Design Reference Missions and ISS as Analog for Mars Transit

MIT Aerospace Human Factors Lecture 3

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Chief Scientist, NASA Human Research Program
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Delivered to NASA Administrator and Office of Science and Technology Policy
Provides context for discussing future destinations
Background

  • Long term goal – *To expand permanent human presence beyond LEO and so where practical, in a manner involving international partners*
  • Key objectives (as related to ISS as an analog for exploration):
    • *Sustain the capability for long-duration presence in LEO*
    • *Determine if humans can live in an extended manner in space with decreasing reliance on Earth, starting with utilization of LEO infrastructure*

• NASA established Human Exploration Framework Team (HEFT) in 2010 to develop insights for future human exploration missions esp. systems requirements and technology drivers required for mission success
  • Provided impetus of “capability driven framework”
  • Note: HEFT superseded by Human Architecture Team (HAT) in 2011.

• Results of these ongoing efforts are utilized in identifying technology investments and mission planning for across NASA
Capability Driven Exploration

Notional Incremental Expansion of Human Space Exploration Capabilities

- Mars
- "Planetary Exploration" Access to Planetary Surfaces
- Phobos/Deimos
- "Full Capability" NEA
- "Exploring Other Worlds" Access to Low-Gravity Bodies
- "Minimal" NEA Mission
- "Into the Solar System" Human Exploration of Interplanetary Space
- Increments in technology, systems, flight elements development and operational experience

Key

Candidate Destination

Terrestrial and In-Space Analogs – Ground and Flight Capability Demonstrations

www.nasa.gov/exploration/humanresearch
Common Capabilities Identified for Exploration

Capability Driven Human Space Exploration

Capability Driven Architecture Elements (Building Blocks)

Cross Cutting Systems

Technologies, Research, and Science

OCT Cross Cutting Technology Developments

Human Exploration Specific Research (such as ECLSS, EVA)

HEO and SMD Cross Cutting Research & Science

Human Exploration Specific Technologies

www.nasa.gov/exploration/humanresearch
A Sequence for an Asteroid

Reference NEA Mission: DRM 34B (NEA 2008EV5 with SEP)

- 2008EV5 - Opportunity in 2024
- NEA Mission Duration - 399 days
- Block 2 CPS (LBO), Block 1 CPS (no LBO)
- E-M L1 propellant abort reserve is jettisoned prior to C3 departure burns
- Entry Velocity exceeds MPCV capability (11.5 km/s)

Notes:
- spacecraft icons are not to scale
- ΔV's include 5% FPR
- RCS burns not displayed in chart
- Not all discrete burns displayed
- SEP transit includes 95% thrusting duty cycle

www.nasa.gov/exploration/humanresearch
Mars Design Reference Architecture

- Transition to Mars of ~180 days [max of 210 days]
- Stay of up to 18 months on the surface
- Return to earth ~180 days [max of 210 days] transition
- Early launch of cargo and habitat prior to human launch

Long-surface Stay + Forward Deployment
- Mars mission elements pre-deployed to Mars prior to crew departure from Earth
  - Surface habitat and surface exploration gear
  - Mars ascent vehicle
- Conjunction class missions (long-stay) with fast inter-planetary transits
- Successive missions provide functional overlap of mission assets

Benefits from this DRA
- Mars DRA spans the spectrum of possible HSF exploration missions (NEA, Moon, or Mars)
- Identifies the core risks for exploration

Figure 2-2. Mars Design Reference Architecture 5.0 mission sequence summary (NTR reference)
Design Reference Missions

- Near-Earth Asteroids, 6-month (12-month?) missions
- Mars, 30-month missions
  - Artificial gravity option under consideration for new DRM

