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

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READy Vision & Goals

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 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 Cis-lunar 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*

Integrated Operational Tests (Analog Missions): Who, What, Where, Why, & How

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

WHO

MULTI-ORGANIZATIONAL TEAMS

EXPLORATION INTEGRATION & SCIENCE DIRECTORATE

coordinated integration

- PLANNING
- EVA
- SCIENCE
- TECHNOLOGY

WHAT

INTEGRATION THEMES

- TOOLS
- TECHNIQUES
- TECHNOLOGIES
- TRAINING

WHERE

RELEVANT ENVIRONMENTS

- AQUATIC
- TERRESTRIAL
- LABORATORY

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

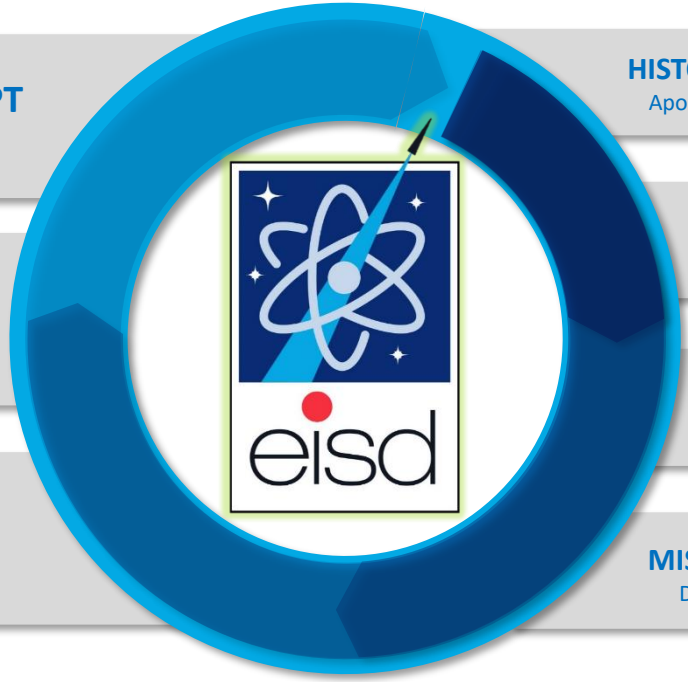
HOW

INTEGRATED OPERATIONAL TESTING

WHO: NASA's Exploration Integration and Science Directorate

Unique blend of capability and skill sets …

- **MISSION CONCEPT DEVELOPERS**
- **PLANETARY SCIENTISTS**
- **EVA SYSTEM DEVELOPERS**



Leverage extensive knowledge and experience from …

- **HISTORICAL MISSIONS**
  Apollo Surface Operations
- **HUMAN SPACE FLIGHT**
  ISS, Shuttle
- **ROBOTIC MISSIONS**
  Mars Missions, OSIRIS-REx
- **MISSION SIMULATIONS**
  D-RATS, NEEMO & others

WHO: Partners outside EISD from NASA, Academia, Research, Industry, and DoD

JSC GSFC ARC JPL KSC

esa CSA ASC JAXA

And a multitude of others…

XI XM XX CB EC ER SK FIU AQUARIUS HONEYBEE ROBOTICS NPS NAVSEA NAVAL SEA SYSTEMS COMMAND

CORAL RESTORATION FOUNDATION™ JOHNS HOPKINS UNIVERSITY ihmc FLORIDA INSTITUTE FOR HUMAN & MACHINE COGNITION USF UNIVERSITY OF SOUTH FLORIDA EMBRY-RIDDLE AERONAUTICAL UNIVERSITY TELEDYNE TECHNOLOGIES INCORPORATED NMT AllTraq UNCW DRAPER VEGA Telehealth TELOREGEN IMaGeS Lab SHARK MARINE TECHNOLOGIES INC. AESA University of Houston Clear Lake voxer

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

TOOLS

EVA Systems
- EVA tools and equipment
- Large equipment transport
- Small tool transport on suit
- Informatics
- Crew rescue
- EVA Support System & IV Workstation
- Science instruments and sample acquisition tools

Instrumentation
- Sample identification / high-grading
- ISRU verification

Sample Acquisition
- Collection
- Curation
- Contamination Mitigation
- Preservation/Storage

