Space Medicine in the Human System Integration Process

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Space Medicine in the Human Systems Integration Process

◆ Acknowledgements

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- Michelle C. Scheuring
Space Medicine in the Human Systems Integration Process

- The HSI Knowledge Broadcast is intended to educate personnel about the importance of considering the human (health, performance and limitations) in the early stages of a project's lifecycle, thus reducing costs, increasing safety and improving overall system performance.
Historical Precedence

Lunar Surface Operations

- Metabolic expenditure: deconditioning or poor pre-flight preparation?
Historical Precedence

Lunar Surface Operations

- Recommendations\(^1\)
  - The hatch and ingress corridor should be sized appropriately for an inflated 1/6 g pressure suit

Space Medicine in the Human Systems Integration Process

Overview
- Evidence Base
- Medical Condition List
- Medical Technology Development

Human in the Loop testing
- Analog Testing of Medical Hardware

Research
- How can we do better?

Operations
- Lessons learned!

Verification
- Were requirements met?

Requirements Development

Design
- Hands-on architectural involvement

Requirements Integration
- Negotiating project buy-in

Space Flight Human System Stnd - Levels Of Care
- HSIR Medical Requirements

Operations
- Shuttle
- ISS
- Apollo

- Flight Surgeons assigned to Projects
  - Orion, LSS, EVA

Verification
- Were requirements met?
Operations

Lessons learned!

- In-flight sleep disturbances
- Post-flight herniated discs (HNP)
- Lunar dust
- Thrust oscillations
- Risk factors for lunar surface injuries
- In-flight hypothermia
- Apollo EVA suit issues
- Landing/Recovery
- Waste management systems
Injury Prevention

Lunar Surface Operations

- Risk factors for injuries identified
  - Limit navigation into craters to < 20-26° slope
  - Rover activities
    - CDR
    - LMP
  - Falling from a height
    - Ladder
    - Rim of a crater

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Water Egress Training

- Crew experience with egress training
- Elevated heart rates (>120s) due to heat stress
- 2-4 Kg weight loss from sweating
- Elevated core body temperature (38.6-40.0°C)

Video courtesy of Serena Aunon, MD
Research

How can we do better?

Space Medical Issues - Back to the Future

Expected illnesses and problems\textsuperscript{2,3,4}
- Orthopedic and musculoskeletal problems
- Infectious, hematological, and immune-related diseases
- Dermatological, ophthalmologic, and ENT problems

Acute medical emergencies
- Wounds, lacerations, and burns
- Toxic exposure and acute anaphylaxis
- Acute radiation illness
- Dental, ophthalmologic, and psychiatric conditions

Chronic diseases
- Radiation-induced problems
- Responses to dust exposure
- Presentation or acute manifestation of nascent illness


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- What conditions do we expect to see for long lunar stays?

  - Outpost Medical Condition List
    - [Lunar Outpost Conditions.xls](#)

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Health Monitoring on the Lunar Surface\textsuperscript{5,6}

- **Lab analysis**
  - Blood
    - CBC w/differential
    - Chemistries
    - Oxidative stress markers
  - Urine
    - Solutes
    - Dipstick
      - Spec G, Cells, LE, etc.
  - Saliva
    - Immune parameters, shed virus, etc.

- **Pulmonary function tests (PFT’s)**
- **Ultrasound**
- **ECG monitoring (IVA)**
- **HR monitoring (EVA)**

\textsuperscript{5}Grigoriav AI, Popatov LN, Jones JA, Sullivan TA, Scheuring RA. Medical Support for Interplanetary Space Flights, in Space Biology and Medicine, Volume V. "U.S./Russian Cooperation in Space Biology and Medicine". In press, 2009.


In-vivo Real Time Imaging Cervical Spine

Ultrasound (USN)  MRI

C4  C5

1.72mm

Courtesy of Dan Buckland, 2009.

R.A. Scheuring  3-9769
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- Medical Technology Development
  - High Intensity Focused Ultrasound (HIFU)
  - Non-invasive blood analyzers
  - Non-contact electrodes
  - Lightweight trauma module
  - Oxygen concentrators
  - Real-time radiation dosimetry
  - Ultrasound stethoscope
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NASA HQ Standard

Requirements Development

NASA Technical Standard

NASA-STD-3001

NASA Space Flight Human System Standard

Volume 1: Crew Health

Approved: 03-05-2007
Expiration Date: 03-05-2012


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Constellation Req’ts

Vehicle Requirements and Specifications

Space Med Req’ts

Crew Function Req’ts

Levels of Care Performance Stnds

Requirements Development

Requirements Development

Requirements Development
### Levels of Care

<table>
<thead>
<tr>
<th>Level of Care</th>
<th>Mission</th>
<th>Example Capability</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>LEO &lt; 8 days</td>
<td>SMS, BLS, First Aid</td>
</tr>
<tr>
<td>II</td>
<td>LEO &lt; 30 day; e.g. STS EDOMP</td>
<td>Level I + Clinical Diagnostics, Ambulatory Care, Private Audio, (+/- Video) Telemedicine</td>
</tr>
<tr>
<td>III</td>
<td>LEO &gt; 30 day (ISS or Lunar Sortie)</td>
<td>Level II+ Limited Advanced Life Support, Trauma Care, Telemedicine, Minor Surgical and Dental Care</td>
</tr>
<tr>
<td>IV</td>
<td>Lunar &gt; 30 day (Outpost)</td>
<td>Level III+ Imaging, Sustainable ALS</td>
</tr>
<tr>
<td>V</td>
<td>Mars Expedition</td>
<td>Level IV+ Autonomous ALS, Basic Surgical Care</td>
</tr>
</tbody>
</table>