1969: NERVA
1999: Bimodal NTR
2002: NEP

~4 rpm
~125 m

www.nasa.gov/exploration/humanresearch
<table>
<thead>
<tr>
<th>ID</th>
<th>Exploration Mission RISK</th>
<th>ISS Demo Candidate (DRAFT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M-EDL</td>
<td>EDL of large Mars payloads</td>
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<td>E-EDL</td>
<td>Earth re-entry at high velocities</td>
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<tr>
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<tr>
<td>A-ISp</td>
<td>Reliability verification of advanced in-space propulsion</td>
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<tr>
<td>Env</td>
<td>Environmental risks: radiation, MMOD, dust, electromagnetic</td>
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<tr>
<td>Dock</td>
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<td>X</td>
</tr>
<tr>
<td>Sys</td>
<td>Systems failures: ECLSS, power, avionics, thermal</td>
<td>X</td>
</tr>
<tr>
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<td>EVA system/suit failure</td>
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<tr>
<td>Comm</td>
<td>Operations under time delayed communication</td>
<td>X</td>
</tr>
<tr>
<td>Aut</td>
<td>Autonomous crew/vehicle operation</td>
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</tr>
<tr>
<td>Health</td>
<td>Crew health: behavioral, health care/remote medical, micro-gravity</td>
<td>X</td>
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<tr>
<td>SW</td>
<td>Software failure</td>
<td>X</td>
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<td>Hum</td>
<td>Human error</td>
<td>X</td>
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<td>ISRU</td>
<td>ISRU equipment failure: propellant, consumables</td>
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<td>ID</td>
<td>HAT Exploration Mission RISKS</td>
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**Analogs and Risk Reduction**

- Evaluate proposed candidates -
  - Risk reduction, need, priority, feasibility
  - Analog integration

**Candidate Analog Exploration Proposals**

**Analog Platforms**

- **Terrestrial Analogs**
  - DRATS, Haughton-Mars, Mars-500
- **Partial Gravity**
  - NEEMO, NBL, bedrest
- **No gravity**
  - ISS
Why ISS as a Mars Analog?

- Crew durations that mimic Mars transit phase (approx 6 mos)
- Continuous operations in zero-g provides systems durations that span the Mars mission – validates system performance requirements
- Long duration “microgravity” environment – pressurized and un-pressurized payloads
- Science laboratories from four international space agencies: US, Europe, Japan, Russia
- Life support, power, data, and facilities for 6 astronauts (subjects and operators)
- Ground control and on-orbit support for 24/7 operations
# Potential Exploration Candidates for ISS Testing Roadmap

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</thead>
<tbody>
<tr>
<td>R2 0-G Mobility System IVA/EVA</td>
<td>Robotic Free Flyer Inspector</td>
<td>Robotic Free Flyer Satellite Servicing</td>
<td>RCS Sled / Manipulators</td>
<td>Super Safer Personal Mobility System</td>
<td>Adv. Suits and PLSS</td>
<td>Exploration Test Vehicle w/Suit Port</td>
<td>SEV w/Adv Suits</td>
</tr>
<tr>
<td>ISS Airlock to Test Exploration Atmosphere and EVA ops</td>
<td>Exploration Optical Comm Loop</td>
<td>Radiation Mitigation Testing</td>
<td>SEV ECLSS sub-system Test</td>
<td>Exploration Comm Loop</td>
<td>Modular Power Systems (Batteries, PV)</td>
<td>Advanced Logistics and Waste Mgt.</td>
<td>ISS/DSH Reliable ECLSS</td>
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More details and images available at www.nasa.gov/exploration/humanresearch.
Human research on ISS supports crew health and performance for current and future space missions

- Pre-screening
- Exercise
- Nutrition
- Pharmaceuticals
- Operational workarounds
- Other countermeasures as needed
ISS as an Exploration Test Bed - Objectives

◆ Evaluate new exploration technologies as they become available

◆ Advance preparations for crew autonomous operations for Mars or NEA exploration

◆ Exercise ground elements training and technology development

◆ Long Term Goal

......Conduct long duration Mars Transit and Landing Transition simulations using technology and operational tools & concepts developed and tested during previous On-Orbit and Earth-based Analogs
What can ISS offer to human research in a simulated Mars transit?

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Weaknesses</th>
</tr>
</thead>
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<tr>
<td>◆ Weightless duration comparable to opposition-class mission Earth-to-Mars and Mars-to-Earth transits</td>
<td>◆ Shielded from deep-space radiation environment</td>
</tr>
<tr>
<td>◆ Physiology and countermeasures development and validation</td>
<td>◆ Proximity to Earth</td>
</tr>
<tr>
<td>◆ High-fidelity representation of astronauts in a spacecraft in the flight environment with operational tasks and facing meaningful risks</td>
<td>◆ Minimal time delay in communications</td>
</tr>
<tr>
<td></td>
<td>◆ Frequent abort opportunities</td>
</tr>
<tr>
<td></td>
<td>◆ Earth is always just outside the window</td>
</tr>
</tbody>
</table>

Behavioral health and performance
Human factors
Exploration-related NASA biomedical planning

◆ “Mars Surface Analog Project”
  - NASA JSC, 2002-2003
  - Three workshops of long-duration astronauts, flight medicine specialists, biomedical researchers
  - Discussed capabilities of astronauts on Mars immediately after 6-month transit
    - ISS Expedition 6, May 2003
    - Bloomberg, Functional Task Test
  - HRP established in 2005 for Mars-focused human research and technology

◆ “ISS Crew Increment Durations: Extension and Simulation of Mars Missions”
  - NASA HRP/JSC/ARC, Sep. 2009
  - A workshop of NASA subject matter experts
    - How to extend ISS crew increments to 9-12 months?
    - How to use ISS to mimic a Mars mission?

