Preparing for the Next Generation of Planetary Surface Exploration

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Tuesday, November 8th, 2016
Overview

• Who I am, What I do
• Solar System Exploration: past, current, and future
• Analog Testing
• Field Portable Instruments
• Looking Forward
Solar System Exploration
Apollo History of Planetary Surface Exploration

- 6 surface missions from 1969 – 1972
- Sample collection
- Surface science experiments
- Lunar Roving Vehicle
Scientific Drivers for Planetary Exploration

- Massive advancements made since Apollo surface missions, but there are still a number of outstanding science questions across all potential targets of interest for human exploration
- Areas of interest include geology, geophysics, geochemistry, atmospheres, life-related chemistry, etc.
  - Varying levels of human interaction
  - Astrobiology: Planetary Protection
Future Planetary Surface Exploration

- Destinations include small bodies, the Moon, and Mars
- Variable communications delays and atmospheric and gravity conditions
- Flexible technology development is crucial
JOURNEY TO MARS

- HUBBLE
- INTERNATIONAL SPACE STATION
- SPACE LAUNCH SYSTEM (SLS)
- ORBITERS
- LANDERS
- PHOBOS DEIMOS
- SOLAR ELECTRIC PROPULSION
- ASTEROID REDIRECT MISSION
- IN-SPACE HABITAT
- MARS TRANSFER SPACEDRAFT

EXPLORATION
TECHNOLOGY
COMMERCIAL CARGO AND CREW
ORION
HUMAN EXPLORATION
NASA’s Journey to Mars

EARTH RELIANT
MISSION: 6 TO 12 MONTHS
RETURN TO EARTH: HOURS
Mastering fundamentals aboard the International Space Station
U.S. companies provide access to low-Earth orbit

PROVING GROUND
MISSION: 1 TO 12 MONTHS
RETURN TO EARTH: DAYS
Expanding capabilities by visiting an asteroid redirected to a lunar distant retrograde orbit
The next step: traveling beyond low-Earth orbit with the Space Launch System rocket and Orion spacecraft

MARS READY
MISSION: 2 TO 3 YEARS
RETURN TO EARTH: MONTHS
Developing planetary independence by exploring Mars, its moons and other deep space destinations

www.nasa.gov
Moving Forward from Apollo

- International Space Station
- Earth Observations
- Science Experiments
- Long Duration Spaceflight
Planetary Surface Exploration

- What do we need to do to get ready to send humans to other destinations
- Test, test, test
- Requires an ongoing, integrated approach
Terrestrial Field Testing

Field testing technology has always been a crucial part of preparing for future exploration.
Analog Testing

- Multi-disciplinary field test that allows for early end-to-end testing of operational concepts and hardware in a real operational environment
- Evaluates objectives mapped to specific needs and knowledge/technology gaps
- Benefits programs from ISS to Exploration
Desert RATS

- Integrated team of engineers and scientists including most NASA Centers, other Agencies, Military, Academia, High Schools, commercial & international participants

- Tests validate hardware and software as well as mission operations concepts to identify & establish realistic technical requirements applicable to future missions
HABITAT ROVER

- Evaluated next generation habitat rover
- Two rovers simultaneously operating with crews of one astronaut and one geologist

SAMPLE COLLECTION

- Apollo-style tools re-evaluated in new exploration paradigm
- Design, test, re-design
- Multi-year tool evolution between geologists and engineers

HABITAT LABORATORY

- Designed for long duration surface stays
- Real-time, in situ analysis allows for sample high-grading
Integrated EVA Science Operations

- Examined con ops that enable interaction between the MCC & the crew over varying comm latencies including:
  - Interaction with an integrated Science Team
  - Authentic scientific objectives and hypothesis
  - Flexecution methodology

Sample Collection and Curation Procedures

- Assessed varying procedures for scientific data collection
- Investigated what and how much data must be collected during EVA

Crew Training

- Follow-up from initial Astronaut Candidate training
- Best practices for training analog crews
- Relationships between astronaut and geologist crewmembers

WITH VARYING COMMUNICATION LATENCY CON OPS
**DRATS - Science**

**San Francisco Volcanic Field, Arizona**
- Analog site north of Flagstaff, AZ
- Mapped by NASA/USGS team with remote sensing data
- Traverse plans developed for each mission

**Real-time Sample Collection and Geologic Mapping**
- Multiple EVAs designed to map volcanic field
- Samples collected and curated for “return to Earth”
- Initial sample analysis performed in habitat laboratory

**Follow-up Science**
- New projects funded based on results from DRATS
- Seismic studies of volcanic terrain
- Geochemical studies to map flows and cones
• Successful 16 day mission living and working from Aquarius Reef Base

