLINE AIRLOCK (Acceptability) cont.

Totally Acceptable		Acceptable		Borderline		Unacceptable		Totally Unacceptable	
No improvements necessary and/or No deficiencies		Minor improvements desired and/or Minor deficiencies		Improvements warranted and/or Moderate deficiencies		Improvements required and/or Unacceptable deficiencies		Major improvements required and/or Totally unacceptable deficiencies	
1	2	3	4	5	6	7	8	9	10

- **Q4. Transfer of 2.0 SPLCs through the Airlock opening. (Airlock volume, disconnecting container, stacking containers, "dings" to hatch seals, etc.):**
- **Rating = 3**
- **Comments:**
  - Very straight forward due to the slack in the zipline (sim issue).
  - Easy to control.
  - No bumps on the hatch seals.
  - Center tether point would have been helpful for unloading, avoiding the need for reorientation by the receiving crew member.

- **Q5. The number of crew for this transfer method:**
- **Rating = 7**
- **Comments:**
  - If two crewmembers are required to lift 2.0 SPLCs, an additional crew member on the lander is required.
  - We believe we could lift/move them with one crewmember.
  - No additional crew required in A/L.

- **Q6. The conceptual dust migration procedures:**
- **Rating = 5**
- **Comments:**
  - Task didn’t require container dust mitigation with this method.
  - In the suit, wrist mobility is limited so operations may be limited to one direction (as opposed to a "paintbrush" technique).
  - There needs to be a procedure for dusting, including order (top to bottom) and crew member movements.
  - A long handle brush would be helpful, along with handrails for single-footed stability during dusting.
  - Without a staging area, stacking SPLCs is preferred as stacking minimizes dusting.

Scenario 05 – 2.0 ZIPLINE AIRLOCK (Acceptability) cont.

Totally Acceptable		Acceptable		Borderline		Unacceptable		Totally Unacceptable	
No improvements necessary and/or No deficiencies		Minor improvements desired and/or Minor deficiencies		Improvements warranted and/or Moderate deficiencies		Improvements required and/or Unacceptable deficiencies		Major improvements required and/or Totally unacceptable deficiencies	
1	2	3	4	5	6	7	8	9	10

- **Q7. The cargo packing (i.e., layout of SPLCs) on the lander deck for transfer operations:**
- **Rating = 5**
- **Comments:**
    - If single crew member is on the lander and two is required to lift 2.0 SPLCs, lifting/lowering device is required.
    - A jack/palette could be involved in packing.

- **Q8. Overall acceptability of using this transfer method from end-to-end (including risk to crew) for 2.0 SPLCs**
- **Rating = 7**
- **Comments:**
    - Handling heavy payloads with a single crew member on the platform leads to additional crew risk. A/L ops risk is minimal.

Scenario 06 – 2.0 REVERSE DAVIT (Acceptability)

Totally Acceptable		Acceptable		Borderline		Unacceptable		Totally Unacceptable	
No improvements necessary and/or No deficiencies		Minor improvements desired and/or Minor deficiencies		Improvements warranted and/or Moderate deficiencies		Improvements required and/or Unacceptable deficiencies		Major improvements required and/or Totally unacceptable deficiencies	
1	2	3	4	5	6	7	8	9	10

- **Q1. Using the Davit for transfer operations (reach, attachments, loading/unloading containers, davit handle, crank, hook, etc.)**
- **Rating = 7**
- **Comments:**
    - Mechanisms
        - Ratchet design helpful as mechanical stop for crew member brakes.
            - » Increasing the crank length was required for the crew member to get additional torque on the handle while raising 2.0 SPLCs.
        - Yawing the davit inboard brought the crewmember very close to the lunar lander edge.
        - The davit needs to be more centered on the lunar lander, or the arm needs to be able to pitch to facilitate these operations and keep the crew member safely away from the platform edge or lunar lander barrier/wall.
        - A telescoping/articulating davit could also alleviate some of these issues. .
    - Loading/Unloading
        - Manually lowering/raising anything with the davit is not a reasonable solution.
        - Heavier 2.0 SPLCs exacerbated issues associated with 1.0 Regardless, motion is not feasible with the limited range of motion in the suit. SPLC davit operations.
        - Raising SPLCs was substantially more challenging than lowering them.
        - Unloading the davit was awkward considering the lack of a centered tether point on the SPLCs.
            - » Work required substantial reorientation.

Scenario 06 – 2.0 REVERSE DAVIT (Acceptability) cont.

Totally Acceptable		Acceptable		Borderline		Unacceptable		Totally Unacceptable	
No improvements necessary and/or No deficiencies		Minor improvements desired and/or Minor deficiencies		Improvements warranted and/or Moderate deficiencies		Improvements required and/or Unacceptable deficiencies		Major improvements required and/or Totally unacceptable deficiencies	
1	2	3	4	5	6	7	8	9	10

- **Q2. The lander deck for transfer operations (deck volume, lander height, etc.)**
- **Rating = 7**
- **Comments:**
  - Lander deck/davit placement and 2.0 geometry brings the crew member substantially closer to the edge of the lunar lander platform.
    - – An unacceptable level of risk.