◆ “ISS as Testbed for Analog Research (ISTAR)”
  - NASA-wide since Sep. 2010
    - HRP planning meeting "Toward a unified HRP perspective on ISS as Mars transit analog," Jan. 2011
    - Bill Gerstenmaier quoted in Aviation Week & Space Technology, Mar. 7, 2011
  - Early ISTAR emphasis includes time-delay, crew autonomy aspects of simulated Earth-Mars transit
Exploration Capability Phased Development Strategy

Phase I
Build the Foundation


ISS Operations and Exploration Capability Testing on ISS

Phase II
Develop the Capabilities

Exploration Mission Development and Validation

Phase III
Test the Capabilities

Exploration Capabilities Development

Phase IV
Sustainable Exploration of the Solar System

Exploration Capabilities Testing

Human Exploration Missions

www.nasa.gov/exploration/humanresearch
ISTAR is a joint collaboration project between NASA’s Exploration and International Space Station (ISS) Programs

- An ISTAR Integrated Product Team (IPT) has been established
- Defines and ranks Exploration Development Test Objectives (xDTOs)

ISTAR xDTO categories established to mitigate Key Exploration Risks and answer Architectural Questions

- Human Research including Behavioral, Medical, and Performance
- Autonomous Operations
- Mission Planning & Execution
- Exploration Technology Demonstration

ISTAR collaborates with NASA Earth-based analogs

- DRATS - Desert Research and Technology Studies
- NEEMO - NASA Extreme Environment Mission Operations
- PLRP – Pavillion Lake Research Project
- Space Station Training Facility (SSTF), Neutral Buoyancy Lab (NBL), MCC (!), etc.
## 4 Phased Approach for ISS as Mars or NEA Testbed

<table>
<thead>
<tr>
<th>Phase</th>
<th>Major features of plan</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A</strong></td>
<td>ISTAR will use planned ISS operations and activities for Mars and NEA Risk Abatement. Operational, experimental protocols to protect safety, health, efficiency of ISS crewmembers are evaluated for their applicability to Mars (and NEA) missions. Other analog environments are reviewed to ensure maximum utilization &amp; lessons learned prior to manifesting on ISS.</td>
</tr>
<tr>
<td><strong>B</strong></td>
<td>An initial Mars transit mission simulation is planned for Summer 2012. This simulation will include evaluation of countermeasures for communications delays, medical and behavioral experiments, technology / process improvement research and human/robot interactions. Crew procedures and MCC oversight will be modified to provide more realistic experience in autonomous operations to both crew and ground personnel. Emphasis on crew and ground behavioral and performance measures, autonomy. Architectural risk mitigation limited due to hardware development, processing and manifesting timelines.</td>
</tr>
<tr>
<td><strong>C</strong></td>
<td>Longer periods of autonomy will be simulated. Comm delays will be used to simulate those that will be encountered in Mars transitions. Crew procedures and MCC oversight continue to be modified to provide more realistic experience in autonomous operations to both crew and ground personnel. Other technology and process improvement research experiments will also be conducted. Increasing emphasis on DTOs for hardware, subsystems, food systems, logistics, etc. May include IV and EV experiments. Post-landing multi-day activities will be conducted.</td>
</tr>
<tr>
<td><strong>D</strong></td>
<td>Transits to Mars (and NEAs) will be simulated as rigorously as feasible in low Earth orbit with existing infrastructure. Progressively increasing communications delays may be introduced, reaching the maximum delay after 6 months to mimic Mars proximity. On-board science operations to be compatible with Mars-like mission parameters. Emphasis gradually shifting to efficacy of countermeasures for behavioral, health and performance. Subsystem level hardware analysis, e.g. ECLSS, EPS, etc. Post-landing exploration mission analogs will be expanded.</td>
</tr>
</tbody>
</table>