TECHNIQUES

Exploration Operations
- Procedure development/ refinement
- Signal latency & blockage
- Bandwidth limitations

EVA Operations
- EVA concepts of operations
- EVAs in undefined environments
- Advanced capabilities & informatics

Science Operations
- Flexecution methodology
- Decision making protocols
- Transverse planning

Robotic Operations
- Autonomous
- Crew controlled
- Human-Robotic interface & integration

TECHNOLOGIES

Emerging Technologies
- Virtual/Hybrid reality opportunities
- Relevant cutting-edge systems and capabilities for Exploration and EVA
- Rapid testing environment for development of emerging technologies

Innovations Incubator
- Relevant environments and operational constraints are a breeding ground for innovation

Partnerships
- Opportunities for external partners to demonstrate current capabilities
- Direct collaboration leading to proposal and funding avenues
- Strengthens international partnerships

TRAINING

Cross-Disciplinary Training
- Learning each others language, requirements, and drivers in EISD
- Ex. Geo-Science Field Training for managers and engineers

Astronaut Crew Training
- Additional expeditionary and leadership opportunities
- Enhances both operational and science training objectives

Operational Training
- Provides ops training prior to payload flights for payload PIs and teams
- Enables development of engineers and scientists not normally exposed to operations

WHERE: Environments for Tests and Simulations

AQUATIC

EXAMPLES

Neutral Buoyancy Laboratory (NBL)

Aquarius Reef Base (NEEMO)

ESA's Neutral Buoyancy Facility

Others …

TERRESTRIAL

EXAMPLES

Geo-Science Field Exercises & Sites

Field Training Areas

Extreme Environments (ex. Antarctica)

Others …

LABORATORY

EXAMPLES

Active Response Gravity Offload System (ARGOS)

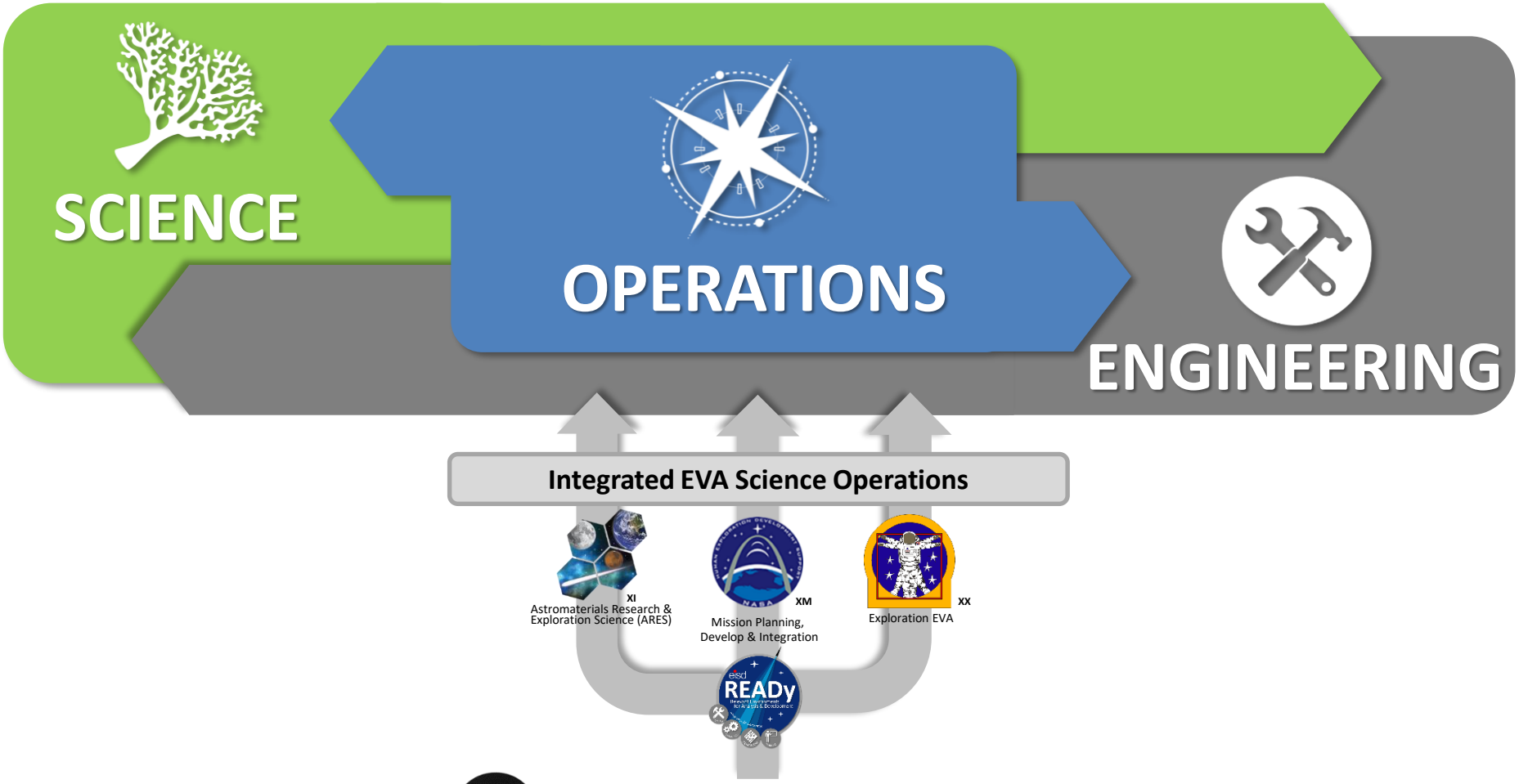
Virtual Reality & Hybrid Reality Laboratories

