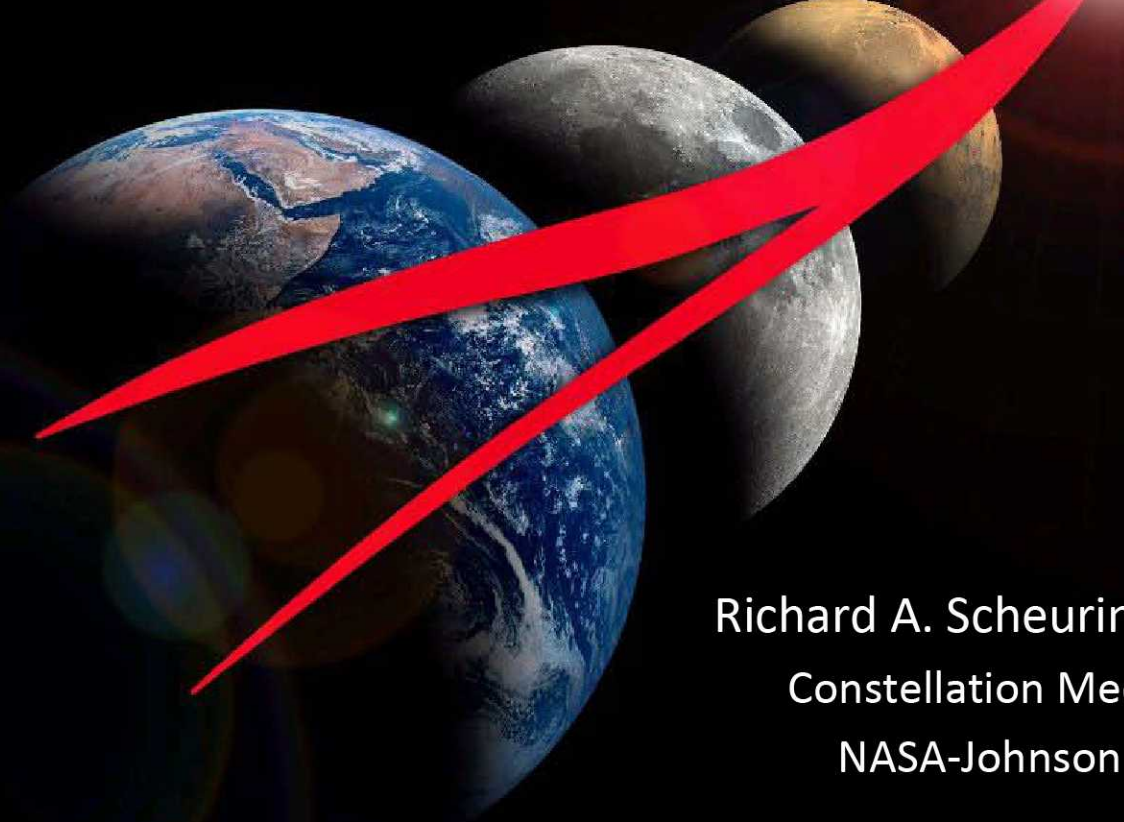
Space Medicine in the Human System Integration Process



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Space Medicine in the Human Systems Integration Process

Acknowledgements

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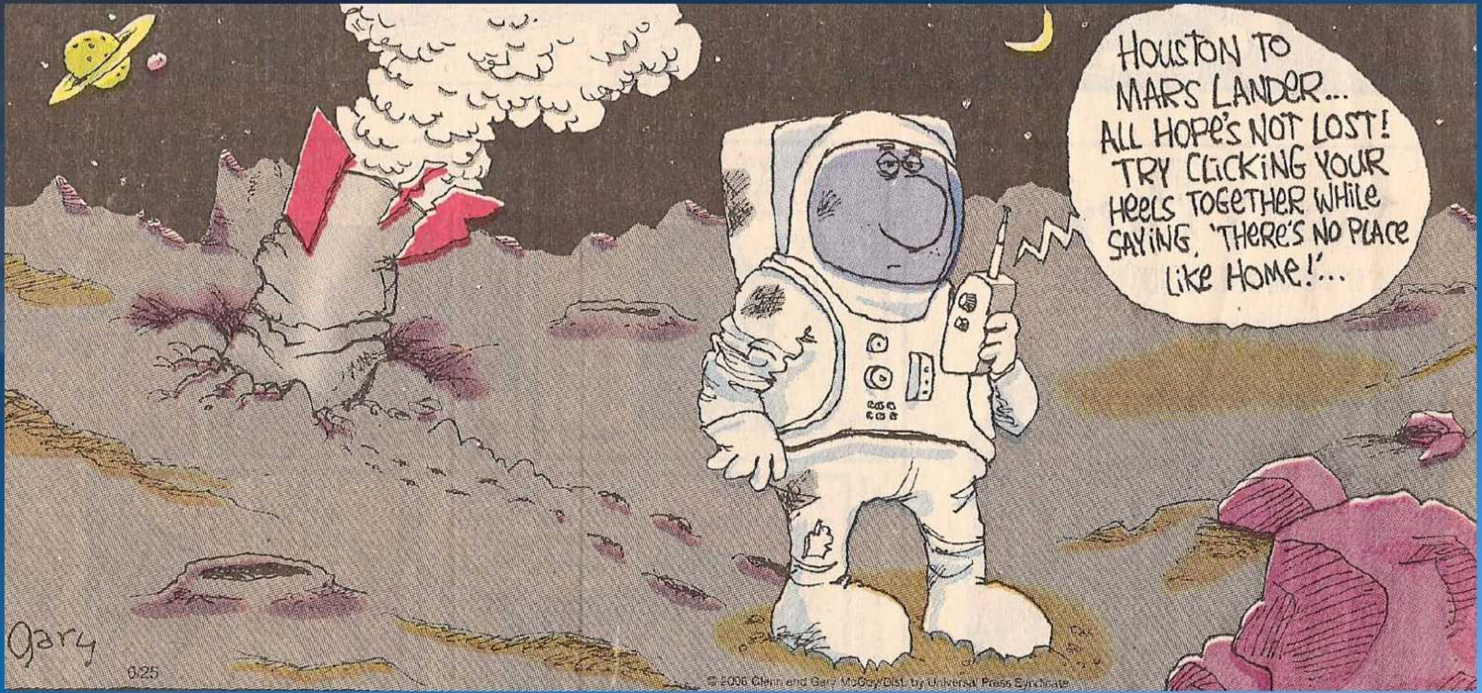
- Jenn Fogarty, PhD
- JD Polk, DO
- Pete Bauer, Serena Aunon, David Alexander, Kjell Lindgren, Duane Chin, Tom Hatfield, David Gillis, Doug Hamilton, Dov Adelstein, Brian Daniel, John Bolte, Brent Buetter, Marsha Ivins, Evan Brown, Phil Root, and a lot of other folks
- Michelle C. Scheuring