- **Q3. The conceptual large SPLC container for use with a zipline (handrails, size, shape, connection points, etc.)**
- **Rating = 6**
- **Comments:**
  - We consider a 2.0 SPLC feasible to be lifted by one crew member. Translation may require two crew members.
  - Unloading the davit was awkward considering the lack of a centered tether point on the SPLCs.
    - Work requires substantial reorientation.
  - Yawing the davit inboard brought the crewmember very close to the lunar lander edge.
    - Davit needs to be more centered on the lunar lander, or the arm needs to be able to pitch to facilitate these operators and keep the crew member safely away from the platform edge or lunar lander barrier/wall.
    - A telescoping/articulating davit could also alleviate some of these issues.

- **Q4. Transfer of SPLCs from A/L to staging area (below davit)**
- **Rating = 6**
- **Comments:**
  - Dust generation from dragging the SPLC over the hatch seal protector at the open A/L hatch would be untenable.
  - Some lowering mechanism through the A/L would be helpful. A mechanism for blocking dust (door protector?) could help. Ideally, one crew member would be staged outside the A/L.
    - – Crew member would receive the SPLC from a crew member inside the A/L, then be able to carry the SPLC a few feet away on the lunar surface.

- **Q5. Size of Staging area (below the davit)**
- **Rating = 2**
- **Comments:**
  - Stacking the 2.0 SPLCs on top of each other, using a 4 x 2.0 SPLC area, seemed reasonable.
  - One crew member could stack the SPLCs.
  - Hook is mobile, so attaching the hook to SPLCs throughout the staging area was reasonable.

Scenario 06 – 2.0 REVERSE DAVIT (Acceptability) cont.

Totally Acceptable		Acceptable		Borderline		Unacceptable		Totally Unacceptable	
No improvements necessary and/or No deficiencies		Minor improvements desired and/or Minor deficiencies		Improvements warranted and/or Moderate deficiencies		Improvements required and/or Unacceptable deficiencies		Major improvements required and/or Totally unacceptable deficiencies	
1	2	3	4	5	6	7	8	9	10

- **Q6. The number of crew for this transfer method**
- **Rating = 4**
- **Comments:**
  - Additional crew member at the lunar lander for reorientation assistance would be helpful/efficient.
  - Centered tether point would also be helpful with a single crew member on the lander platform.
  - Mechanical/automatic release of a payload would be ideal.

- **Q7. The cargo packing (i.e., layout of SPLCs) on the lander deck for transfer operations**
- **Rating = 6**
- **Comments:**
  - Additional crew member at the lunar lander for reorientation assistance would be helpful/efficient.
  - Centered tether point would also be helpful with a single crew member on the lander platform.
  - Mechanical/automatic release of a payload would be ideal.

- **Q8. Overall acceptability of using this transfer method from end-to-end (including risk to crew) for 2.0 SPLCs**
- **Rating = 7**
- **Comments:**
  - The davit is not a reasonable solution for 2.0 SPLCs.
  - The requirement for two crewmembers to translate the 2.0 SPLC makes this scenario challenging.

Scenario 07 – 2.0 DAVIT (Acceptability)

Totally Acceptable		Acceptable		Borderline		Unacceptable		Totally Unacceptable	
No improvements necessary and/or No deficiencies		Minor improvements desired and/or Minor deficiencies		Improvements warranted and/or Moderate deficiencies		Improvements required and/or Unacceptable deficiencies		Major improvements required and/or Totally unacceptable deficiencies	
1	2	3	4	5	6	7	8	9	10

- **Q1. Using the Davit for transfer operations (reach, attachments, loading/unloading containers, davit handle, crank, hook, etc.)**
- **Rating = 6**
- **Comments:**
    - Attachments
        - Centered tether point would also be helpful with a single crew member on the lander platform
    - Loading/Unloading
        - Davit as lifting device (did not maneuver 2.0 SPLCs toward davit, rather let out davit hook to meet SPLC soft good handles).
        - Crewmember would then raise the SPLC slightly with the davit crank before yawing, enabling the payload to always clear the lunar platform edge.
    - Mechanisms:
        - Use of the davit (cranking) is challenging.

Scenario 07 – 2.0 DAVIT (Acceptability) cont.

Totally Acceptable		Acceptable		Borderline		Unacceptable		Totally Unacceptable	
No improvements necessary and/or No deficiencies		Minor improvements desired and/or Minor deficiencies		Improvements warranted and/or Moderate deficiencies		Improvements required and/or Unacceptable deficiencies		Major improvements required and/or Totally unacceptable deficiencies	
1	2	3	4	5	6	7	8	9	10

- **Q2. The lander deck for transfer operations (deck volume, lander height, etc.)**
- **Rating = 7**
- **Comments:**
  - Largest concern with the lander deck was the size and the crew member getting too close to the edge.
  - Lander deck/davit placement and 2.0 geometry brings the crew member substantially closer to the edge of the lunar lander platform.

- **Q3. The conceptual 2.0 SPLC container for use with a davit (handrails, size, shape, connection points, etc.)**
- **Rating = 7**
- **Comments:**
  - We consider a 2.0 SPLC feasible to be lifted by one crew member.
  - Unloading the davit was awkward considering the lack of a centered tether point on the SPLCs.
    - Work requires substantial reorientation.
  - Yawing the davit inboard brought the crewmember very close to the lunar lander edge.
    - Davit needs to be more centered on the lunar lander, or the arm needs to be able to pitch to facilitate these operations and keep the crew member safely away from the platform edge or lunar lander barrier/wall

- **Q4. Size of Staging area**
- **Rating = 6**
- **Comments:**
  - Dust generation from dragging the SPLC over the hatch seal protector at the open A/L hatch would be untenable.
  - Some lowering mechanism through the A/L would be helpful.
  - A mechanism for blocking dust (door protector?) could help. Ideally, one crew member would be staged outside the A/L.
  - Crew member would receive the SPLC from a crew member inside the A/L, then be able to carry the SPLC a few feet away on the lunar surface.