International Space Station

Others …

WHY: Exploration Capability Development via Integrated Operations

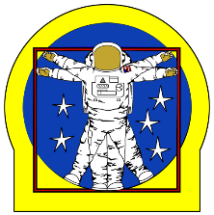
Enabling human space exploration through the integration of mission architecture, EVA, science, engineering, and operations

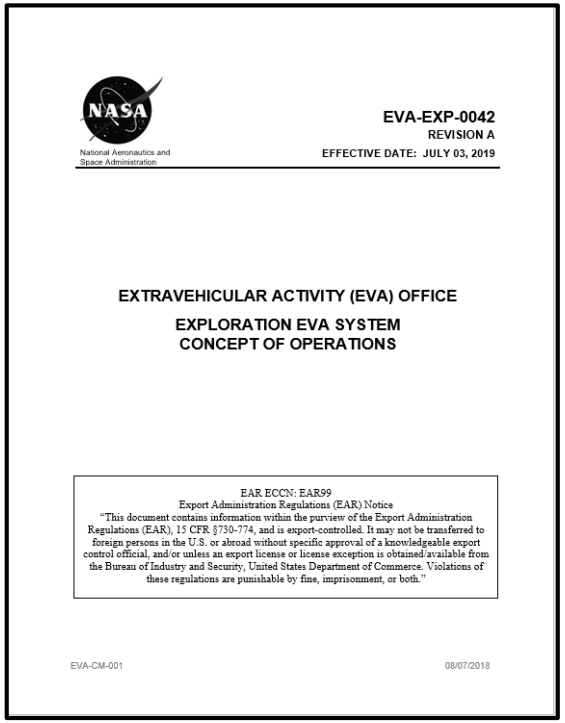


WHY: EVA-Specific Goals for Integrated Operational Testing

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




NASA
National Aeronautics and Space Administration

EVA-EXP-0042
REVISION A
EFFECTIVE DATE: JULY 03, 2019

EXTRAVEHICULAR ACTIVITY (EVA) OFFICE

EXPLORATION EVA SYSTEM
CONCEPT OF OPERATIONS

EAR ECCN: EAR99
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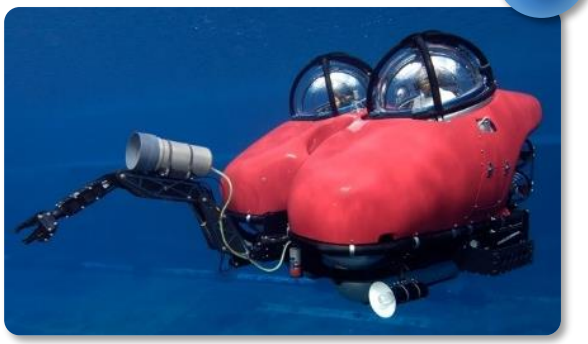
EVA-CM-001 08/07/2018

