Space Medicine in the Human System Integration Process

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- Michelle C. Scheuring
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

- Recommendations¹

  - 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

Research

How can we do better?

Operations

Lessons learned!

Verification

Were requirements met?

Requirements Development

Requirements Integration

Negotiating project buy-in

Design

Hands-on architectural involvement

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

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

• Shuttle
• ISS
• Apollo

• Human in the Loop testing
• Analog Testing of Medical Hardware

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R.A. Scheuring 3-9769
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
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


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

- Outpost Medical Condition List\(^4\)
  - [Lunar Outpost Conditions.xls](#)

Health Monitoring on the Lunar Surface

- **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)**

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In-vivo Real Time Imaging Cervical Spine

Ultrasound (USN)  MRI

Courtesy of Dan Buckland, 2009.
Exploration Vehicles Atmospheres

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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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Requirements Development

NASA HQ Standard

Constellation Req’ts

Vehicle Requirements and Specifications

Levels of Care Performance Stnds

Space Med Req’ts Crew Function Req’ts

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### 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>

<table>
<thead>
<tr>
<th>Level of Care</th>
<th>Mission</th>
<th>Example Capability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>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</td>
</tr>
</tbody>
</table>

### HSIR Medical Req’ts

- 3.2.1.4.4 Lunar Dust Contamination

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Flight Surgeons integrated with Projects during the development stages

Requirements Integration

Negotiating project
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 Arms & Gloves

Thigh Bearing

Modular LTA

Modular boots

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

Accelerometers
Results: Post 4
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- **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
Rear-Entry Suit Port (Shoulder Study)

- 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>Haughton-Mars</th>
<th>H Remote Sci</th>
<th>Desert RATS</th>
<th>Mars Desert R</th>
<th>Flashline Arctic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical space for infrastructure setup</td>
<td>HI</td>
<td>Lo</td>
<td>HI</td>
<td>HI</td>
<td>HI</td>
</tr>
<tr>
<td>Physical space for an Outpost configuration (at least 0.5 sq km)</td>
<td>HI</td>
<td>Lo</td>
<td>HI</td>
<td>HI</td>
<td>HI</td>
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<tr>
<td>Extended physical space for long distance testing (able to traverse up to 100 km)</td>
<td>Med</td>
<td>Lo</td>
<td>HI</td>
<td>HI</td>
<td>HI</td>
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<tr>
<td>Regolith Handling</td>
<td>HI</td>
<td>Lo</td>
<td>HI</td>
<td>HI</td>
<td>HI</td>
</tr>
<tr>
<td>Power source (electricity via generators or grid connection)</td>
<td>Med</td>
<td>HI</td>
<td>Med</td>
<td>Med</td>
<td>Med</td>
</tr>
<tr>
<td>Full Internet access to remote locations</td>
<td>Med</td>
<td>HI</td>
<td>Med</td>
<td>Med</td>
<td>Med</td>
</tr>
<tr>
<td>Good vista (not too many man made objects or vegetation insight, looks like the Moon or Mars)</td>
<td>HI</td>
<td>Lo</td>
<td>Med</td>
<td>Med</td>
<td>HI</td>
</tr>
<tr>
<td>High Temperature extremes (≈ 100 degrees F)</td>
<td>Lo</td>
<td>Lo</td>
<td>Med</td>
<td>HI</td>
<td>Lo</td>
</tr>
<tr>
<td>Low Temperature extremes (≈ -32 degrees F)</td>
<td>HI</td>
<td>Lo</td>
<td>Med</td>
<td>HI</td>
<td>Lo</td>
</tr>
<tr>
<td>Zero-G capability</td>
<td>Lo</td>
<td>Lo</td>
<td>Lo</td>
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<td>Lo</td>
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<tr>
<td>Partial-G</td>
<td>Lo</td>
<td>Lo</td>
<td>Lo</td>
<td>Lo</td>
<td>Lo</td>
</tr>
<tr>
<td>Site Diversity</td>
<td>Med</td>
<td>Lo</td>
<td>HI</td>
<td>Lo</td>
<td>Lo</td>
</tr>
<tr>
<td>Access for large equipment</td>
<td>Lo</td>
<td>HI</td>
<td>Hi</td>
<td>Lo</td>
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<tr>
<td>Access for People</td>
<td>Lo</td>
<td>Hi</td>
<td>Med</td>
<td>Lo</td>
<td>Hi</td>
</tr>
<tr>
<td>Cost of working there</td>
<td>$$$$</td>
<td>$$$$</td>
<td>$$$$</td>
<td>$$$$</td>
<td>$$$</td>
</tr>
<tr>
<td>Partnerships/Shared Costs</td>
<td>HI</td>
<td>Med</td>
<td>Lo</td>
<td>Med</td>
<td>Med</td>
</tr>
</tbody>
</table>

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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 “Experiments” 5 days/week
3rd Party Assisted Rescue on Sloped Terrain
(haul from top)$^9$

Procedure
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 testing¹⁰

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Q Questions?

- Research
  How can we do better?

- Requirements Development

- Requirements Integration
  Negotiating project buy-in

- Design
  Hands-on architectural involvement

- Verification
  Were requirements met?

- Operations
  Lessons learned!