Relevant Environments for Analysis and Development (READy):

Enabling Human Space Exploration Through Integrated Operational Testing

EVA Exploration Workshop
July 25, 2019
Integrated Operational Testing for Space Exploration

Lead the development and execution of high-fidelity operational exploration analog missions that closely mimic the space environment of interest, thus developing and testing concepts that enable Exploration missions.

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

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

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

Inform the design of the Exploration EVA System and xEVA Concept of Operations.
READy Charter Objectives

• Establish a portfolio of relevant environment test facilities and approaches to support Human Exploration and Operations Mission Directorate (HEOMD) – including Gateway Utilization Phase 0-4 – as well as Science Mission Directorate (SMD) and Space Technology Mission Directorate (STMD) Exploration Research & Technology (ER&T) missions

• To establish an institutional resource for mission development integration, including for Gateway the Lunar Surface

• Fulfill key objectives of Exploration Integration & Sciences Directorate (EISD) Charter and Roadmap that enable the Journey to Cislunar space, the Moon, and Mars

• Provide synergy and ensure integration across a wide variety of on-going, active NASA and Exploration work

• Provide a unique service to select and integrate objectives and testing locations across the Center and Agency; become the “go-to” resource for JSC and Agency operational development testing requirements and align existing dispersed capabilities within a strategic and tactical plan

High-fidelity integrated multi-disciplinary operational development missions that closely mimic the space environment of interest, and allow for end-to-end operations, thus developing and testing concepts that enable Exploration spaceflight missions.

<table>
<thead>
<tr>
<th>WHO</th>
<th>WHAT</th>
<th>WHERE</th>
<th>HOW</th>
</tr>
</thead>
<tbody>
<tr>
<td>MULTI-ORGANIZATIONAL TEAMS</td>
<td>INTEGRATION THEMES</td>
<td>RELEVANT ENVIRONMENTS</td>
<td>INTEGRATED OPERATIONAL TESTING</td>
</tr>
<tr>
<td>SCIENCE</td>
<td>TOOLS</td>
<td>AQUATIC</td>
<td></td>
</tr>
<tr>
<td>EVA</td>
<td>TECHNIQUES</td>
<td>TERRESTRIAL</td>
<td></td>
</tr>
<tr>
<td>PLANNING</td>
<td>TECHNOLOGIES</td>
<td>LABORATORY</td>
<td></td>
</tr>
<tr>
<td>TECHNOLOGY</td>
<td>TRAINING</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**WHY**

To achieve mission readiness through integration and testing of technologies, systems, operations, and science in relevant environments:

- Close technology, exploration, and science gaps
- Identify and develop the best systems, innovations, and operational approaches
- Drive out results not found in standalone testing, including things that do and do not work in a mission environment
- Inform strategic architectural and concept of operations development efforts
- Facilitate EVA concepts of operations development

**OUTCOME**: These efforts will ultimately lead to mission readiness and success, reduce the risk, increase the scientific return, and improve the affordability of NASA programs and missions.

For NEEMO Use Only
WHO: NASA’s Exploration Integration and Science Directorate

unique blend of capability and skill sets within ...

- XI - ASTROMATERIALS RESEARCH & EXPLORATION SCIENCE
- XX - EXTRAVEHICULAR ACTIVITY
- XM - MISSION PLANNING & DEVELOPMENT
- Other XA components

Leverage extensive knowledge and experience from ...

- HISTORICAL MISSIONS
  - Apollo Surface Operations
- HUMAN SPACE FLIGHT
  - ISS, Shuttle
- ROBOTIC MISSIONS
  - Mars Missions, OSIRIS-REx
- “ANALOG” MISSIONS
  - D-RATS, NEEMO & others

REAdy core management and execution is a collaboration between NASA JSC’s ARES, EMPO, and EVA divisions
WHO: Partners outside EISD from NASA, Academia, Research, Industry, and DoD