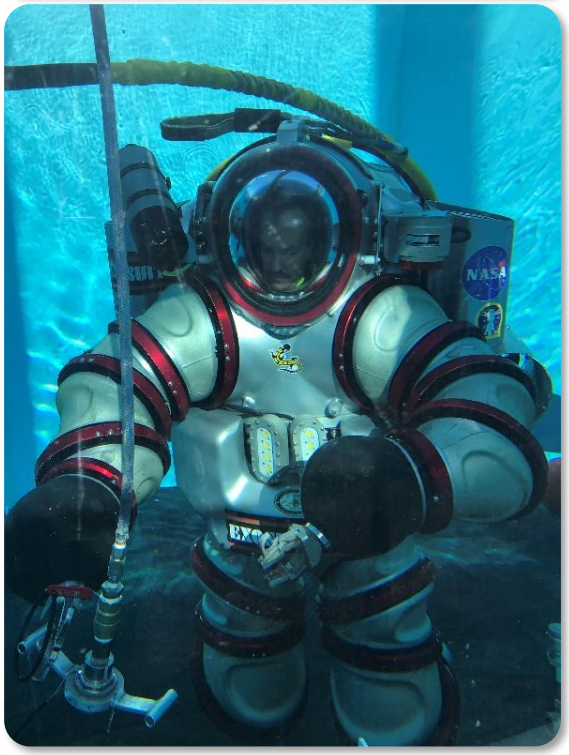
HOW: NASA Extreme Environment Mission Operations (NEEMO)

- 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)

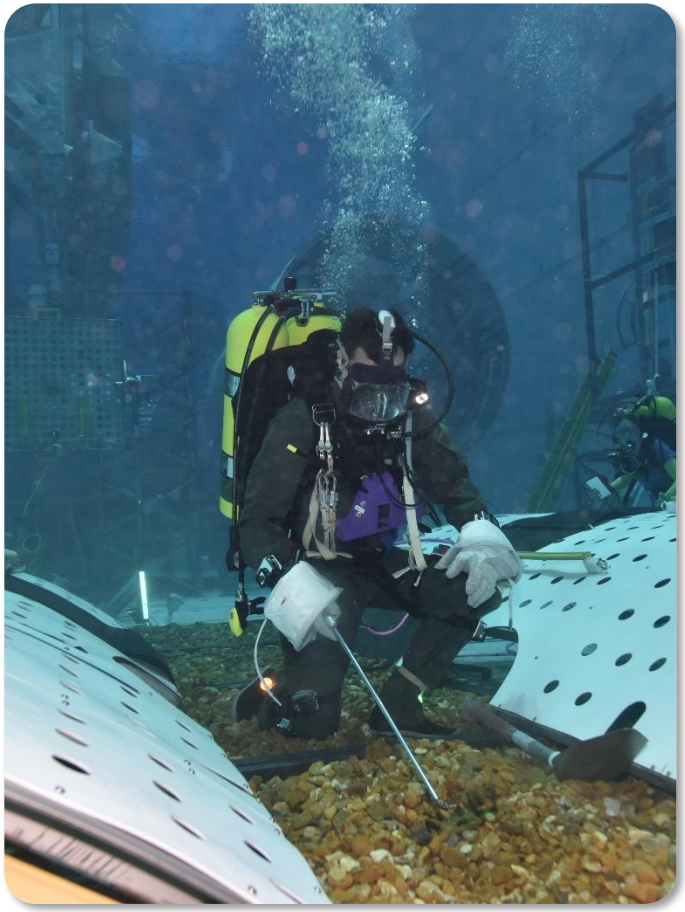
- Concept currently in development for an add-on and eventual follow-on for NEEMO
- Focuses on Exploration operations development and training, xEVA informatics, xEVA con ops, and integration of science operations
- Offers a high intensity operationally challenging environment, with high workload, elevated 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