- **Q5. The number of crew for this transfer method**
- **Rating = 3**
- **Comments:**
  - Two crew members seemed suitable for this operation. Moving to the SPLCs to hook them up to the davit seemed inefficient.

Scenario 07 – 2.0 DAVIT (Acceptability) cont.

Totally Acceptable		Acceptable		Borderline		Unacceptable		Totally Unacceptable	
No improvements necessary and/or No deficiencies		Minor improvements desired and/or Minor deficiencies		Improvements warranted and/or Moderate deficiencies		Improvements required and/or Unacceptable deficiencies		Major improvements required and/or Totally unacceptable deficiencies	
1	2	3	4	5	6	7	8	9	10

- **Q6. The conceptual dust migration procedures**
- **Rating = 7**
- **Comments:**
    - With our dust mitigation procedures, we would have kicked up a lot of dust at the A/L EV hatch over the hatch seal protector.
    - Dusting should occur further from the hatch seal or there needs to be additional protection in the proximity of the A/L.

- **Q7. The cargo packing (i.e., layout of SPLCs) on the lander deck for transfer operations**
- **Rating = 2**
- **Comments:**
    - Suitable

- **Q8. Overall acceptability of using this transfer method from end-to-end (including risk to crew) for 2.0 SPLCs**
- **Rating = 7**
- **Comments:**
    - Overall acceptability scores driven largely by proximity of crew member to lander platform edge and dust mitigation issues.

Scenario 08 – 2.0 AIRLOCK TRANSFER OPS (Acceptability)

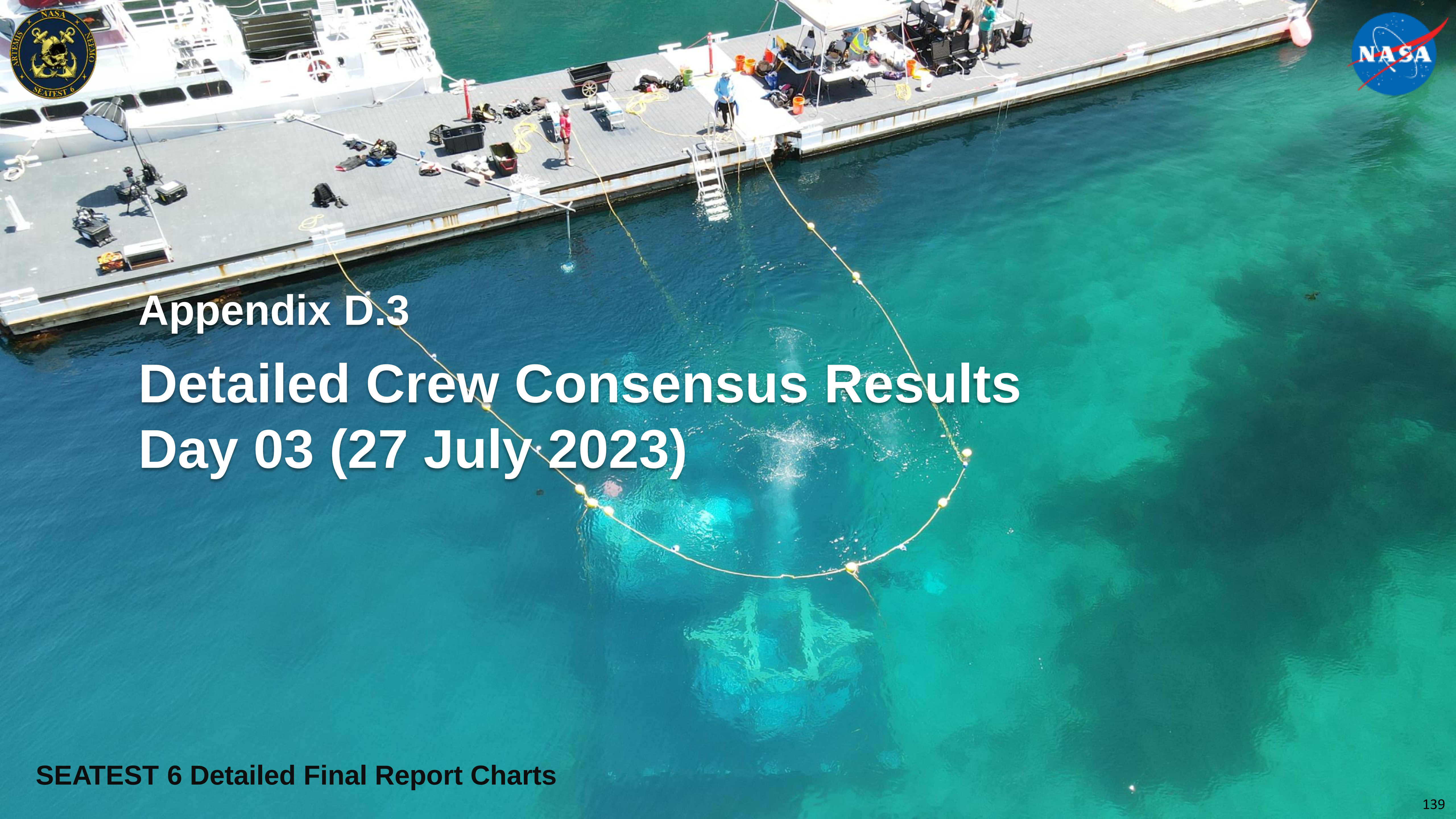
Totally Acceptable		Acceptable		Borderline		Unacceptable		Totally Unacceptable	
No improvements necessary and/or No deficiencies		Minor improvements desired and/or Minor deficiencies		Improvements warranted and/or Moderate deficiencies		Improvements required and/or Unacceptable deficiencies		Major improvements required and/or Totally unacceptable deficiencies	
1	2	3	4	5	6	7	8	9	10