And a multitude of others...
**Tools**
- EVA Tools & Systems
  - Handheld Tools for Building & Repair
  - Handheld Tools for Science
  - Power Tools
  - Tool Transport & Stowage Systems
  - Mobility & Compatibility Requirements
  - Crew Rescue Systems
- Instrumentation
  - In-Situ Analytical Instruments
  - Instrument Packages & Payloads
- Sample Collection
  - Sample Acquisition & Handling
  - Contamination Mitigation
  - Transportation & Stowage

**Techniques**
- Exploration Operations
  - Procedure Development
  - Communication Methods & Protocols
  - Data Visualization & Management
  - Timeline Tracking & Scheduling
- EVA Operations
  - EVA Concepts of Operations
  - Advanced EVA Capabilities
- Science Operations
  - Traverse Planning
  - Science Decision Making Protocols
  - Sample Acquisition & Documentation
- Robotic Operations
  - Autonomous vs Crew Controlled
  - Human-Robotic Interfaces

**Technologies**
- Emerging Technologies
  - Informatics & Intelligent Systems
  - Virtual/Hybrid Reality Environments
  - Medical & Human Performance
  - EVA Support Systems & IV Workstation
  - Advanced Spacesuit Developments
- Technology Collaborations
  - Commercial Connections
  - University & Institute Collaborations
  - Other Government Agencies Links
  - International Partnerships
- Innovations Incubator
  - Rapid Testing & Development
  - Idea Generation & Gap Recognition

**Training**
- Cross-Disciplinary Training
  - Involvement of Multiple Disciplines
  - Sharing Between Diverse Skill Sets
  - Extensive Expertise & Experiences
- Training Opportunities
  - Operational Training
  - Science Training
  - EVA & Space Suit Training
  - Tool & System Training
  - Student Opportunities
- Astronaut Crew Training
  - Expeditionary Opportunities
  - Leadership Opportunities
  - Mission Realistic Environments

**WHAT: Development & Integration Themes (4-T’s)**

[Image of astronauts and tools]
WHERE: Environments for Tests and Simulations

**AQUATIC**
- Neutral Buoyancy Laboratory
- Aquarius Reef Base (NEEMO)
- ESA's Neutral Buoyancy Facility

**TERRESTRIAL**
- Operational & Science Sites
- Field Training Location
- Extreme Environments

**LABORATORY**
- Active Response Gravity Offload System (ARGOS)
- Virtual Reality & Hybrid Reality Laboratories
- Mockups & International Space Station
WHAT: Capability Development via Integrated Operations

Integrated EVA Science Operations

- Astromaterials Research & Exploration Science (ARES)
- Mission Planning, Develop & Integration
- Extravehicular Activity Office
- Crew & Thermal Systems - Tools

Astronaut Office
The primary goal for EVA is to inform the **Exploration EVA System Concept of Operations** by exploring the combination of **Operations** and **Engineering** with **Science** for Exploration destinations in a mission-like environment.

- Advance the future of the Exploration EVA System and operations
- Understand EVA capability needs and concepts of operations for a wide range of Exploration destinations being considered by NASA
- Assess the system and architectural interactions between Operations, Engineering, and Science
- Determine and document closures to gaps in EVA capabilities and knowledge
- Develop and document concepts of operations for EVA at the Exploration destinations (**EVA-EXP-0042**)  
- Realize the needs of EVA equipment and enable the development of concepts for design maturation on the road-to-flight
HOW: NASA Extreme Environment Mission Operations (NEEMO)

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

- Concept currently in development for an add-on and eventual follow-on for NEEMO
- Focuses on Exploration operations development and training, xEVA informatics, xEVA con ops, and integration of science operations
- Offers a high intensity operationally challenging environment, with high workload, elevated stress, high bandwidth, time pressure, and unexpected external perturbations
- Utilizes Nuytco Research Exosuit and Dual DeepWorker submersibles
- Exosuit provides an analogous restrictive suit that requires similar effort for positioning and working in an EVA suit, along with a relatively large helmet volume at 1 ATM to evaluate off the shelf informatics hardware
Neutral Buoyancy Laboratory