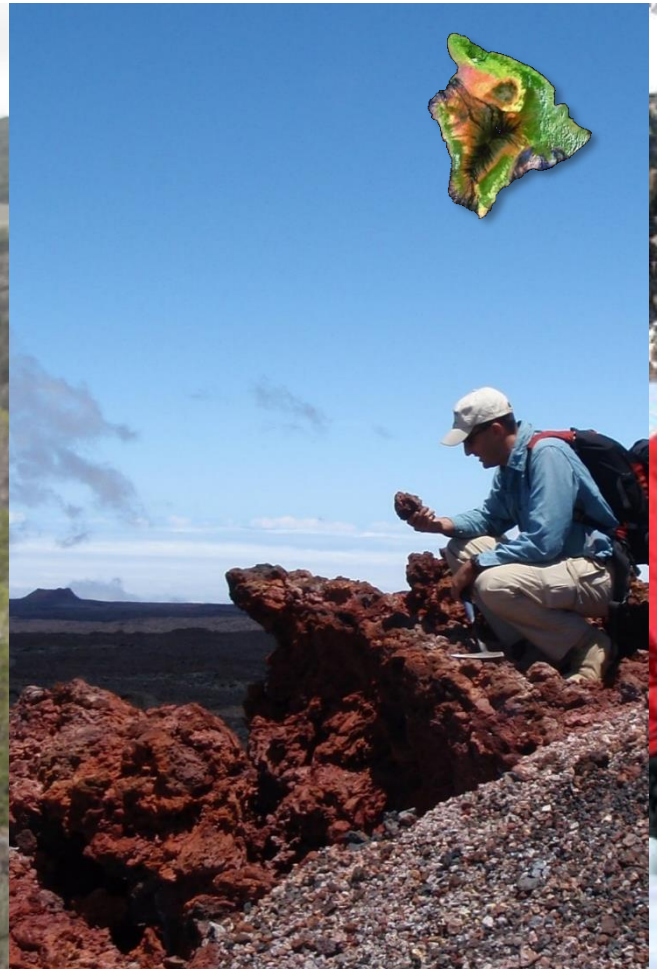
HOW: 1/6-G in Neutral Buoyancy

Neutral Buoyancy Laboratory



Neutral Buoyancy Facility

HOW: Geology Field Exercises and Training



HOW: Solar System Exploration Research Virtual Institute (SSERVI)

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

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

Multispectral Imaging & LiDAR for broad FOV

hXRF & XRD for in situ chemistry and mineralogy

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

HOW: Potential Follow-on to NASA Desert RATS Campaigns

Desert Research and Technology Studies (RATS) missions were a planetary analog

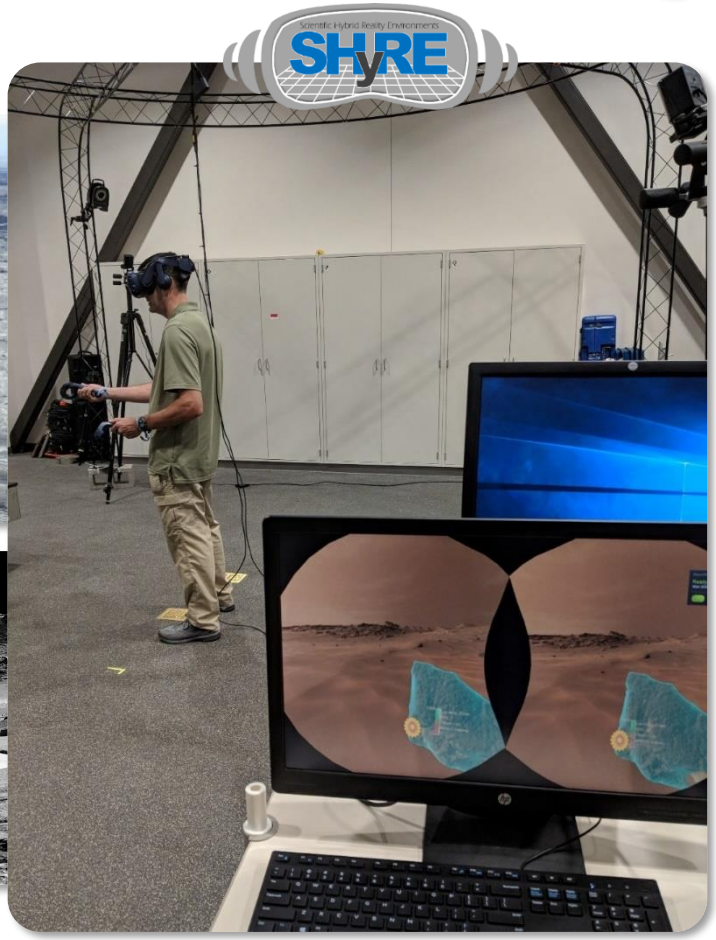
- Took place at the Black Point Lava Flow near Flagstaff, AZ
- Provided environment analogous to Moon and/or Mars, with crew conducting geoscience operations
- Allowed immersion of whole team, both flight crew and flight controllers
- Geoscience data still utilized for research