• Completed a combination of Exploration EVA and ISS/Orion related objectives

• International crew with partial crew rotation mid-mission

• Numerous participating organizations across NASA, JSC, ESA, DoD, Research Institutions, Universities, and Industry Partners
NEEMO - Science

NURSERY CONSTRUCTION & SCIENCE

- Constructed and conducted initial science investigation on two long-term coral nurseries near ARB
  - 50’ nursery
  - 90’ nursery (deepest in the world)
- Constructed 5 tree-structures at each site; emplaced 600 samples for scientific research

REEF FOLLOW-UP SCIENCE

- Continued research and sampling conducted during NEEMO 20
- Science team developed the overall sampling strategy and traverse plans

REEF EXPLORATION SCIENCE

- Explored and expanded into new sites and new coral species
- Described, documented, and sampled over 80 additional samples

Authentic science now fully integrated into NEEMO EVA operations
Successfully completed all science objectives during 60+ hours of science driven EVA operations
Examined con ops that enable interaction between the MCC & the crew over a long comm latency including:

- Interaction with an integrated Science Team
- Authentic scientific objectives and hypothesis
- Flexecution methodology

Successfully deployed, tested, and evaluated a prototype optical communications system

Assessed tool needs for navigation
- Traverse plan and map on cue cards showed crew regions and paths, and tasks to complete
- Utilized Doppler relative nav system for crew to find ROI/zones

Utilized an ROV as a robotic asset for IV and ST situational awareness of the EVA

WITH LONG (15 MIN) COMMUNICATION LATENCY CON OPS
NEEMO - Technology

**DIGITAL CUE CARDS**
- Evaluated digital cue cards for EVA crew that allowed crew to operate more effectively and offload IV tasks
- Potential “one-device” for cue cards/procedures, images/video, instrument control, etc.

**IV SUPPORT SYSTEM**
- Evaluated tools the IV crew needs to handle the large amount of real-time EVA information
- Evaluated effective setup in constrained location
- Multiple displays of camera feeds, timeline, nav/comm/sub systems, procedures, logs, etc.

**SCIENCE SAMPLING TOOLS & GEOLOGY SAMPLING KIT**
- Evaluated EVA tools and hardware for science sampling
- Sample Briefcase housed various end effectors with two different drivers (manual and powered)
Field Portable Instrumentation

- Goal of any instrument is to maximize science return and increase efficiency of real-time surface operations.

- Influences not only sample collection, but also in situ data analysis to inform traverse activities.
Field Portable Instrumentation

Solar System Exploration Research Virtual Institute
RIS$^4$E Field Methods

- New science
- Evaluate role of portable instruments for *in situ* analysis
- Recommendations for instrument operations and technology development
RIS$^4$E Field Operations

Aerial kite image from S. Scheidt
RIS$^4$E FIELD SITE: Kīlauea December 1974 Flow

Designed to study physical volcanology & characterize chemistry & mineralogy of lava and alteration products.
The D1974 Flow as an Analog

- Desert environment with brief damp periods
- Alteration resulting from plume-flow interaction
- Basaltic flows interspersed with basaltic ash and basaltic sediments
- Low-slope flow morphology
RIS\textsuperscript{4}E Field Instrumentation

- Multispectral Imaging & LiDAR for broad FOV
- GPR for subsurface structure
- hXRF & XRD for in situ chemistry and mineralogy
- Airborne data for site context
The D1974 Flow as an Analog

- Alteration Coatings: hXRF, XRD, multispectral imaging
- Solfatara: hXRF, XRD, multispectral imaging
- Flow morphology and emplacement: LiDAR, Kite
Operational Considerations

- While increased science value is important, what effect does instrument incorporation have on overall EVA timeline?

- RIS$^4$E builds off of D-RATS heritage to develop operational timelines
hXRF Case Study
Unit Descriptions

- **Unit vf1**: low Al, high K, high Zr, low Ti, mid Mg #
- **Unit vf2**: high Al, low K, low Zr, mid Ti, mid Mg #
- **Unknown unit**: high Al, low K, mid Zr, high Ti, low Mg #
hXRF Case Study

Cost of two minutes per sample
Field Portable Instruments

- Field portable instrumentation is highly beneficial in both sample high grading and gaining real-time contextual insight.

- Selecting an instrumentation suite is non-trivial and should be a priority regardless of target destination.

- Work is ongoing to investigate how these instruments will integrate effectively into future planetary EVAs but continued testing in relevant field environments is crucial.
Crew Training
Crew Training

Sarychev Volcano, Russia
Value of Exploration
Value of Exploration

Cygnus Launch, Oct 17th, 2016

Launch from H St NE

NASA/Bill Ingalls

SpaceX/Dragon
Thank you

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