- **Q1. Stacking the containers**
- **Rating = 4**
- **Comments:**
  - Stacking 2.0 SPLCs three-high was a huge efficiency and seemed reasonable for two crew members.
  - 8 2.0 SPLCs stacked seemed better than 16 1.0 SPLCs.
  - To manage unstacking the containers, crew member used one hand on the soft good handles and used one hand to tend the SPLC as it slid toward the A/L floor.

- **Q2. Airlock container reconfiguration within the given airlock volume**
- **Rating = 4**
- **Comments:**
  - If stacked 3 high, A/L volume easily manageable.
  - If 2 high, one suit port would likely be blocked to allow one crew member to assist the other to doff their suit.
  - If 2.0 SPLCs are stacked 2 high both forward in front of the IV hatch and aft/port or stbd around the EV hatch, maneuvering in the corridor created by the SPLCs would be too tight in the suit.
  - If one of the suit ports is blocked by SPLCs, this becomes more manageable

- **Q3. Suit don/doff in the given airlock volume**
- **Rating = 4**
- **Comments:**
  - If stacked 3 high, this is reasonable with minimal reconfig.
  - If stacked 2 high, reconfig is required which would block one suit port at a time.

- **Q4. Consensus Acceptability Ratings + Comments**
- **Overall acceptability of using this transfer method from end-to-end (including risk to crew)**
- **Rating = 4**
- **Comments:**
  - Overall acceptable if we are able to stack SPLCs 3 high.



Appendix D.3

Detailed Crew Consensus Results
Day 03 (27 July 2023)

SEATEST 6 Detailed Final Report Charts

Day 03 – CAPABILITY DATA

CAPABILITY ASSESSMENT SCALE									
Essential/Enabling		Significantly Enhancing		Moderately Enhancing		Marginally Enhancing		Little to No Enhancement	
Impossible or highly inadvisable to perform mission without capability		Capabilities are likely to significantly enhance one or more aspects of the mission		Capabilities likely to moderately enhance one or more aspect of the mission or significantly enhance the mission on rare occasions		Capabilities are only marginally useful or useful only on very rare occasions		Capabilities are not useful under any reasonably foreseeable circumstances	
1	2	3	4	5	6	7	8	9	10

- **Q1. The davit transfer concept**
- **Rating = 2**
- **Comments:**
  - Some mechanism to lift the PLCs which has a flexible loading/unloading capability is essential to the mission.
  - The lunar platform is too high to safely operate without such a mechanism.
  - This capability assessment does not include the functionality of the specific davit used in this test.
  - Rather, crew consider some mechanism to transfer payloads from the lunar platform to the surface essential since not all payloads need to go directly to the A/L.

- **Q2. The zipline transfer concept**
- **Rating = 3**
- **Comments:**
  - Allows for potentially dust free transfer.
  - Fast way to transfer cargo.
  - The attachment points of the zipline are restrictive, and the attachment itself requires lifting.
  - These are limitations of the zipline.
  - However, the dust free transfer method and ease of transfer is worthwhile.
  - While we might achieve mission success without the zipline, the time requirement for such operations would be prohibitive

- **Q3. Additional Comments:**
  - Depending on the height of the lander, some mechanism is needed to do a couple things:
    - 1) Lift the cargo to the attach point
    - 2) Deliver the cargo to the lunar surface/directly to the airlock.
  - Seems intuitive to use the zipline to lower equipment dust free to a certain place.
  - Efficient operations:
    - Difficult to use the zipline to raise equipment.
    - The davit concept is good for lifting equipment (especially large items like the 2.0 SPLC or MPLC).
    - A combination or hybrid of these two concepts would be useful.