15 Sep. 2011  
[www.nasa.gov/exploration/humanresearch](http://www.nasa.gov/exploration/humanresearch)
**ISTAR - 5 Year Strategic Plan**

*Utilizes* **phased approach** to reduce Exploration Risks, answer Architectural Questions, and execute long-duration Exploration Mission Simulations

- Begin with short duration ISTAR Analogs to test risk mitigating technologies & operational tools
- Establish baselines for crew performance, behavior, and medical procedure; develop and test countermeasures
- Increase periods of Crew/Vehicle Autonomy Simulations
  - Crew procedures & Mission Control operations will be modified to provide more realistic experience to crew/ground control personnel.
  - Perform Comm Delays leading to full (voice/data/command) Mars Transit-delays by 2016 (Notional) \( \sim 12 \text{ minutes each way} \)
- Post-landing exploration mission analogs will be added eventually

*Continue development of ISTAR Analog Groundrules & Constraints*

*Continue working with technology & science experiment developers of risk mitigating xDTOs candidates and map them to future ISS Increments*

*ISTAR 5 Year Plan will be integrated with larger multi-year plan for all Exploration Analogs*
Assumptions

- No Mars Mission related test will place ISS vehicle or astronauts at risk
  - Develop rules for simulation breakouts for ISS nominal events and anomalies, while maximizing continuous simulation time
  - Assume an ISS flight control team for comm, timelines, systems experts
- Effects on “non-Mars” payloads to be minimized
- Agreement by, and involvement of, all ISS partners is sought
- Use current Soyuz crew rotation scheme, and preserve or accommodate original ISS visiting vehicle schedule
- Involve flight crewmembers and ground elements (possibly up to and including families) and technology development
- This will not be a one-time event
  - Multiple opportunities throughout ISS operational life
    - Initial tests: days to weeks to evaluate test protocols
    - Later: weeks to months to evaluate complex FTO’s
  - Exploit early (low cost or no cost) opportunities for ISS to advance preparations for Mars and NEO missions
Variation in Distance and Communications Delay Between Earth and Mars (example: 2001-2005)

Variation in Distance and Communications Time Delay Between Earth and Mars, 2001-2005

Distance (AU)

Comm. delay (min.)

Farthest from Earth

Closest to Earth

Outbound transit to be simulated on ISS

Calendar date

08/26/00 02/24/01 08/25/01 02/23/02 08/24/02 02/22/03 08/23/03 02/21/04 08/21/04 02/19/05 08/20/05 02/18/06 08/19/06

0
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22

www.nasa.gov/exploration/humanresearch
Human Research Program (HRP) is developing a comm delay research investigation JSC-HRP-076 [Voice Comm Delay] to fly on Incr 35/36.

In preparation for HRP comm delay research, the ISTAR team has prepared a proposal for Incr 31/32 and 33/34 to evaluate operational countermeasures for the crew and ground to use when voice comm is not available [video clips, text, voice sound clips (eg: MP3 files)]

Objectives for Incr 31/32

• Evaluate comm-delay countermeasures for use in long duration zero-g missions
• Begin training the FCT for more autonomous crew operations
### ISTAR 1 xDTOs
Planned for ISS Increment 31-32 (Mar – Sep 2012)

