Space Medicine in the Human System Integration Process

Richard A. Scheuring, DO, MS, FAAFP
Constellation Medical Operations
NASA-Johnson Space Center
Acknowledgements

- David Baumann, ExMC project lead
- Kate Kubicek and Debbie Berdich
- Jeff Jones, MD
- Jenn Fogarty, PhD
- JD Polk, DO
- Pete Bauer, Serena Aunon, David Alexander, Kjell Lindgren, Duane Chin, Tom Hatfield, David Gillis, Doug Hamilton, Dov Adelstein, Brian Daniel, John Bolte, Brent Buetter, Marsha Ivins, Evan Brown, Phil Root, and a lot of other folks
- 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?
Lunar Surface Operations

- Recommendations
  - 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?

Requirements Development

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

Operations

Lessons learned!

Requirements Integration

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

Verification

Were requirements met?

Design

- Hands-on architectural involvement

- Human in the Loop testing
- Analog Testing of Medical Hardware
Space Medicine in the Human Systems Integration Process

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
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

---

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
How can we do better?

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

- **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

---


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)**

---


In-vivo Real Time Imaging Cervical Spine

Ultrasound (USN)  MRI

C4  C5

3.72mm

Courtesy of Dan Buckland, 2009.
Exploration Vehicles Atmospheres

Pre-launch Transition

Shuttle/EVA Preparation

Lunar Sortie CEV

LER/Outpost

Ascent Transition

Early Apollo Design

Shuttle/Mir/ISS

Normoxic Equivalent

Hypoxic Boundary

Historical Designs

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
Space Medicine in the Human Systems Integration Process

Requirements Development

Levels of Care
Performance Stnols

NASA HQ Standard

NASA SPACE FLIGHT HUMAN SYSTEM STANDARD
VOLUME 1: CREW HEALTH

MEASUREMENT SYSTEM IDENTIFICATION: NONE

APPROVED FOR PUBLIC RELEASE – DISTRIBUTION IS UNLIMITED

Constellation Req’ts

Vehicle Requirements and Specifications

Space Med Req’ts
Crew Function Req’ts

28-Apr-2009

R.A. Scheuring 3-9769
## 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-1: Levels of Care is matched to mission duration and destination**

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

## HSIR Medical Req’ts

- 3.2.1.4.4 Lunar Dust Contamination

---


Space Medicine in the Human Systems Integration Process

Flight Surgeons integrated with Projects during the project stages

Requirements
Integration

Negotiating project

Orion Crew Exploration Vehicle Project

Jim McMahon, Integration

CEV Parachute System

Thermal Protection Advanced Concept

Landing Deceleration

Direct

** Dual reporting (to V1O)
Design

Hands-on architectural involvement

• Thrust Oscillations
Space Medicine in the Human Systems Integration Process

ESR2 Config 1 suit testing

Shoulder Bearing

Modular Arms & Gloves

Body Seal Closure (BSC)

Wrist Bearing

Thigh Bearing

Hip Bearing

Modular LTA

Modular boots

EVA Suit Reference (ESR)- Configuration 1
Space Medicine in the Human Systems Integration Process

Instrumentation of the PMHS

Accelerometers
Results:
Post 4
Space Medicine in the Human Systems Integration Process

♦ Vehicle development

- Orion
- Altair
- Lunar Electric Vehicle (LEV)
- Lunar Outpost
Lunar Lander (Altair) and Ascent Stage
Space Medicine in the Human Systems Integration Process
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 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>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>
</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>HI</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>Power source (electricity via generators or grid connection)</td>
<td>Med</td>
<td>HI</td>
<td>Med</td>
<td>Med</td>
<td>HI</td>
</tr>
<tr>
<td>Full Internet access to remote locations</td>
<td>Med</td>
<td>HI</td>
<td>Med</td>
<td>Med</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>HI</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>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>Med</td>
</tr>
<tr>
<td>Partial -G</td>
<td>Lo</td>
<td>Lo</td>
<td>Lo</td>
<td>Hi</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>Hi</td>
<td>Med</td>
<td>Med</td>
<td>Hi</td>
<td>Lo</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>

**Notes:**
- HI: High
- Lo: Low
- Med: Medium
- DRAFT
- **NEEMO**: 6
- **Integrity**: 7
- **Intl. Space Station**: 8
- **Mars Yard Chamber**: 9
- **Antarctic/Desert**: 10
- **PISCES**: 11

**Dates:**
- 28-Apr-2009
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 “Expeditions” of 1 month or more /days/week
3rd Party Assisted Rescue on Sloped Terrain (haul from top)\(^9\)

Procedure

Photos courtesy of HMP 2000/J. Jones
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

Were requirements met?

Verification
Were requirements met?

Design
Hands-on architectural involvement

Requirements Integration
Negotiating project buy-in

Operations
Lessons learned!

Research
How can we do better?

Requirements Development