Day 03 – CREW DEBRIEF

- **Q1. Any other general thoughts on cargo logistics lander configurations (e.g., how logistics are packaged on a lander for offloading) and capabilities (e.g., specs for ladders, davits, winches, etc.)? E.g., can you envision lander details that are extremely prohibitive vs. extremely mission enhancing, etc.?**
- **Comments:**
  - Safety
    - Feel strongly that some railing or safety mechanism is required for operations on the lander deck.
    - Can be a rail/strap guard around the perimeter or a tether system which allows you to continue operations while restricting you to the safe area of the lander deck.
  - Ladder
    - Ladder mockup had a helpful height to allow crew members to push through the gap between the ladder handrails while cleaning the PLSS.
    - Height was good for the alternate method of swinging around one handrail to get to the ladder rails with your feet.
    - A sloped ladder would aid the crewmember in ascending/descending with the weight of the suit and PLSS (estimate 5-15deg).
  - Mechanisms:
    - Concept of a winch operation to lift and lower payloads of various sizes and mass is a valuable concept, however there are significant problems with the current davit iteration.
      - » 1) The metabolic demands to manually operate a crank to lower and raise a hook is unacceptable.
        - It is very difficult in current suit designs with the existing shoulder mobility capabilities to freely operate a crank handle such as the manual davit in SEATEST-6.
        - Even if the shoulder mobility of the next gen spacesuit could support that kind of mobility, the metabolic demands of such an operation are not sound. It would use up a lot of resources, namely time and oxygen, which was reflected in the increased air usage from the SCUBA tanks for the astronaut that was manually operating the davit.
          - A solution would be to have an electric motor operated by push buttons or pedal design with manual operation as a backup.
      - » 2) Having the ability to offset payloads closer or farther from the davit is useful.
        - Effectively, being able to adjust the cosine of the davit angle (the arm of the davit is the hypotenuse) can bring payloads closer or further away.
        - Being able to increase the offset of payloads is helpful if the payload is large and needs to be offset further to avoid hitting the lander platform as it's being lowered.
          - There are a couple ways to accomplish this.
            - Make the pitch of the davit adjustable or use a telescoping davit arm.
            - We'll leave it to the engineers to figure out the best solution to accomplish the function we are looking for.
      - » 3) The yawing capability of the davit is very important but feel having a pedal to lock/unlock the davit yaw angle in place would be helpful, similar to how the APFR on station has a pedal to unlock/lock its yaw angle.

Day 03 – CREW DEBRIEF

- **Q2. Any other general thoughts on dust mitigation strategies for logistic transfer ops?**
- **Comments:**
  - Dust mitigation with the zipline into the airlock was great.
    - Should be some way to raise and lower the attach point on the rover to account for different distances away from the lander platform to create the correct angle for the equipment to slide into the airlock.
  - Tarps could be used in temporary staging areas.
  - Possibly some type of grating at the entrance to the airlock to rest/set dusty equipment.
  - A "foot brush" also could help to wipe off feet and equipment.

- **Q3. What are your thoughts on the current logistics manifest for a 14-day rover mission for a crew of 2 (i.e., all 15 of the 1.0 SPLCs + 8 of the 2.0 SPLCs)? How do you propose we think about logistics for ~7 to 30-day surface mission (e.g., in pressurized rover and/or surface habitat)? What are your recommendations for determining (e.g., through analysis, testing + eval, etc.) what quantity of logistics is appropriate for these missions?**
- **Comments:**
  - MPLC with transfer port is much preferred over the 1.0, 2.0 solutions.
  - Space and dust mitigation are optimized with MPLC design.
  - If MPLCs are not feasible, the size of 2.0 SPLCs seem preferable to 1.0s to minimize extra volume taken up by the containers.
  - See suggestions in scenario feedback regarding requirements for handles and stacking.

- **Q4. What are your concerns and recommendations with regard to our ability to simulate the lunar surface environment and Artemis mission operations in these SEATEST analog tests?**
- **Comments:**
  - The major concerns are:
    - 1) lack of ability to simulate the space suit (the addition of a 3-d printed HUT, gloves, boots, or some sort of mobility restraint would add fidelity to this test).
    - 2) the additional stability added by water resistance giving the crewmember an unrealistic sense of safety on the lunar lander platform.
    - 3) the addition of a realistic safety system on the lander deck is essential in the real lunar environment, so should be mocked up here.
    - 4) Finally, weight the subject to lunar gravity (1/6 g) while working on the mockup.

- **Q5. Any other feedback (e.g., for logistic handling)**
- **Comments:**
  - A fulcrum over the A/L hatch protector could be helpful to move large loads in/out of the A/L easily, especially if two crew members are required to lift the load.

Appendix E

Additional Rules of Engagement

Additional Rules of Engagement

1. Plan for Lost Test Days

The Mission Management Team (MMT) will determine how to salvage broader overall test objectives in the face of partial or test day losses due to mechanical failure, comm difficulties, weather, etc. Each situation will be assessed in light of its unique challenges, but the tools available in probably priority order are:

a. Use contingency day for full day loss
b. Cut scenarios, working up the list from the lowest priority