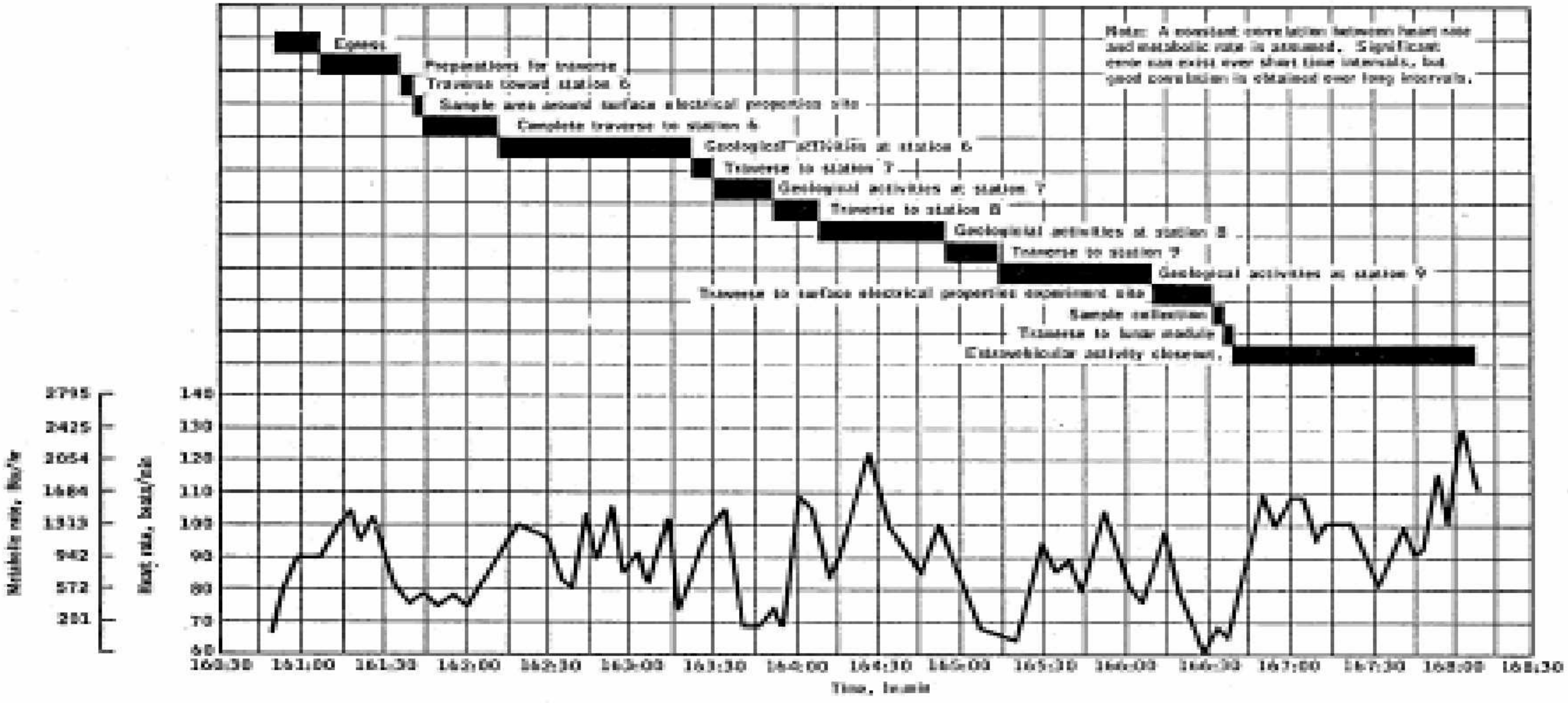
Space Medicine in the Human Systems Integration Process

- ***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.***



Lunar Surface Operations

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



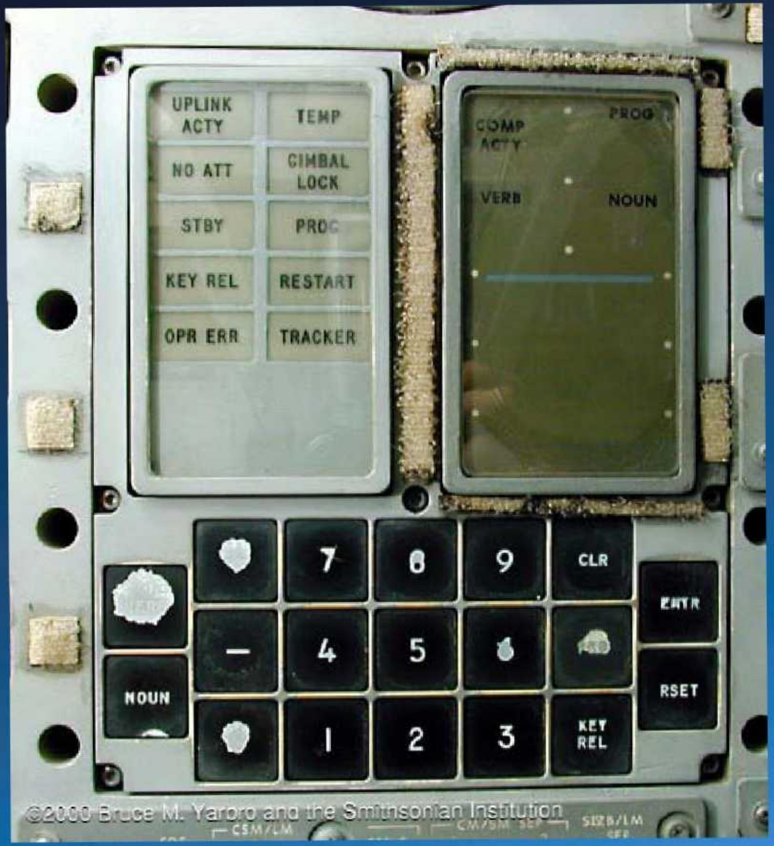
(b) Lunar Module Pilot.