Final Desert RATS mission took place in 2011

Possible follow-ons for any Lunar mission program

HOW: Scientific Hybrid Reality Environment (SHyRE)

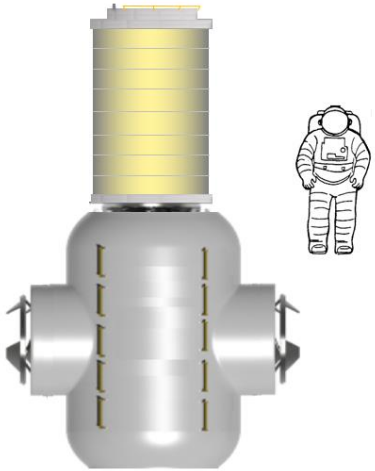
- Developing a high scientific fidelity hybrid reality (HR) model of real-world geological sites of interest, including embedded data and applicable tool usage
- Builds off of several years of RIS^{4}E *in situ* data collection in addition to data collected at the December 1974 flow, Kilauea Volcano,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



HOW: NASA Next Space Technologies for Exploration Partnerships (NextSTEP)

Integration with tests to evaluate future habitation concepts for exploration missions

Numerous components also being developed in other READy activities



HOW: Potential Follow-on to NASA RATS 2012 Simulation

Research & Technology Studies

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

RATS 2012 was an asteroid analog mission

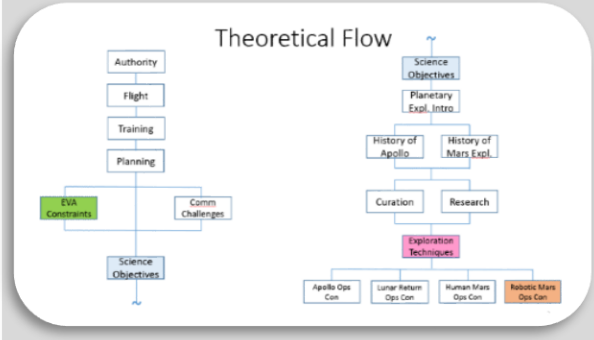
- EVAs conducted in VR Lab and on ARGOS
- Vehicle/asteroid sim was tied to VR lab/EVA sim to allow vehicle and EV interaction

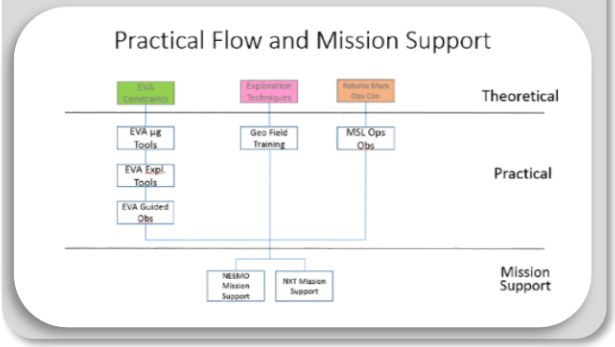
Possible surface-focused follow-ons for any Lunar mission program