2. Test Delays or Pauses

a. Comm
   i. Full comm capabilities will be part of pre-dive checks and will be Dive Commit Criteria for splashing.
   ii. If experiencing comm problems that preclude operations as planned, the Comm team will be given up to 5 minutes to solve it. MCC/CapCom will keep the timer. If no joy, divers will be recovered to the surface.
   iii. If comm problems arise that allow continuing operations (even though degraded), the dive will continue. The MCC Lead is responsible for making that determination.
b. Hardware failures
   i. Priority 1 – Dive for one or both buddy teams ends for troubleshooting. Dive Sup will determine if/when/how to proceed.
      1. Critical Dive Gear failure
      2. Diver declaration of hypothermia
      3. Imminent Bingo on air
   ii. Priority 2 – Operations proceed while troubleshooting. If no joy after 5 min, Dive Sup and MCC lead will confer and jointly determine how to proceed. MCC/CapCom will keep the timer.
      1. Diver comm system
      2. MCC Systems (Comm, video, tracking, etc.)
   iii. Priority 3 – Operations proceed while troubleshooting, but run continues to completion.
      1. Support diver camera failure
      2. SA or helmet camera failure
      3. Partial but not crippling comm failure
c. Weather
   i. The Dive Sup will stop operations for:
      1. Lightning
      2. Imminent flash flooding
      3. Imminent wildfire
      4. Earthquake
      5. Tsunami warning
d. Injury in the Field
   i. If an injury occurs that is serious enough to require evacuation, the MMT will determine whether to continue operations that day/night
e. Safety Timeout
   i. All team members are empowered to call a safety time out and STOP OR CANCEL OPERATIONS AT ANY TIME FOR ANY REASON without penalty of any kind.
   ii. The Dive Sup will determine when it’s safe to continue

Additional Rules of Engagement (cont.)

3. Run Time Management

a. CapCom will routinely check w/ test subjects for thermal state and air pressure – dives will end if either hypothermia or air pressure of any diver requires it

b. Until onset of hypothermia and air use are better understood, run time goal will be minutes in water. A tank swap out will be planned for all divers at a convenient time near ~ 30 min into each dive

c. Goal to demonstrate each applicable phase (Offload, transport, dust removal, load, and A/L cycle) in each scenario.

d. It is likely not all 15 (1.0 SPLCs) or 8 (2.0 SPLCs) can be unloaded and still get through the entirety of each scenario. Once enough data has been gathered in each phase to extrapolate, it will be ok to move to the next phase.

e. MCC will manage the scenario time and make the decision to move to the next phase when appropriate. When that happens, support divers will help move any remaining containers to the next location.

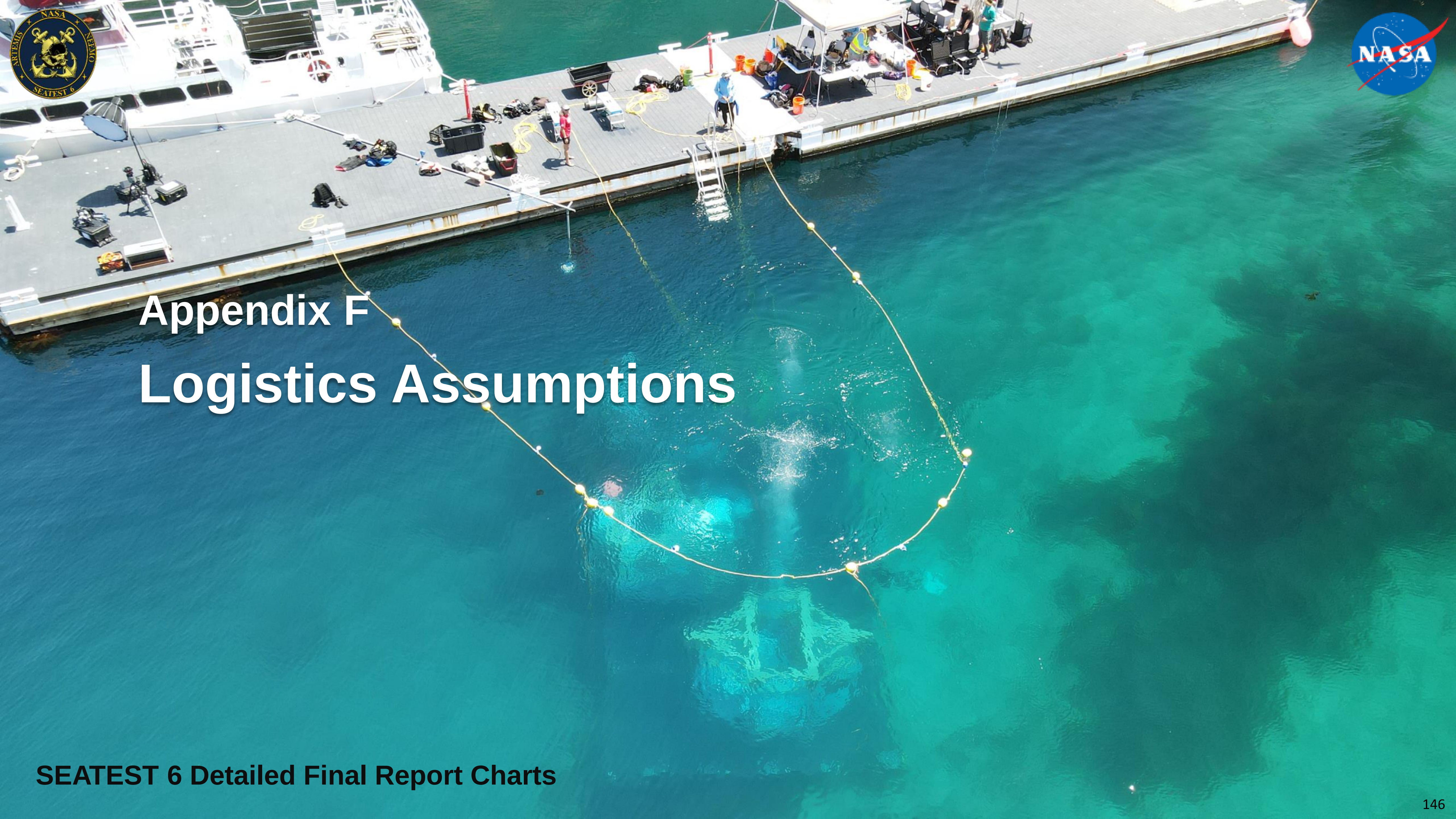
4. Crew Scheduling

a. Test subjects schedule will be built to ensure equal evaluation opportunities for all test subjects

b. Test subjects are highly encouraged to observe runs they are not personally conducting from MCC; different insights may be gained by watching tasks than are gained by doing them, and all of it helps build the strongest crew consensus data possible.