Figure 11-4.- Concluded.

Historical Precedence

♦ Lunar Surface Operations

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



[1]Scheuring RA, Jones JA, et. al. The Apollo Medical Operations Project: Recommendations to Improve Crew Health and Performance for future Exploration Missions and Lunar surface Operations. NASA/TM-2007-214755.

Space Medicine in the Human Systems Integration Process

Overview

- Evidence Base
- Medical Condition List
- Medical Technology Development

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

Research
How can we do better?

Requirements Development

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

Requirements Integration
Negotiating project buy-in

Design
Hands-on architectural involvement

Verification
Were requirements met?

Operations
Lessons learned!

- Shuttle
- ISS
- Apollo

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

Space Medicine in the Human Systems Integration Process

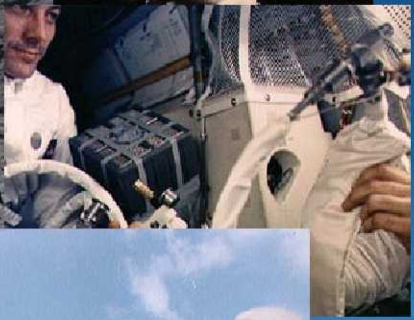
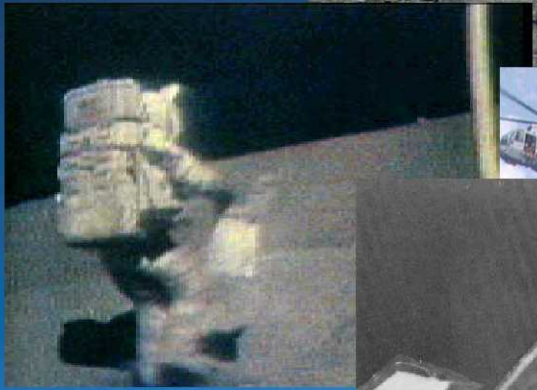
Operations

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



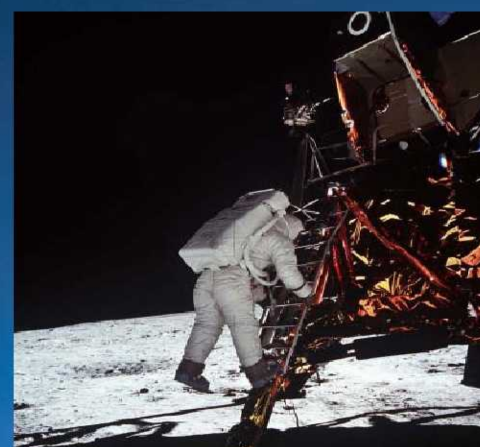


Injury Prevention

- **Lunar Surface Operations**[1]
  - 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

Apollo 17 LMP H. Schmitt near North Massif at Taurus-Littrow



[1]Scheuring RA, Jones JA, et. al. The Apollo Medical Operations Project: Recommendations to Improve Crew Health and Performance for Future Exploration Missions and Lunar Surface Operations. NASA-TM-2007–214755.

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[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

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

[2]Scheuring RA, Mathers C.H., et. al. Musculoskeletal Injuries and Minor trauma in Space: Incidence and Injury Mechanisms in U.S. Astronauts. Aviat Space Environ Med 2009; 80:117-24.

[3]Scheuring RA, et. al. The Apollo Medical Operations Project: Recommendations to Improve Crew Health and Performance for Future Exploration Missions and Lunar Surface Operations. NASA-TM-2007–214755. September, 2007.

[4]Kerstman EL, Watkins S. The Integrated Medical Model. NASA/Wyle Integrated Science and Engineering Group, 2009.

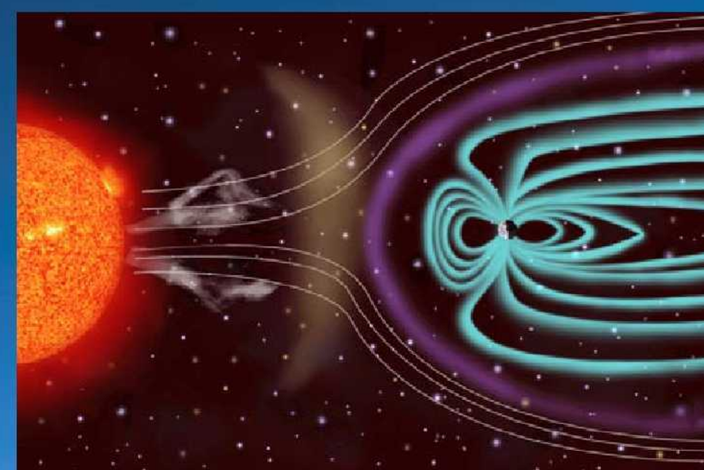
Space Medicine in the Human Systems Integration Process

- **What conditions do we expect to see for long lunar stays?**
  - Outpost Medical Condition List[4]
    - Lunar Outpost Conditions.xls

[4]Kertsman EL, Watkins S. The Integrated Medical Model. NASA/Wyle Integrated Science and Engineering Group, 2009.

