International Space Station
Mars Analog Update

Brief to NASA Advisory Council – August 2, 2011
NASA/JSC/Charlie Stegemoeller
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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 the Human Exploration Framework Team in 2010 to develop insights for future human exploration missions with cognizance on the systems requirements and technology drivers required for mission success
  • Provides the impetus of the “capability driven framework”
  • The results of these ongoing efforts are utilized in identifying technology investments and mission planning for across the agency
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
- "Gaining the High Ground" Human Access to Cis-Lunar Space
- GEO/HEO Missions
- Lunar Flyby & Orbit
- Lunar Surface Missions
- New LEO Missions

Increments in technology, systems, flight elements development and operational experience

Key
Candidate Destination

Terrestrial and In-Space Analogs – Ground and Flight Capability Demonstrations
Common Capabilities Identified for Exploration

Capability Driven Human Space Exploration

Capability Driven Architecture Elements (Building Blocks)

Cross Cutting Systems

Technologies, Research, and Science

Human Exploration Specific Research
(such as ECLSS, EVA)

Human Exploration Specific Technologies
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
# Exploration Mission Risks

Reference: Human Spaceflight Architecture Team (HAT)

<table>
<thead>
<tr>
<th>ID</th>
<th>Exploration Mission RISK</th>
<th>ISS Demo Candidate (DRAFT)</th>
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<tbody>
<tr>
<td>M-EDL</td>
<td>EDL of large Mars payloads</td>
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<td>Earth re-entry at high velocities</td>
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<td>Lndr</td>
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</tr>
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<td>CSM</td>
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<td>A-ISP</td>
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<tr>
<td>Env</td>
<td>Environmental risks: radiation, MMOD, dust, electromagnetic</td>
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<td>Dock</td>
<td>Docking/assembly failures</td>
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<td>Crew health: behavioral, health care/remote medical, micro-gravity</td>
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<td>Software failure</td>
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<tr>
<td>Hum</td>
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<td>ISRU</td>
<td>ISRU equipment failure: propellant, consumables</td>
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**Analogs and Risk Reduction**

Evaluate proposed candidates -
- Risk reduction, need, priority, feasibility
- Analog integration
  [Are we using the right analog to buy down the risk?]

**Candidate Analog Exploration Proposals**

**Analogue Platforms**
- Terrestrial Analogs
  [DRATS, ISRU, Haughton-Mars]
- Partial Gravity
  [NEEMO, NBL]
- Micro-gravity
  [ISS]

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Why ISS as a Mars Analog?

- The ISS provides crew durations that mimic Mars transit phase (approx 6 mos)
- The ISS continuous operations in micro-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, and Russia
- Life support, power, data, and facilities for 6 crew (subjects and operators)
- Ground control and on-orbit support for 24/7 operations
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
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
Exploration Capabilities Development

Phase III
Test the Capabilities
Exploration Capabilities Testing

Phase IV
Sustainable Exploration of the Solar System
Human Exploration Missions

TBD

Human Exploration Missions

TBD
Potential Exploration Candidates for ISS Testing Roadmap

- **2012**
  - R2 0-G Mobility System
  - IVA/EVA

- **2013**
  - Robotic Free Flyer Inspector

- **2014**
  - Robotic Free Flyer Satellite Servicing

- **2015**
  - RCS Sled / Manipulators

- **2016**
  - Super Safer Personal Mobility System

- **2017**
  - Adv. Suits and PLSS

- **2018**
  - Exploration Test Vehicle w/Suit Port

- **2019**
  - SEV w/Adv Suits

**Human Health**

- ISS Airlock to Test Exploration Atmosphere and EVA ops

- Exploration Optical Comm Loop

- Radiation Mitigation Testing

- ISS/DSH Reliable ECLSS

**Robotic Systems**

- Modular Power Systems (Batteries, PV)

- Advanced Logistics and Waste Mgt.

**EVA Systems**

- SEV ECLSS sub-system Test

- Exploration Comm Loop

- ISS/DSH Reliable ECLSS

**SEV**

- Modular Power Systems (Batteries, PV)

- Advanced Logistics and Waste Mgt.

**DSH**

- Exploration Test Vehicle w/Suit Port

- Exploration Test Vehicle w/Suit Port

**CPS**

- CPS Protoflight Test

**Mission Operations**

- Time Delayed Mission Ops

- Autonomous Mission Ops
International Space Station Test bed for Analog Research (ISTAR)

◆ 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 – Pavilion Lake Research Project
  • Space Station Training Facility (SSTF), Neutral Buoyancy Lab (NBL), etc.
<table>
<thead>
<tr>
<th>Phase</th>
<th>Major features of plan</th>
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</thead>
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<tr>
<td><strong>A Eval ISS capabilities [2011]</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 Short-period simulations &amp; experiment packages [2012-2013]</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 Longer-period simulations &amp; experiment packages [2014-2016]</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 6 month mission and crew [2016-2020]</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>
<tr>
<td>ISTAR ID</td>
<td>Proposer</td>
</tr>
<tr>
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<tr>
<td>JSC- HEDS-001</td>
<td>HEDS</td>
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<tr>
<td>JSC-011</td>
<td>JSC/SF2</td>
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<tr>
<td>JSC-017</td>
<td>ARC</td>
</tr>
<tr>
<td>JSC-091</td>
<td>JSC/ER4</td>
</tr>
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ISTAR Assumptions

◆ Mission priorities:
  • Support Exploration risk reduction and strategy needs
  • No Mars Mission related analog test should place the ISS vehicle or crew at risk
  • No impacts to current ISS protocols near term

◆ Maximize number of crew members involved to evaluate team FTO’s

◆ Use current Soyuz crew rotation scheme

◆ Preserve or accommodate original ISS VV schedule

◆ Assume an ISS flight control team for comm, timelines, systems experts

◆ Develop rules for simulation breakouts for ISS nominal events and anomalies [while maximizing continuous sim time]
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
Miniature Exercise Device (MED)

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.
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)
Human & Architectural Risks

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

Coming to NASA Summer 2012

ISTAR - International Space Station Test Bed for Analog Research

ISTAR xDTOs mitigate the risks and challenges facing astronauts on long distance voyages to asteroids, planet Mars and perhaps destinations even further from Earth.”