c. If a test subject is unable to dive successfully on a given day (for example, has trouble clearing one day) their place in the rotation will be swapped with the one not planned for that dive.

d. All crew test subjects will participate in consensus discussions daily.



Appendix F

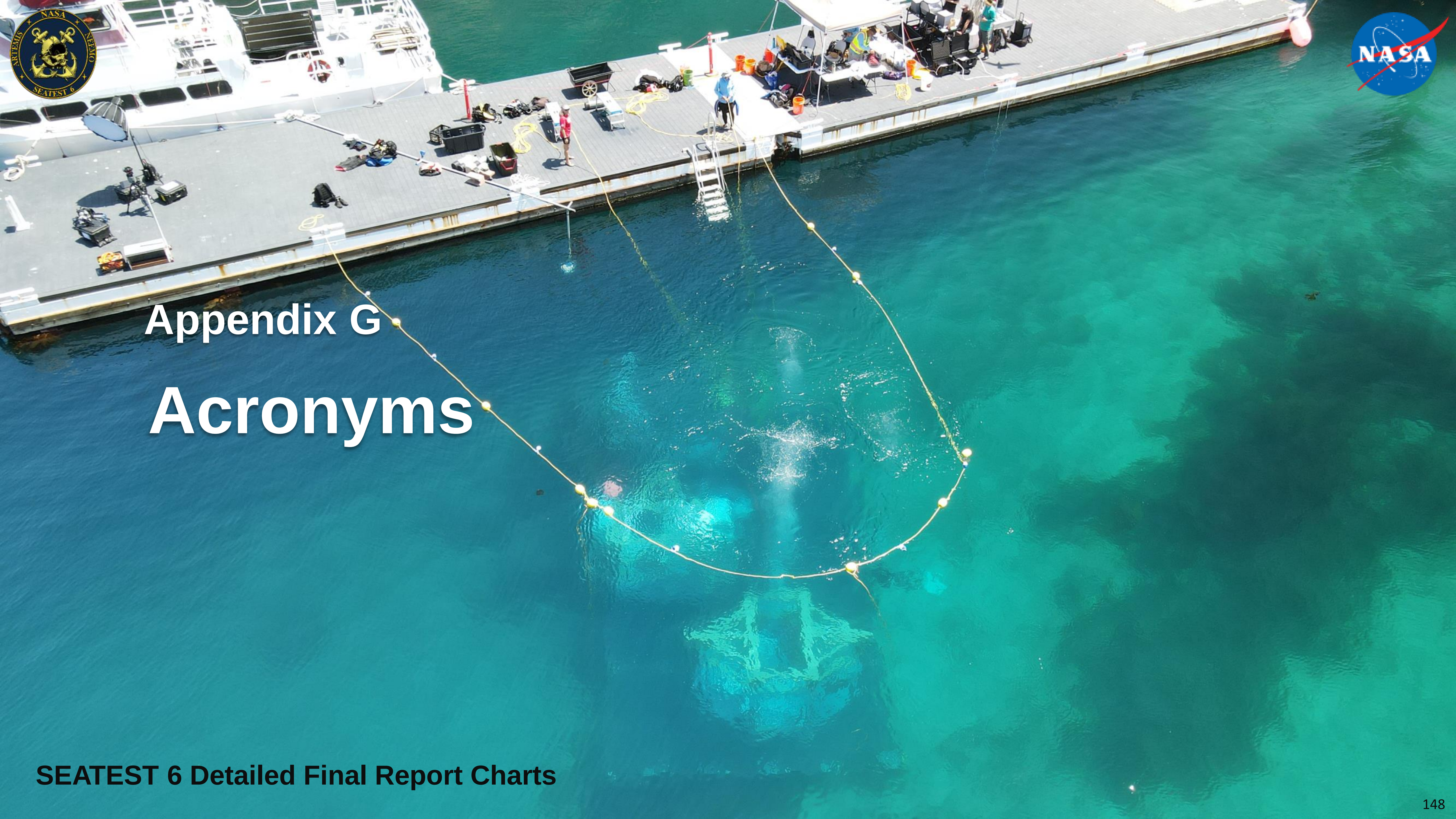
Logistics Assumptions

SEATEST 6 Detailed Final Report Charts

Logistics Assumptions – Pressurized Rover 14-Day Manifest

Crew Size	2 Crew	2 Crew	2 Crew	2 Crew	4 Crew	4 Crew	4 Crew	4 Crew
Elements	**PR**	**PR**	**PR**	**PR**	**PR & SH**	**PR & SH**	**PR & SH**	**PR & SH**
Duration in Surface Elements	**7 Days**	**14 Days**	**21 Days**	**28 Days**	**7 Days**	**14 Days**	**21 Days**	**28 Days**
Total Surface Duration	**12 Days**	**19 Days**	**26 Days**	**33 Days**	**12 Days**	**19 Days**	**26 Days**	**33 Days**
Food (kg)	42.64	79.40	116.16	152.92	84.18	156.60	229.02	301.44
Wipes and Gloves (kg)	2.80	5.60	8.40	11.20	5.60	11.20	16.80	22.40
Health Care Consumables (kg)	1.26	2.52	3.78	5.04	2.52	5.04	7.56	10.08
Trash Bags (kg)	0.42	0.84	1.26	1.68	0.84	1.68	2.52	3.36
Waste Collection (kg)	3.78	7.56	11.34	15.12	7.56	15.12	22.68	30.24
Operational Supplies (kg)	5.00	5.00	10.00	10.00	10.00	10.00	20.00	20.00
Recreation & Personal Stowage (kg)	10.00	10.00	20.00	20.00	20.00	20.00	40.00	40.00
Hygiene (kg)	7.45	8.61	8.61	9.19	14.90	17.22	17.22	18.38
Clothing (kg)	7.08	13.01	13.92	17.18	14.16	23.36	27.84	34.36
Towels (kg)	1.37	3.27	4.10	5.46	2.74	6.00	8.20	10.92
Replacement System Spares (kg)	76.00	76.00	76.00	76.00	152.00	152.00	152.00	152.00
LiOH Cannisters (kg)	0.00	0.00	0.00	31.50	0.00	0.00	0.00	31.50
EVA Consumables (kg)	84.30	101.66	119.02	136.37	162.18	187.83	213.48	241.77
EVA Spares (kg)	20.78	80.66	80.66	80.66	41.56	160.32	160.32	160.32
Utilization (kg)	50.00	50.00	50.00	50.00	100.00	100.00	100.00	100.00
Bags, Foam, Packaging (kg)	16.19	31.13	36.52	41.92	31.96	60.59	70.55	79.68
10% Margin (kg)	32.91	47.53	55.98	66.42	65.02	92.70	108.82	125.65
TOTAL (kg)	**345.79**	**491.66**	**579.23**	**688.74**	**683.26**	**959.07**	**1126.46**	**1302.42**
Total Volume (CTBE)	**19.50**	**37.50**	**44.00**	**50.50**	**38.50**	**73.00**	**85.00**	**96.00**

NOTE[1]: Manifest source from the NASA Explore Moon to Mars Logistics Requirements and Delivery Assessment GR&As presentation dated 30 March 2023