Health Monitoring on the Lunar Surface[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)**

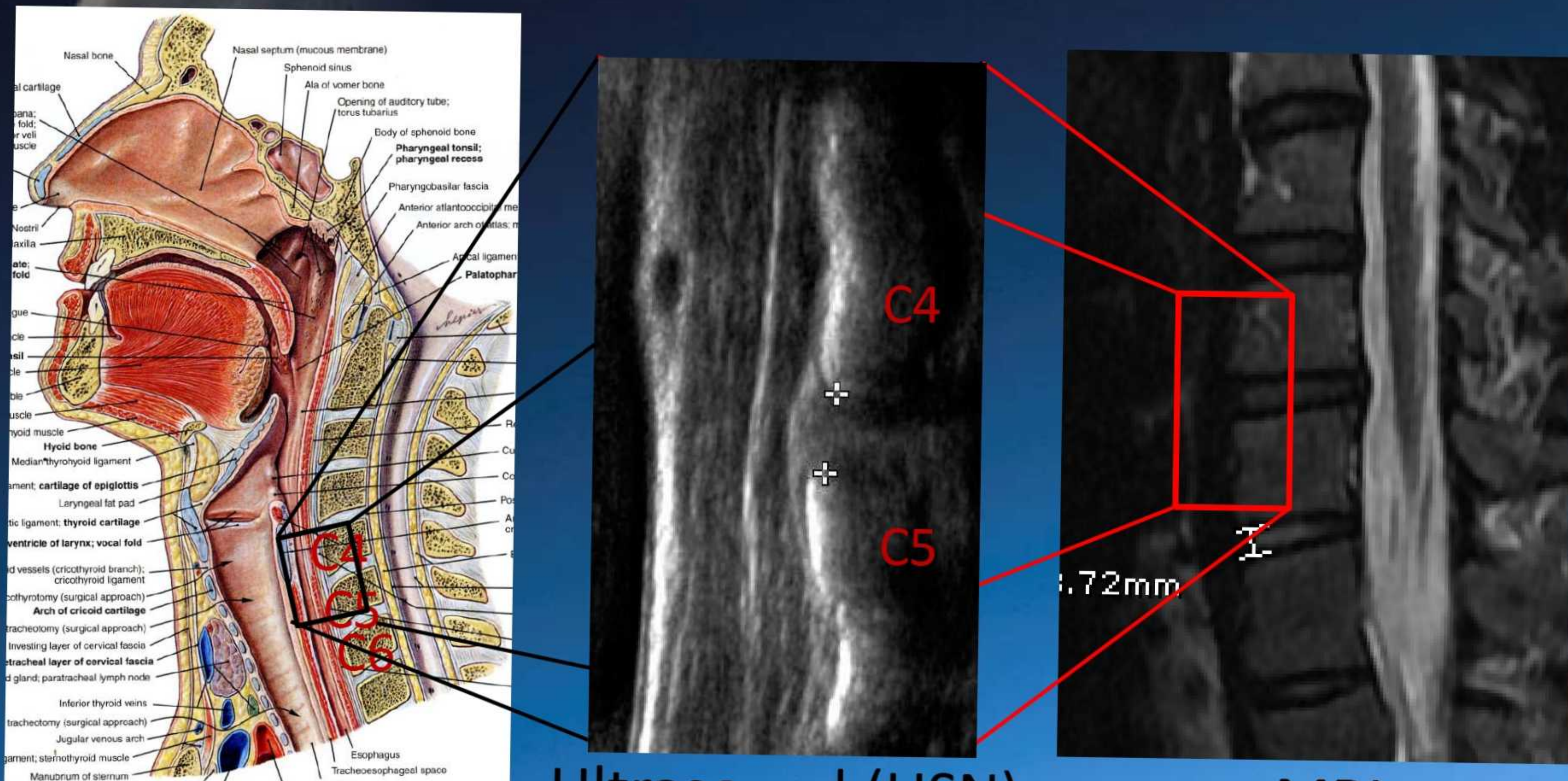


[5]Grigoriav AI, Popatov LN, Jones JA, Sullivan TA, Scheuring RA. Medical Support for Interplanetary Space Flights, in Space Biology and Medicine, Volume V "U.S./Russian Cooperation in Space Biology and Medicine". In press, 2009.

[6]Jones JA, Polk JD, Scheuring RA. Exploration Medical Support Systems: The Future of Human Space Flight. USAF Flightlines, Oct, 2007.

Scheuring RA, Van Baalen M, Jones JA, Vasquez M, Zapp N, Shaver M. Management of Acute Radiation Exposures on the Lunar Surface for Exploration Crews