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

Neutral Buoyancy Facility

NBF
- Tests have been done with the Lunar Evacuation System Assembly (LESA), a concept by ESA for rescuing an incapacitated EVA crewmember
- Evaluations have been conducted for various geology sampling tools and transportation equipment
Other Science Field Campaigns and Geology Training
Integration with Solar System Exploration Research Virtual Institute (SSERVI)-funded projects

- **RIS⁴E: Remote, In Situ and Synchrotron Studies for Science and Exploration**
  - Focus: Remote sensing of airless bodies, field operations and metrics for human exploration, reactivity and toxicity of regoliths, synchrotron analyses of samples, volcanics and impact crater analog research
  - Investigates the effects of incorporating field portable instrumentation into science-driven EVA timelines

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

Final Desert RATS mission took place in 2011
Possible follow-ons for any Lunar mission program
• Developing a high scientific fidelity hybrid reality (HR) model of real-world geological sites of interest, including embedded data and applicable tool usage

• Builds off of several years of RISE in situ data collection in addition to data collected at the December 1974 flow, Kilauea Volcano, HI

• Testing environment that will be utilized for:
  • Ops con development for science-driven EVAs
  • Instrument deployment procedures
  • EVA Support System and IV Workstation capabilities for science
  • Crew training platform
Integration with tests to evaluate future habitation concepts for exploration missions
Numerous components also being developed in other READy activities
Research & Technology Studies

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

RATS 2012 was an asteroid analog mission

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

Possible surface-focused follow-ons for any Lunar mission program
Exploration Training Concept

1. Exploration Ops Class Training
   - Seminar and/or classroom-based curriculum focused on training Exploration personnel on operations and flight control, EVA constraints, and science techniques and considerations. Priority given to EISD personnel.

2. Field Geology Ops Training
   - Geology training in the field geared towards Engineers and managers to provide an understanding and appreciation of science tasks and methodology.

3. Integrated Operational Mission
   - Support a Mission-class integrated operational field test (e.g., NEEMO or NEEMO NXT).
   - Take a responsible role (e.g., science team member) engaging in:
     - Timeline development
     - Priorities discussions
     - Ops product development
     - Planning and plan reviews
Swim lanes intersect at stand-alone and mission class tests to ultimately meet objectives

<table>
<thead>
<tr>
<th>Programmatic Milestones</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>Aug</th>
<th>Sept</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
</tr>
</thead>
<tbody>
<tr>
<td>EVA Info con ops usability</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EVA Info equipment capability</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IV Workstation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>General Build</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gateway Robo Task</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lunar Rover</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lunar EVA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Virtual Reality/Hybrid Reality</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exploration Science Ops Center</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rapid</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aug/Sept</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand blast/melt</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Argos</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VR Training (PaleBlue)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cross-Disciplinary Exploration Training (incl. Science, EVA, etc.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>XA Exploration Trng</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NEX</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geo Training</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VR Training</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Op Tests (Playbooks, Pilot - HR)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EVA H-port (NEX)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bionic Gear (HR)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deployer Science Payloads (e.g. electronics)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interior Science (HR/NA, AllTraq)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Countermeasure (HR/SA)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iss (and beyond) Relevant</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

**Objective of informing xEVA con ops and requirements**

**Integrated mission class field tests**

**Informing Gateway Hab requirements**

**Cross-Directorate training to break down silos**

**Contributing to technology readiness for flight**

---

**Objectives and Milestones**

- **Integration with VR/AR/HR**
- **Focus on testing for xEVA System**
- **Development of Support Systems for EVA**
- **Increased integration with VR/AR/HR**
- **Enhancing capability and experience of EISD**
- **ISS (and beyond) Relevant**

---

**Ultimate Objective**

- **xEVA Reqs**
- **Gateway Hab Reqs**
- **xEVA Ops Reqs**
- **XA Personnel Exploration Training**
- **TRL Advancement Flight Demo**

---

**Programmatic Milestones**

- **April**
- **May**
- **June**
- **July**
- **Aug**
- **Sept**
- **Oct**
- **Nov**
- **Dec**
- **Jan**
- **Feb**
- **Mar**
- **Apr**
- **May**
- **Jun**

---

**IV Workstation**

- **General Skill**
- **Tests of APACHE**
- **Gateway Robo Task**
- **Lunar Rover**
- **Lunar EVA**