**LEO**= Low Earth Orbit; **STS**= Shuttle Transport System; **EDOMP**= Extended Duration Orbiter Medical Project; **SMS**= Space Motion Sickness; **BLS**= Basic Life Support; **ALS**= Advanced Life Support

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### HSIR Medical Req’ts

- 3.2.1.4.4 Lunar Dust Contamination

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Space Medicine in the Human Systems Integration Process

Flight Surgeons integrated with Projects during key stages

**Requirements Integration**

*Negotiating project*

Jim McMohan

CEV Parachute

JSC/EAJ

Thermal Protection Advanced Project

ARC/Jim Scott

Landing Deceleration Recovery

LaRC/B
Design

Hands-on architectural involvement

• Thrust Oscillations
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ESR2 Config 1 suit testing

Shoulder Bearing

Body Seal Closure (BSC)

Wrist Bearing

Hip Bearing

Modular LTA

Modular boots

EVA Suit Reference (ESR)- Configuration 1
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Instrumentation of the PMHS

Accelerometers
Results:
Post 4
Vehicle development

- Orion
- Altair
- Lunar Electric Vehicle (LEV)
- Lunar Outpost
Lunar Lander (Altair) and Ascent Stage
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Lunar Electric Rover

- Exploration range of up to 1000km (vs. 240km w/ large pressurized rover)
- Shirt-sleeve environment with visibility as good as suited EVAs
- Single-person EVA capability
- **Dust control through use of suitport**
- SPE protection within 20mins
- Pressurized safe-haven within 20mins
- DCS treatment within 20mins
- Expedited on-site treatment and/or medication of injured crewmember
- Reduces suit induced trauma
- Better options for nutrition, hydration, waste management
- Provides resistive and cardiovascular exercise (75% VO2 peak) during otherwise unproductive translation time
- Better background radiation shielding vs. EVA suit
Examine rear-entry suit port in overhead and “dip” position to determine force loads on the shoulder.
Verification

Were requirements met?

• Analog testing of medical hardware, procedures, and concepts
<table>
<thead>
<tr>
<th>Characteristics</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
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<tbody>
<tr>
<td>Physical space for infrastructure setup</td>
<td>HI</td>
<td>Lo</td>
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<tr>
<td>Physical space for an Outpost configuration (at least 0.5 sq km)</td>
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<td>Extended physical space for long distance testing (able to traverse up to 100 km)</td>
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<td>Regolith Handling</td>
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<td>Med</td>
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<tr>
<td>Good vista (not too many man made objects or vegetation, looks like the Moon or Mars)</td>
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<td>Lo</td>
<td>Med</td>
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<tr>
<td>High Temperature extremes (-100 degrees F)</td>
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<td>Low Temperature extremes (-32 degrees F)</td>
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<td>Site Diversity</td>
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<td>Access for large equipment</td>
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<td>Access for People</td>
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Notes:
- NEEMO
- Integrity
- Intl. Space Station
- Mars Yard/Chamber
- Antarctic/desert
- PISCES
Verification

Were requirements met?

- Analog testing/training for Lunar Surface Operations
  - To ensure operational success and optimize performance of the crews
  - Allow adequate time to practice mission activities in a variety of environments including good analogs that allows preparation for off-nominal events
Analog Exploration Environments

- Backyard/Nearby
  - Rockpile
  - Desert RATS

- Remote/Extreme Environments
  - Devon Island, Haughton Crater- HMP
  - NEEMO
  - Antarctica- Coastal and Polar Stations

- Flight
  - Zero- and partial-g Aircraft
  - ISS

Docs are operational oriented and focused on developing experienced-based confidence in medical support system
Many are ex- or current military and/or have experience in expeditionary support
Apollo Medical Operations Recommendations

- Analog environments
  - Remote location, not easily accessible
  - Operationally focused - multiple “Earth” days/weeks
3rd Party Assisted Rescue on Sloped Terrain (haul from top)^9

Procedure

Photos courtesy of HMP 2000/J. Jones
Analog Exploration Environments

Benefits of the Analog Environment

- Mission Constraints
- Timeline
- Crew dynamics
- Limited resources
- Coordination w/ teams
- Collaboration w/ centers
- Simulated planetary environments
- Lack of one perfect analog
- Psychological factors
- Training
- Similar dimensions to space vehicles (NEEMO)
- Testbed for hardware and systems
- Recommendation from Apollo crewmembers
- Subsystem testing vs. system integration testing\(^\text{10}\)

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Questions?

Research
How can we do better?

Requirements Development

Design
Hands-on architectural involvement

Verification
Were requirements met?

Operations
Lessons learned!

Requirements Integration
Negotiating project buy-in