In-vivo Real Time Imaging Cervical Spine

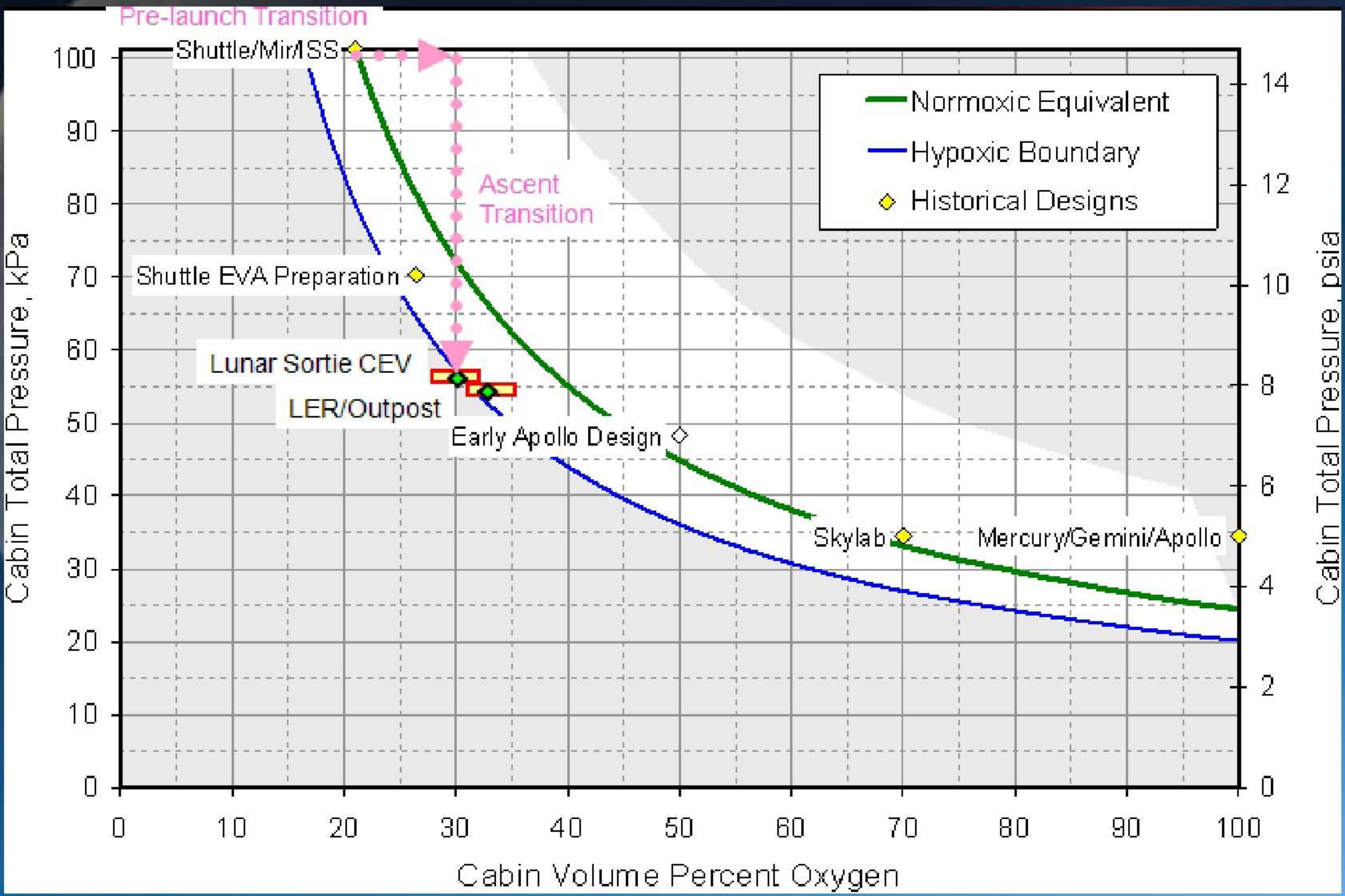


Ultrasound (USN)

MRI

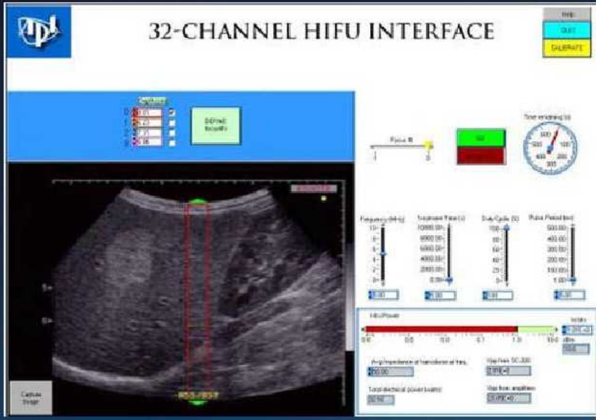
Courtesy of Dan Buckland, 2009.

Exploration Vehicles Atmospheres[7]



[7]Scheuring RA, Jones JA, Conkin J, Gernhardt M. Optimal Total Pressure-Oxygen Concentration Levels for Future Spacecraft, Spacesuits, and Habitats. NASA/TP-2008-214775.

Space Medicine in the Human Systems Integration Process



- **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

NASA HQ Standard

NASA TECHNICAL STANDARD

NASA-STD-3001

National Aeronautics and Space Administration
Washington, D.C. 20546-0001

Approved: 03-05-2007
Expiration Date: 03-05-2012
Superseding NASA-STD-3000, Vol. 1, Chapter 7 and JSC 26882, Space Flight Health Requirements Document

NASA SPACE FLIGHT HUMAN SYSTEM STANDARD

VOLUME 1: CREW HEALTH

MEASUREMENT SYSTEM IDENTIFICATION:
NONE

APPROVED FOR PUBLIC RELEASE – DISTRIBUTION IS UNLIMITED

Levels of Care

Performance Stnds

Constellation Req'ts

National Aeronautics and Space Administration

CxP 70024
REVISION C
RELEASE DATE: MARCH 6, 2009

CONSTELLATION PROGRAM
HUMAN-SYSTEMS INTEGRATION REQUIREMENTS

Approved for Public Release; Distribution is Unlimited.

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Verify this is the correct version before use.

Space Med Req'ts

Crew Function Req'ts

Vehicle Requirements and Specifications

Space Medicine in the Human Systems Integration Process

- **Levels of Care**
- **HSIR Medical Req'ts**
  - 3.2.1.4.4 Lunar Dust Contamination

Table-1: Levels of Care is matched to mission duration and destination [7,8]

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

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

- 3.2.2.2.1 Potable Water for On-Orbit Drinking
  - [HS3025] The system shall provide a minimum of 2.0 kg (4.4 lbs) of potable water per crewmember per mission day for *drinking*.

[7]NASA Space Flight Human System Standard Volume 1: Crew Health. NASA STD 3001 03-05-2007 NASA Washington D.C. 20546-0001

[8]Scheuring RA, Jones JA, Polk JD. Human Spaceflight Health Systems for the Constellation Project. Aviat Space Environ Med. Vol. 78, No.12 Dec. 2007.