<table>
<thead>
<tr>
<th>ISTAR ID</th>
<th>Proposer</th>
<th>xDTO Name</th>
<th>Description of Candidate</th>
</tr>
</thead>
<tbody>
<tr>
<td>JSC- HEDS-001</td>
<td>HEDS</td>
<td>Communications Delay Countermeasures</td>
<td>Evaluate countermeasures for voice communication delays. Identify what types of tasks are most affected by a communication delay and which countermeasures provide the best results. Participants include flight crew and ground crew. Survey the flight and ground crews in flight for lessons learned that can be incorporated for additional testing later in the increment.</td>
</tr>
<tr>
<td>JSC-011</td>
<td>JSC/SF2</td>
<td>Active Shielding Proof of Concept</td>
<td>Radiation Shielding: Gather real-time in-orbit data on power consumption and particle trajectories to assess the feasibility of implementing a large-scale magnetic field to shield crew. No new hardware required. Will utilize Alpha Magnetic Spectrometer (AMS) measurements. [Requires PI approval]</td>
</tr>
<tr>
<td>JSC-017</td>
<td>ARC</td>
<td>SPHERES Free Flyer Simulated EVA Inspection</td>
<td>The Human Exploration Telerobotics project is working to upgrade the capabilities of the Synchronized Position Hold Engage Reorient Experimental Satellites (SPHERES) to enable interactive control (with crew or from the ground) and utilize an integrated vision system to inspect small IVA features to simulate EVA inspections for MMOD damage. Demonstrate how robotic inspection tasks can reduce the time required for inspections that are normally conducted by the crew.</td>
</tr>
<tr>
<td>JSC-091</td>
<td>JSC/ER4</td>
<td>Robonaut 2 Simulated EVA Routine and Emergency Operations</td>
<td>Robonaut 2 (R2) brings an unprecedented level of robotics dexterity to ISS. Initially, R2 will earn its stripes in the IVA environment and a fixed base progressing over time toward mobility and EVA. In preparation for transitioning to an EVA version of R2, it is proposed to conduct EVA-like tasks using the IVA R2.</td>
</tr>
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</table>
Phase A (Inc 31/32, Inc 33/34):
- Focus on how to deal with communications delays
  - Methods, countermeasures for communications delays
  - Begin developing criteria for autonomously executable procedures
  - Countermeasures tested under normal communications environment (no delay)
- Utilize USOS crew and MCC-H (see xDTO JSC-HEDS-001)
- ISTAR IPT to collect and review results and determine when ready to proceed to next Phase
  - Allow time to implement lessons learned from Phase A for Phase B
  - Review results and determine anything needed for Phase B

Phase B (Inc 35/36...):
- Continue testing from Phase A plus comm delay
- Support for HRP comm delay investigations

Phases C and Beyond: Increase complexity and depth of communications delays – more autonomy
Timeline of Research on Autonomy: NASA Efforts

- 2006-2008: Research on Autonomy in Analog Environments: Nick Kanas
- 2009: Autonomy Workshop
- 2010: Autonomy Literature Review
- 2010: Monitoring Technology Development (SBIR)
- 2010: NEEMO 14 Autonomy Study
- 2010: Autonomy NRA

www.nasa.gov/exploration/humanresearch
Across these analogs, results suggest that participants react positively in autonomous environment

Results also suggest some negative affective outcomes for some of the ground controllers that participated in these

- May suggest that autonomy may have adverse impacts on those that are affected by changes in autonomy during a space mission, especially if participants experience a lack of job clarity and role assignment
- Thus, important to consider space crews AND ground control

<table>
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<tr>
<th>Analog</th>
<th>High Autonomy Condition</th>
<th>Low Autonomy Condition</th>
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<tbody>
<tr>
<td>NEEMO</td>
<td>Measures: •Profile of Mood States</td>
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<td></td>
<td>•Group Environment Scale</td>
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<tr>
<td>Haughton Mars-Project</td>
<td>•Cohesion</td>
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<tr>
<td>Mars 105 Study</td>
<td>•Work Environment Scale</td>
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</table>
### MARS 105 (April 2009 – July 2009)
- **Participants:** 6 crewmembers in habitat (4 Russians and 2 Europeans); 19 mission control
- **Protocol:** First 10 weeks of 15 week protocol, real time com; last 5 weeks, 40-minute two-way with outside (also varied autonomy over schedule)
- **Measures:** Weekly POMS, GES, WES, subjective performance assessment
- **Outcomes:**
  - Communication delay was feasible to implement – no adverse outcomes
  - Crewmembers found high autonomy to be positive, depending less on others for directions
  - Russian crewmembers reported increased work pressure
  - Mission control reported more tension, confusion and less task orientation
  - No findings reported specific to communication delay

### MARS 500 (June 2010 – Nov 2011)
- **Participants:** 6 crewmembers in habitat (three Russian, two European and one Chinese); mission control
- **Protocol:** First and last month, real time audio with mission control. For remaining time, only written com w/ mission control, with delay up to 24 minutes (delay varies from 8 sec to 24 minute two-way, with maximum delay on flight day 351; connection disruptions)
- **Outcomes:** Ongoing

### HMP – Telemedicine (2007)
- **Participants:** Case study evaluating simulated appendectomy through telemedicine with a 15 minute, one-way delay in com bet. locations
- **Protocol:** Remote expert provided video instructions via 15 minute transmission delay to site. Non-expert conducted operation and provided video of procedure back to expert via 15 minute transmission delay to consulting location.
- **Measures:** Subjective assessment of operations
- **Outcomes:**
  - Delay during operative procedure feasible
  - Total time required to perform appendectomy was 2.25 h, which included 1.5 h of built-in communication delays
  - The simulated appendectomy was performed by a minimally trained operator using just-in-time education combined with remote asynchronous guidance delayed for extreme communication distances