HOW: Exploration Operations Training

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





2 Field Geology Ops Training

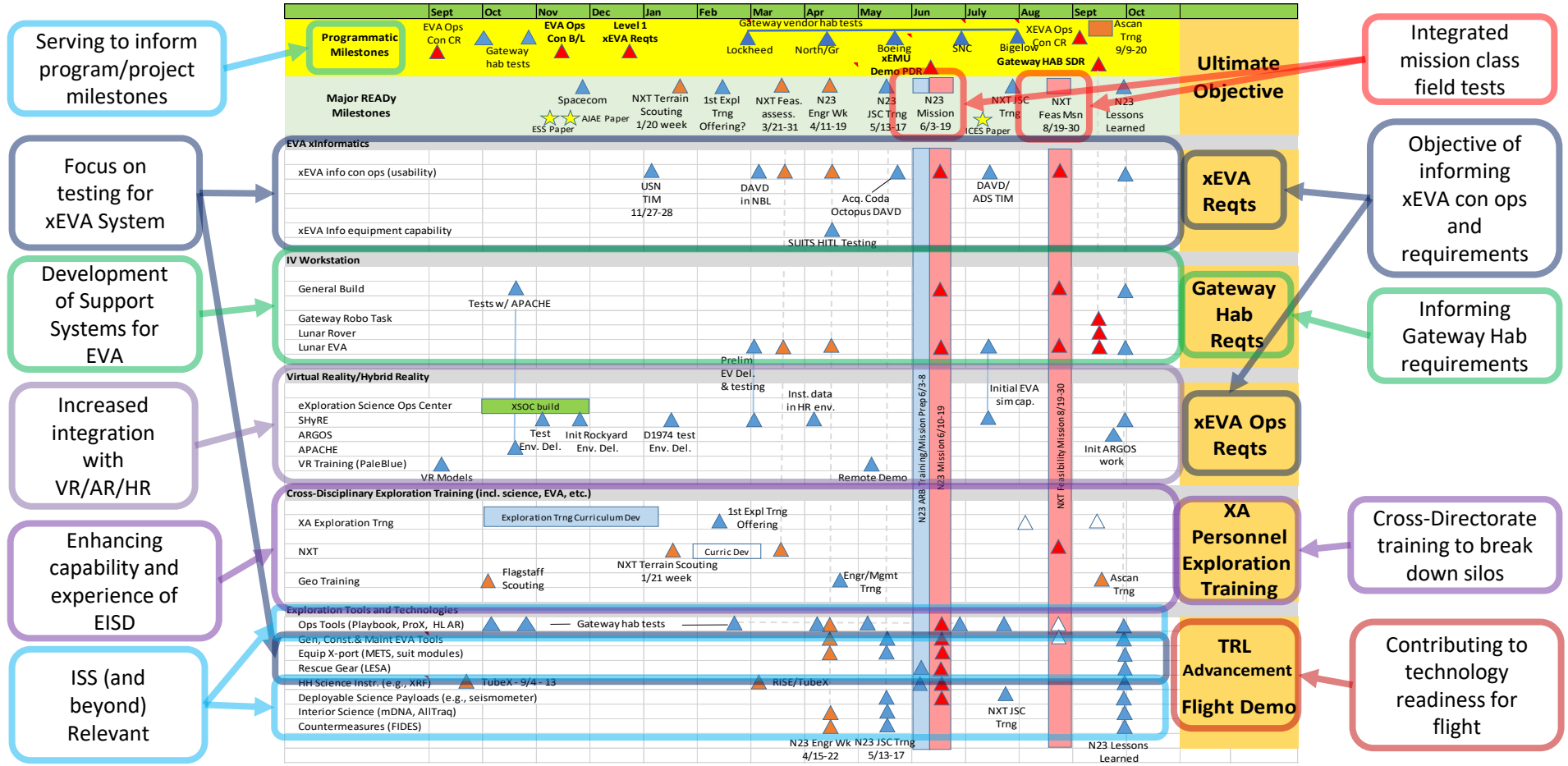
- Geology training in the field geared towards Engineers and managers to provide an understanding and appreciation of science tasks and methodology
- Modeled on the Earth & Planetary Science Training taken by the ASCANs

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

HOW: READy Implementation Plan for FY19

Swim lanes intersect at stand-alone and mission class tests to ultimately meet objectives



READy and the Future of Exploration

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

Acknowledgements

All of the team members and partners that enable the execution of analog missions are critical to the success of READy and Exploration

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Thank you!

Questions?