Space Medicine in the Human Systems Integration Process

Requirements Integration

Negotiating project

Flight Surgeons integrated with Projects during

...tages

Orion Crew Exploration Vehicle Project

RION

Wendy Babb (C
Renee Clokey (
Karen Duna
Teresa Wait

Jim McMahon
Integration**

CEV Parach
System
JSC/EA/Ja

Thermal Prot
Advanced D
Project (
ARC/Jam
Scott

Landing
Deceler
Recovery
LaRC/B

Direct

*Dual assignment
** Dual reporting (to VIO)

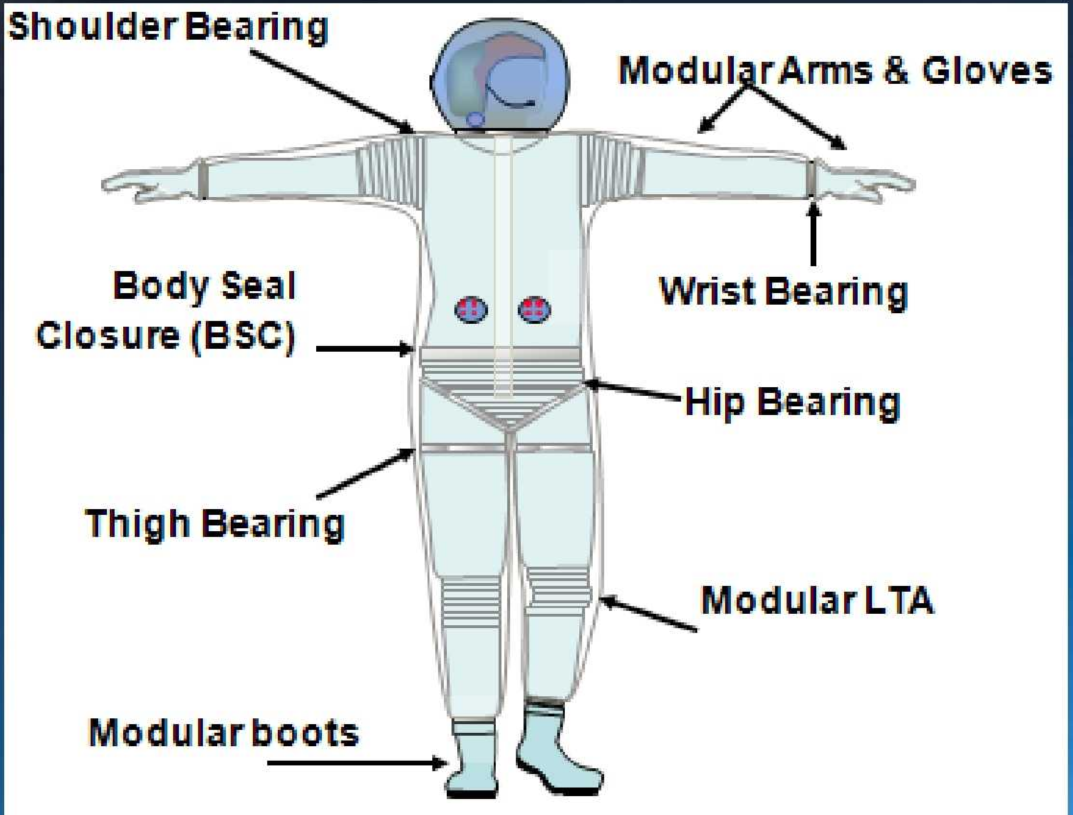
Design

Hands-on architectural involvement

- **Thrust Oscillations**

Space Medicine in the Human Systems Integration Process

ESR2 Config 1 suit testing



EVA Suit Reference (ESR)- Configuration 1

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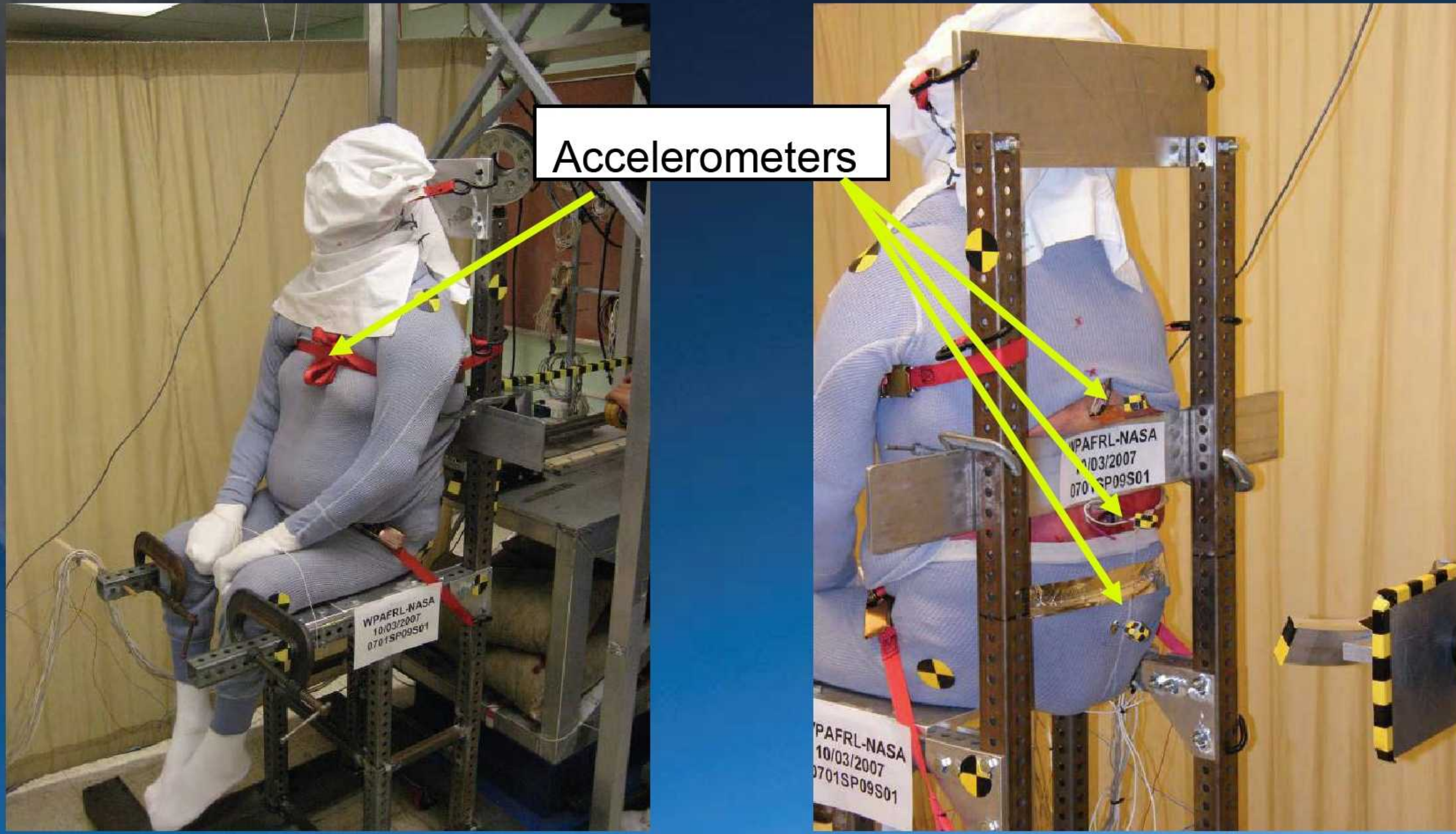
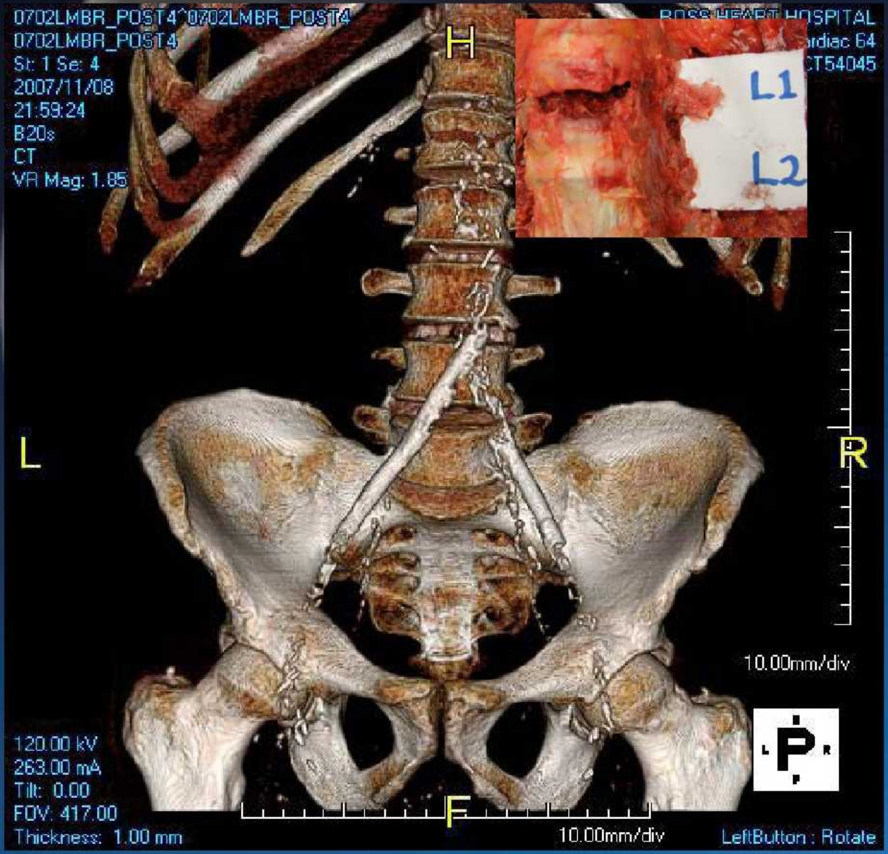
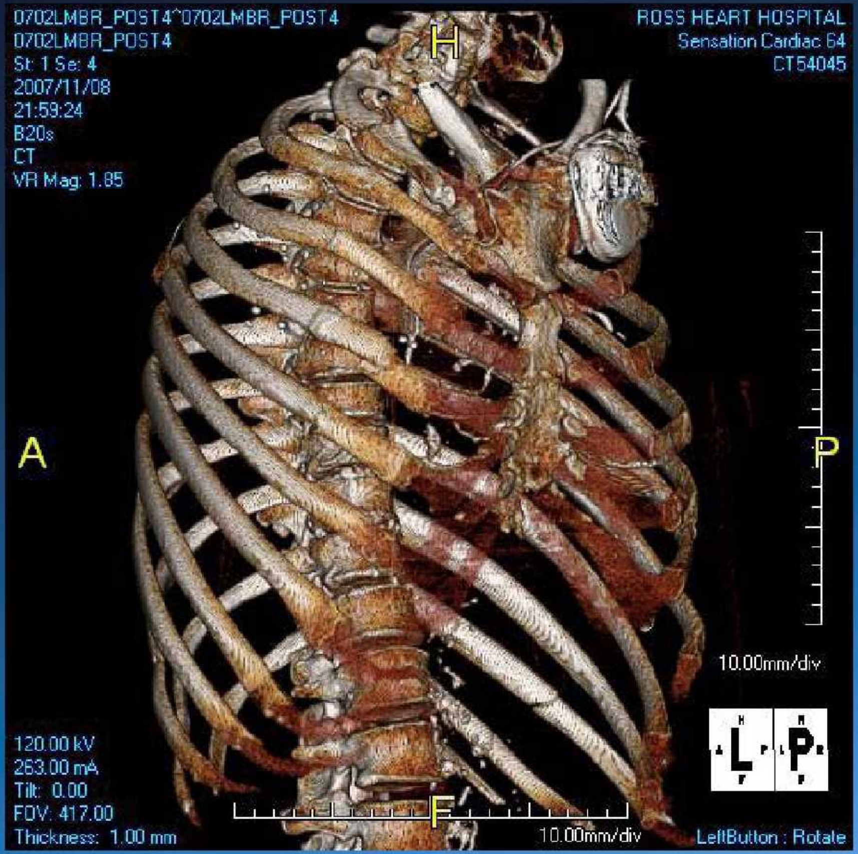
Instrumentation of the PMHS