### NEEMO 12
- **Participants:** 4 NASA crewmembers and 8 “topside” personnel
- **Protocol:** Five days of low autonomy and five days of high autonomy (where crewmembers had more flexibility to plan their own work schedule and experienced a 40-minute two-way communication delay with mission control)
- **Measures:** At the middle and end of mission, completed a questionnaire containing many of the subscales from the POMS, GES, and WES.
- **Outcomes:**
  - High autonomy condition was successfully employed in NEEMO 13 with no adverse results.
  - Confusion increased for topside personnel during high autonomy condition
  - No findings reported specific to communication delay
  - Anecdotal report from NEEMO coordinator that NEEMO commander and crew demonstrated high compliance to following communication delays in accordance with protocol
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<tr>
<td>NEEMO 14</td>
<td>N/A</td>
<td>N/A</td>
<td>Study protocols did not include communication delay as independent variable; crew however tested feasibility of communication delay for future studies</td>
</tr>
<tr>
<td>Laboratory Simulations John Hopkins (2004-2008)</td>
<td>Three-person mixed gender crews conducting a computer-based task (collecting ‘samples’)</td>
<td>Study A: drop in both audio and text com. Study B: three minute delay in text and whiteboard com and five second delay in audio.</td>
<td>Total value of collection samples</td>
</tr>
</tbody>
</table>

**These investigations demonstrate:**
- It is feasible to implement communication delay in space analogs
- Additional investigations are needed to accurately characterize the impact of a systematic communication delay on performance
- Accurate selection criteria and “communication milestones” (designated times where necessary information is relayed to mission control) can offset adverse outcomes (Otto, HMP Telemedicine)
- Essential to isolate variables to minimize confounds and provide more conclusive results; lack of findings specific to communication delays in RCS-105 and NEEMO 12 due to varying other criteria
- Participants should be “on board” with the protocol and attempts should be made to promote perception of “bounded autonomy” and/or communication delay (e.g., approach to communication delay varied between NEEMO 12 and NEEMO 14. NEEMO 12 provided clear protocol and buy-in from crew).
Bounded Autonomy: involves the conditions, constraints, and limits that influence the degree of discretion by the individual and [crew/team] over their choices, actions and support in accord with standard operating procedures.

Important tasks to target:
Results from the hierarchical linear modeling analyses suggest that:

1. Team-member exchange significantly predicted well-being
2. Demands positively predicts well-being when controlling for cohesion
3. Dedication is positively related to performance

Overall, results suggest difference in performance cohesion (and other team results) between low and high autonomy conditions.

Positive effects of increased autonomy on:
- crew performance
- crew dynamics (teamwork)
- crew cohesion
Some ISTAR xDTOs will seek International Partner (IP) participation or use of IP facilities

- "Behavioral" and "Crew Autonomy" investigations may impact visiting vehicle or spacewalk (EVA) scheduling
  - Communications/Data delay xDTOs could impact other operations (e.g. payloads)
  - Multilateral agreements will be required
- New crew planning and execution tool xDTOs are planned
  - All ISS Partners’ Mission Control Center (MCC) procedures and tools for planning and execution are integrated and must stay in sync
- Post-Landing (if it affects landing site ops or crew return)

ISSP has initiated discussions with IPs to seek their cooperation

- Positive but reserved initial reaction received at ISS multi-lateral forums
- ISS IPs have expressed interest in executing their own xDTOs
- Process to integrate IPs’ initiatives is in development
ISTAR
International Space Station Test Bed for Analog Research

Human & Architectural Risks

ISTAR Process
- xDTO Solicitation
- xDTO Screening
- Increment Planning
- xDTO Candidates Selection
- Collaboration with Earth based Analogs

“Using ISS as an analog test platform to develop and demonstrate new technologies and operational concepts. ISTAR xDTOs mitigate the risks and challenges facing astronauts on long distance voyages to asteroids, planet Mars and perhaps destinations even further from Earth.”

Coming to NASA Summer 2012
The End.

