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?
Lunar Surface Operations

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

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Space Medicine in the Human Systems Integration Process

Overview

- Evidence Base
- Medical Condition List
- Medical Technology Development

Research
How can we do better?

Requirements Development

Operations
Lessons learned!

Requirements Integration
Negotiating project buy-in

Design
Hands-on architectural involvement

Verification
Were requirements met?

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

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

- Shuttle
- ISS
- Apollo

- Human in the Loop testing
- Analog Testing of Medical Hardware
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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
Space Medical Issues- Back to the Future

Research
How can we do better?

- **Expected illnesses and problems**
  - 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

Concerns based on Delphi, In-flight Medical Conditions Data Collection, Mission Operational Concepts and Occupational Medical Considerations

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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

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

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


In-vivo Real Time Imaging Cervical Spine

Ultrasound (USN) - MRI

Nasal lone - Nasal septum (mucous membrane)
Pharyngeal tonsil; pharyngeal recess
Pharyngobasilar fascia
Anterior arch of atlas
Arch of cricoid cartilage
Arch of thyroid cartilage
Esophagus
Tracheoosophageal space
Inferior thyroid veins
Tracheotomy (surgical approach)
Jugular venous arch
Vagus/venous thyroid muscle
Meniscus of sternum

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

28-Apr-2009

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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>

### HSIR Medical Req’ts

- 3.2.1.4.4 Lunar Dust Contamination

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Flight Surgeons integrated with Projects during development stages

Requirements Integration

Negotiating project
Design

Hands-on architectural involvement

- Thrust Oscillations
ESR2 Config 1 suit testing

- Shoulder Bearing
- Modular Arms & Gloves
- Body Seal Closure (BSC)
- Wrist Bearing
- Hip Bearing
- 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.

**Diagram:**
- Graph showing joint torque data with various labels indicating different joints and directions.
- Image of a human skeleton in a stressful pose, likely related to the study of forces on the shoulder.
Verification

Were requirements met?

• Analog testing of medical hardware, procedures, and concepts
## Analog Function Characteristics Mapped to Sites

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Haughton-Mars 1</th>
<th>H Remote Sci 2</th>
<th>Desert RATS 3</th>
<th>Mars Desert R 4</th>
<th>Flashline Arctic 5</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>Lo</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>
</tr>
<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>Med</td>
</tr>
<tr>
<td>Regolith Handling</td>
<td>Hi</td>
<td>Lo</td>
<td>Hi</td>
<td>Hi</td>
<td>Hi</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 extremese (~32 degrees F)</td>
<td>Hi</td>
<td>Lo</td>
<td>Med</td>
<td>Lo</td>
<td>Hi</td>
</tr>
<tr>
<td>Zero-G capability</td>
<td>Lo</td>
<td>Lo</td>
<td>Lo</td>
<td>Lo</td>
<td>Lo</td>
</tr>
<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>Med</td>
<td>Lo</td>
</tr>
<tr>
<td>Access for People</td>
<td>Lo</td>
<td>Hi</td>
<td>Hi</td>
<td>Med</td>
<td>Lo</td>
</tr>
<tr>
<td>Cost of working there</td>
<td>$$$</td>
<td>$</td>
<td>$$$</td>
<td>$$$</td>
<td>$$$</td>
</tr>
</tbody>
</table>

**Notes:**
- NEEMO
- Integrity
- Intl. Space Station
- Mars Yard Chamber
- Antarctic/desert
- PISCES
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

Verification
Were requirements met?

Apollo 16 Geological field training in New Mexico
Apollo 12 Lunar Lander Training Vehicle (LLTV) Ellington Field
Apollo 17 Lunar Surface Activity training at JSC
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” days/week
3rd Party Assisted Rescue on Sloped Terrain
(haul from top)\textsuperscript{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 testing\(^\text{10}\)

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Questions?

- Research
  - How can we do better?

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- Operations
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- Verification
  - Were requirements met?

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