---

**Virtual Reality/Hybrid Reality**

- **Exploration Science Ops Center**
- **Sand blast/melt**
- **Aug/Sept**
- **Sand blast/melt**
- **Argos**
- **VR Training (PaleBlue)**

---

**Cross-Disciplinary Exploration Training (incl. Science, EVA, etc.)**

- **XA Exploration Trng**
- **NEX**
- **Geo Training**
- **VR Training**

---

**Op Tests (Playbooks, Pilot - HR)**

- **EVA H-port (NEX)**
- **Bionic Gear (HR)**
- **Deployer Science Payloads (e.g. electronics)**
- **Interior Science (HR/NA, AllTraq)**
- **Countermeasure (HR/SA)**

---

**Iss (and beyond) Relevant**

- **Integration with VR/AR/HR**
- **Focus on testing for xEVA System**
- **Development of Support Systems for EVA**
- **Increased integration with VR/AR/HR**
- **Enhancing capability and experience of EISD**
- **ISS (and beyond) Relevant**

---

**Ultimate Objective**

- **xEVA Reqs**
- **Gateway Hab Reqs**
- **xEVA Ops Reqs**
- **XA Personnel Exploration Training**
- **TRL Advancement Flight Demo**

---

**Programmatic Milestones**

- **April**
- **May**
- **June**
- **July**
- **Aug**
- **Sept**
- **Oct**
- **Nov**
- **Dec**
- **Jan**
- **Feb**
- **Mar**
- **Apr**
- **May**
- **Jun**

---

**IV Workstation**

- **General Skill**
- **Tests of APACHE**
- **Gateway Robo Task**
- **Lunar Rover**
- **Lunar EVA**

---

**Virtual Reality/Hybrid Reality**

- **Exploration Science Ops Center**
- **Sand blast/melt**
- **Aug/Sept**
- **Sand blast/melt**
- **Argos**
- **VR Training (PaleBlue)**

---

**Cross-Disciplinary Exploration Training (incl. Science, EVA, etc.)**

- **XA Exploration Trng**
- **NEX**
- **Geo Training**
- **VR Training**

---

**Op Tests (Playbooks, Pilot - HR)**

- **EVA H-port (NEX)**
- **Bionic Gear (HR)**
- **Deployer Science Payloads (e.g. electronics)**
- **Interior Science (HR/NA, AllTraq)**
- **Countermeasure (HR/SA)**

---

**Iss (and beyond) Relevant**

- **Integration with VR/AR/HR**
- **Focus on testing for xEVA System**
- **Development of Support Systems for EVA**
- **Increased integration with VR/AR/HR**
- **Enhancing capability and experience of EISD**
- **ISS (and beyond) Relevant**
Integrated Operational Testing for Space Exploration

Results from tests conducted and integrated by READy inform the development of key capabilities, systems, and concepts of operations that will enable human space exploration.

READy ensures integration across a wide variety of activities and tests, which provides critical synergy for the success of multiple exploration projects.

For EVA, results derived from READy efforts are fed directly into the Exploration EVA Concepts of Operations and provide critical information for development of the Exploration EVA System.

The ultimate goals are to provide NASA with robust space exploration capabilities that will improve the future of human spaceflight into the Solar System.
Reference for READy

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

https://ttu-ir.tdl.org/handle/2346/84787
Thank you!
Questions?
BACKUP
Relevant Environments for Analysis and Development (READy)
READy Core Team Concept

- XI/ARES, XM/EMPO, XX/EVA team members are the core management and execution team
- Skills include:
  - Identifying applicable mission objectives
  - Establishing contributing partnerships
  - Developing mission timelines and supporting products (e.g., procedures, mission rules, crew training, etc.)
  - Mission operations & execution
  - Capturing post mission lessons learned and briefing appropriate audiences
  - Leverage and expand existing proposals/grants
- Non-READy duties include staying plugged in to HSF ops and architectural activities and feeding READy lessons learned back into them as appropriate:
  - ISS Ops
  - EVA Ops
  - Mars Science Ops (e.g., MSL)
  - Gateway (DSG)
  - BAA NextStep Hab
  - EVA Strategic Planning and Architecture Integration

- xEVA System Development
- Mars Study Capability
- Lunar Science objectives
- Lunar Human Landing System
- Emerging...
**Exploration EVA Objectives Tied to Knowledge & Capability Gaps**

The primary goal for EVA is to inform the *Exploration EVA System Concept of Operations* by exploring the combination of *Operations* and *Engineering* with *Science* for Exploration destinations in a mission-like environment.