Questions?
## Table of Contents

- **Background**
  - Relationship to NASA 2010 Authorization Act
  - Capability Driven Exploration
  - Common Capabilities Identified for Exploration
  - Mars Design Reference Architecture
  - Exploration Mission Risks

- **Analogs and risk reduction**

- **Why ISS as a Mars Analog?**

- **ISS as an Exploration Test Bed - Objectives**

- **Exploration Capability Phased Development Strategy**

- **Potential Exploration Candidates for ISS Testing Roadmap**

- **International Space Station Test bed for Analog Research (ISTAR)**

- **4 Phased Approach for ISS as Mars or NEA Test bed**

- **ISS Exploration Testing Flow**

- **Exploration mission plans for Summer 2012**

- **Future Plans**
RESEARCH OBJECTIVES:
• The Miniature Exercise Device will demonstrate key motion system technology required to reduce the volume and weight of countermeasure equipment that will be needed for long term space flight.
• The goal is to develop countermeasure systems that are small and an order of magnitude lighter than existing systems.

OPERATIONS:
• The ISS Crew will train for installation and operations of the MED. This training is expected to be about 2 to 4 hours.
• The crew will install the MED device on the Advanced Resistive Exercise Device (ARED).
• The crew will use the MED at various load levels and modes of operation. Data will be recorded by the instrumentation on the MED and sent to the ground for evaluation.
• The crew will report observations on the performance of MED to the ground team.
• The ground team will analyze the data and determine control parameter adjustments as needed to tune the MED.
• After making changes to the control parameters the crew will use the MED at various load levels and modes of operation.
• This cycle is repeated for a total of not less than 3 sessions.
Autonomy ‘Tutorial’: Mars/ISS Analog Mission

BHP Research Element
Autonomy Report

Human Research Program
Behavioral Health & Performance Element
Space Medicine Division

March 24, 2010

Cristina Rubino, M.A.
Kathryn E. Kooton, Ph.D.

National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Houston, Texas

Behavioral Health & Performance Research Element
Human Research Program
Space Medicine Division

Team Gap 6: Given the context of long duration missions, what are the optimal ways to support and enable multiple distributed autonomous teams to support task performance, teamwork, and psychosocial performance?

Decision Point: Are additional studies needed in regards to Autonomy?

Summary:

The Behavioral Health & Performance Element (BHEP) is one of six elements within the Human Research Program and is comprised of four Risks, namely the Risk of Behavioral Conditions, the Risk of Psychiatric Disorders (BMed), the Risk of Performance Decrement due to Inadequate Communication, Coordination, and Psychosocial Adaptation within a Team (Team), and the Risk of Performance Errors due to Sleep Loss, Circadian Desynchronization, Fatigue, and Work Overload (Sleep).

The Team Risk is comprised of four primary risk factors: cooperation, coordination, communication, and psychosocial adaptation. These primary risk factors represent the dimensions of teamwork as well as the component of individual and team adaptation within the unique spaceflight environment. Within the Team Risk there are also specific gaps that represent the areas in which critical knowledge is unknown or an adequate mitigation strategy is not yet developed. As long-duration missions are expected to have increased autonomy as a
BHP oversaw two proposals that plan to develop a technology that will monitor level changes of autonomy based upon a theoretical framework that models autonomy over time.
Forward Plan

◆ Continue near term ISTAR efforts to mature exploration capabilities via DTO’s on ISS
   • DTO’s are being proposed for future Increments

◆ More complex system level candidate proposals, from Candidate Roadmap, are being developed jointly between Exploration and ISS teams
   • White papers are being developed for EVA, ECLSS, Communication and Exploration Test Module (ECD = Fall 2011)
Overview of *Hypothetical* Mars Expedition

Based on: *Human Exploration of Mars*, DRA 5.0, NASA-SP-2009-566, July 2009

- **Earth-to-Mars transit**: ~6 months
- **Mars surface stay**: ~18 months
- **Mars-to-Earth transit**: ~6 months

ISS expeditions of ~6 months duration simulate Earth-to-Mars transit
- similar crew condition as at Mars arrival
Overview of *Hypothetical* NEA Expedition

**Earth-to-NEA transit:** ~3-4 months  
**NEA surface ops:** ~2 weeks  
**NEA-to-Earth transit:** ~1-3 months

**NEA expeditions**  
- Validate technologies and procedures for Mars missions  
- Acquire additional unique deep-space data  
  - Dust on and near asteroids  
  - Near-NEA radiation environment  
  - Behavioral health & performance

**ISS expeditions of ~6 months duration simulate ~6-month+ Earth-to-NEA round trip**  
- 0-g baseline  
- Experience base
## ISTAR - Phased Approach for ISS as Exploration Test Bed