Appendix G

Acronyms

Acronyms

A/L – Airlock
ACR – Architecture Concept Review
ADD – Architecture Definition Document
APFR – Articulating Portable Foot Restraint
AAUS – American Academy of Underwater Sciences
CapCom – Capsule Communicator (communicates with crew)
CAVES Cooperative Adventure for Valuing and Exercising
CG – Center of Gravity
Comm – Communications
ConOps – Concept of Operations
CSA – Canadian Space Agency
CTBE – Crew Transfer Bag Equivalent
CWC – Contingency Water Containers (CWC)
D-RATS – Desert Research And Technology Studies
DSB – Dive Safety Board
EHP – Extravehicular Activity and Human Surface Mobility Program
ESA – European Space Agency
ESDMD – Exploration Systems Development Mission Directorate
EV1/EV2 – Extra Vehicular crew number 1 or 2
EVA – Extra-Vehicular Activity
FOD – Flight Operations Directorate
FPS – Felix & Paul Studios
FRP – Fiber-Reinforced Polymer
Hab – Habitat
HDL – Human-class Delivery Lander
HITL – Human in the Loop
HQ – NASA Headquarters
HUT – Hard Upper Torso
IPSM – Integrated Performance and System Management
ISS – International Space Station
IV – Intra-Vehicular
JSC – Johnson Space Center
KSC – Kennedy Space Center
LAT – Lunar Architecture Team
M2M – Moon to Mars
MCC – Mission Control Center
MMT – Mission Management Team
MPLC – Medium Pressurized Logistics Container
NASA – National Aeronautics & Space Administration
NBL – Neutral Buoyancy Lab
NEEMO – NASA Extreme Environment Mission Operations
NOLS – National Outdoors Leadership School
Ops – Operations
PANGAEA – Planetary Analogue Geological and Astrobiological Exercise for Astronauts
PAO – Public Affairs Office
PLSS – Portable Life Support System
PR – Pressurized Rover
ROM – not defined
SAC – Strategic Analysis Cycle
SAO – Strategy & Architecture Office
SCUBA – Self-Contained Underwater Breathing Apparatus
SEATEST – Space Environment Analog for Training, Engineering, Science, and Technology
Sim – Simulation
SPLC – Small Pressurized Logistics Container
ST6 – SEATEST 6
STMD – Space Technology Mission Directorate
TIM – Technical Interchange Meeting
TrRR – Training Readiness Review
TRR – Test Readiness Review
UAE – United Arab Emirates
USC – University of Southern California
VR – Virtual Reality
w.r.t. – with respect to
WMSC – Wrigley Marine Science Center
xEMU – exploration EVA Mobility Unit