<table>
<thead>
<tr>
<th>Informatics</th>
<th>EVA Objectives</th>
<th>EVA Knowledge/Capability Gaps</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><img src="image1.png" alt="Image" /></td>
<td></td>
</tr>
<tr>
<td></td>
<td>✔️ Navy Diver Augmented Vision Display (DAVD)</td>
<td>✔️ EVA Suit Heads-Up Display</td>
</tr>
<tr>
<td></td>
<td>✔️ <em>“EVA Augmented Vision Heads-Up Display”</em></td>
<td>✔️ Mixed / Augmented Reality Capability</td>
</tr>
<tr>
<td></td>
<td>✔️ Spacesuit HUD concept development for NASA</td>
<td>✔️ EVA Graphical Display</td>
</tr>
<tr>
<td></td>
<td>✔️ Operational assessment of DAVD for NAVSEA</td>
<td>✔️ EVA Short Range Navigation</td>
</tr>
<tr>
<td></td>
<td>✔️ Surface navigation for EVA</td>
<td>✔️ IV Support System for EVA Operations</td>
</tr>
<tr>
<td></td>
<td>✔️ EVA Support System and IV Workstation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>✔️ EVA digital cue cards</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tools &amp; Equipment</th>
<th>EVA Objectives</th>
<th>EVA Knowledge/Capability Gaps</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image2.png" alt="Image" /></td>
<td>✔️ Core Sample Acquisition System <em>(Honeybee Robotics)</em></td>
<td>✔️ Tools for Science Sampling on a Surface EVA</td>
</tr>
<tr>
<td></td>
<td>✔️ Modular Equipment Transportation System (METS)</td>
<td>✔️ Subsurface samples (core)</td>
</tr>
<tr>
<td></td>
<td>✔️ Wheeled Equipment Transport (WET)</td>
<td>✔️ Tool Carrier Device</td>
</tr>
<tr>
<td></td>
<td>✔️ Suit-mounted Equipment Carrying System (SECS)</td>
<td>✔️ Tool Attachment/Harness for Surface EVA</td>
</tr>
<tr>
<td></td>
<td>✔️ Pioneering construction</td>
<td>✔️ Surface EVA Incapacitated Crewmember Rescue</td>
</tr>
<tr>
<td></td>
<td>✔️ ESA’s Lunar Evacuation System Assembly (LESA 2.0)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Concepts of Operations</th>
<th>EVA Objectives</th>
<th>EVA Knowledge/Capability Gaps</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image3.png" alt="Image" /></td>
<td>✔️ Integrated EVA operations with science tasks</td>
<td>✔️ Integrated EVA Flight Control Methodology</td>
</tr>
<tr>
<td></td>
<td>✔️ Lunar-focused with signal blockages</td>
<td>✔️ Tools for Interacting with EVA Over a Comm Latency (Blockage)</td>
</tr>
<tr>
<td></td>
<td>✔️ Comparison of crew IV vs ground IV</td>
<td>✔️ Flexible Execution Methodology for EVA Science Operations in Undefined Environments</td>
</tr>
<tr>
<td></td>
<td>✔️ Integrating informatics during EVA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>✔️ Use of advanced informatics concepts during EVA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>✔️ Flexible Execution Methodology (Flexexecution)</td>
<td></td>
</tr>
</tbody>
</table>
NEEMO EVA science activities included deployment of handheld instrumentation, context descriptions, imaging, and sampling.

The marine science activities and associated research objectives serve as an appropriate proxy for planetary surface exploration activities.

Integration, coordination, and education from diverse disciplines and organizations.