<table>
<thead>
<tr>
<th>Phase</th>
<th>Major features of plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Eval ISS capabilities [2011-2012]</td>
<td>Primarily current ISS operations and activities. Operational, experimental protocols to protect safety, health, efficiency of ISS crewmembers are evaluated for their applicability to Mars (and NEO) missions.</td>
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<tr>
<td>B Short-period sims [2013-2014]</td>
<td>Discrete Mars-forward activities inserted, such as intermittent multi-day periods of different degrees of bounded autonomy by ISS crew, including communications delays typical of Mars missions. Sets of assigned tasks to be accomplished with minimal intervention by MCC, but few alterations to on-board procedures and MCC monitoring of ISS systems. Minimize impact to non-Mars onboard science operations. Flight rules specify threshold at which simulation is broken in case of emergency or system malfunction. Add “exploration” tasks to post-landing timeline.</td>
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<td>D 6 month mission and crew deconditioning [post 2015]</td>
<td>Transits to Mars (and NEOs) simulated as rigorously as feasible in low Earth orbit with existing infrastructure. Progressively increasing communications delays may be introduced, reaching the maximum delay after 6 months to mimic Mars proximity. On-board science operations to be compatible with Mars-like mission parameters. Expanded post-landing exploration mission analogs.</td>
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</table>
Notional Architecture Elements

- Space Launch System (SLS)-HLLV
- Multi-purpose Crew Vehicle (MPCV)
- Cryogenic Propulsion Stage (CPS)
- Solar Electric Propulsion (SEP)
- Lander
- Mars Elements

Graphics are Notional Only – Design and Analysis On-going

- EVA Suit
- Multi-Mission Space Exploration Vehicle (MMSEV)
- Deep Space Habitat (DSH)
- Robotics & EVA Module (REM)
- Kick Stage
- NEA Science Package

www.nasa.gov/exploration/humanresearch

15 Sep. 2011
## Technology Applicability to Destination (1)

<table>
<thead>
<tr>
<th>Technology Area</th>
<th>LEO (31A)</th>
<th>Adv. LEO (31B)</th>
<th>Clo-Lunar (32A, B &amp; 33A, B)</th>
<th>Lunar Surface - Sortie (33C)</th>
<th>Lunar Surface - GPPOD (33X)</th>
<th>Min NEA (34A)</th>
<th>Full NEA (34B)</th>
<th>Mars Orbit</th>
<th>Mars Moons (35A)</th>
<th>Mars Surface (35B)</th>
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<tbody>
<tr>
<td>LO2/LH2 reduced boiloff flight demo</td>
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<tr>
<td>LO2/LH2 reduced boiloff &amp; other CPS tech development</td>
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<td>LO2/LH2 Zero boiloff tech development</td>
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<td>In-Space Cryo Prop Transfer</td>
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<td>Electrolysis for Life Support (part of Energy Storage)</td>
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<td>Fire Prevention, Detection &amp; Suppression (for 8 psi)</td>
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<td>Environmental Monitoring and Control</td>
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<td>High Reliability Life Support Systems</td>
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<td>Closed-Loop, High Reliability, Life Support Systems</td>
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<td>Proximity Communications</td>
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<td>In-Space Timing and Navigation for Autonomy</td>
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<td>High Data Rate Forward Link (Ground &amp; Flight)</td>
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<td>Hybrid RF/Optical Terminal (Communications)</td>
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### Behavioral Health
- Optimized Exercise Countermeasures Hardware
- Human Factors and Habitability
- Long Duration Medical
- Biomedical countermeasures
  - Space Radiation Protection – Galactic Cosmic Rays (GCR)
  - Space Radiation Protection – Solar Proton Events (SPE)
  - Space Radiation Shielding – GCR & SPE
- Vehicle Systems Mgmt
- Crew Autonomy
- Mission Control Autonomy
- Common Avionics
- Advanced Software Development/Tools
- Thermal Management (e.g., Fusible Heat Sinks)
- Mechanisms for Long Duration, Deep Space Missions
- Lightweight Structures and Materials (HLLV)
- Lightweight Structures and Materials (In-Space Elements)

---

**Not applicable** | **Probably required**
---|---
**May be required** | **Required technology**
---|---

15 Sep. 2011  www.nasa.gov/exploration/humanresearch
BHP developed a call to study autonomy for spaceflight in a NRA that was posted this summer.

Focused on mitigation strategies for space crew as well as ground control.