Results:
Post 4





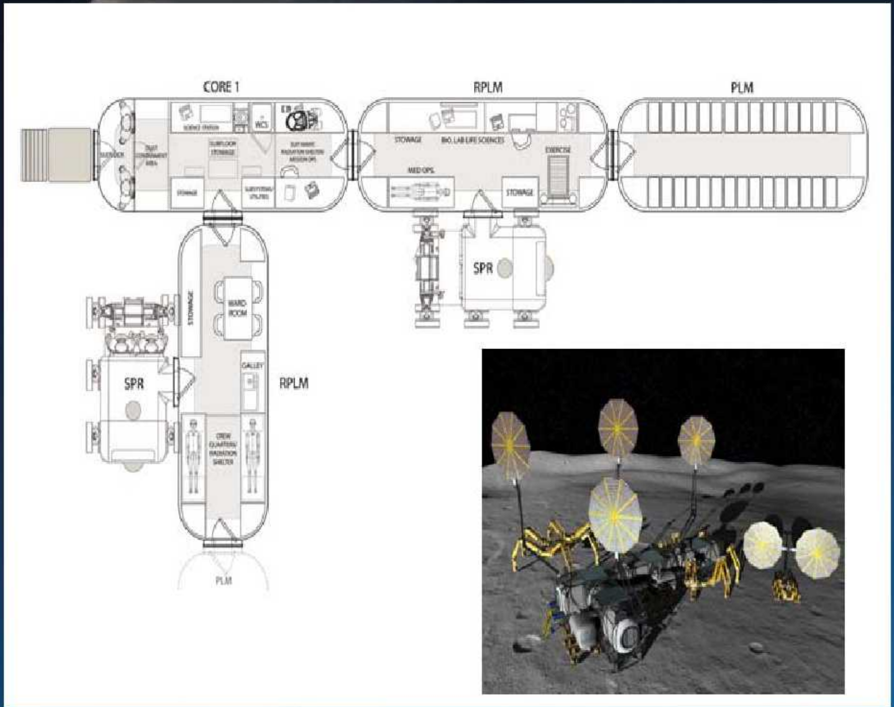
Space Medicine in the Human Systems Integration Process

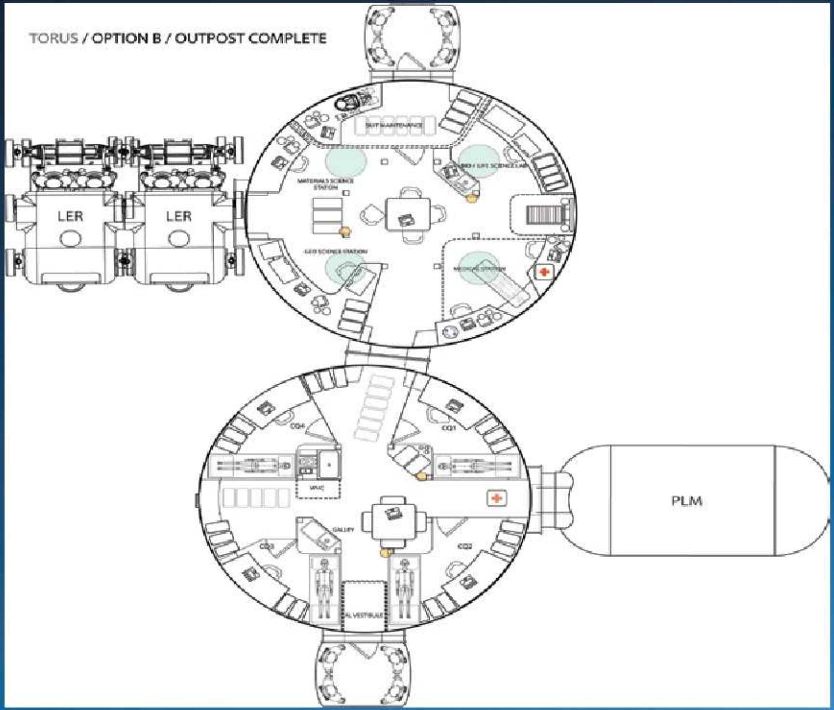
♦ Vehicle development

- Orion
- Altair
- Lunar Electric Vehicle (LEV)
- Lunar Outpost

Lunar Lander (Altair) and Ascent Stage

Space Medicine in the Human Systems Integration Process



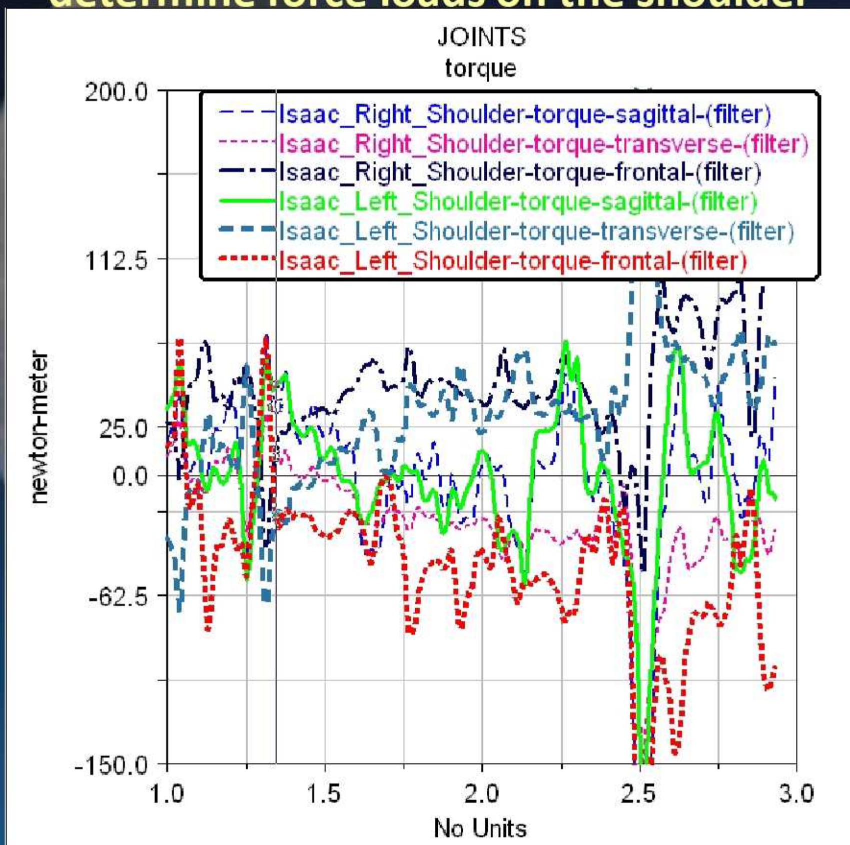


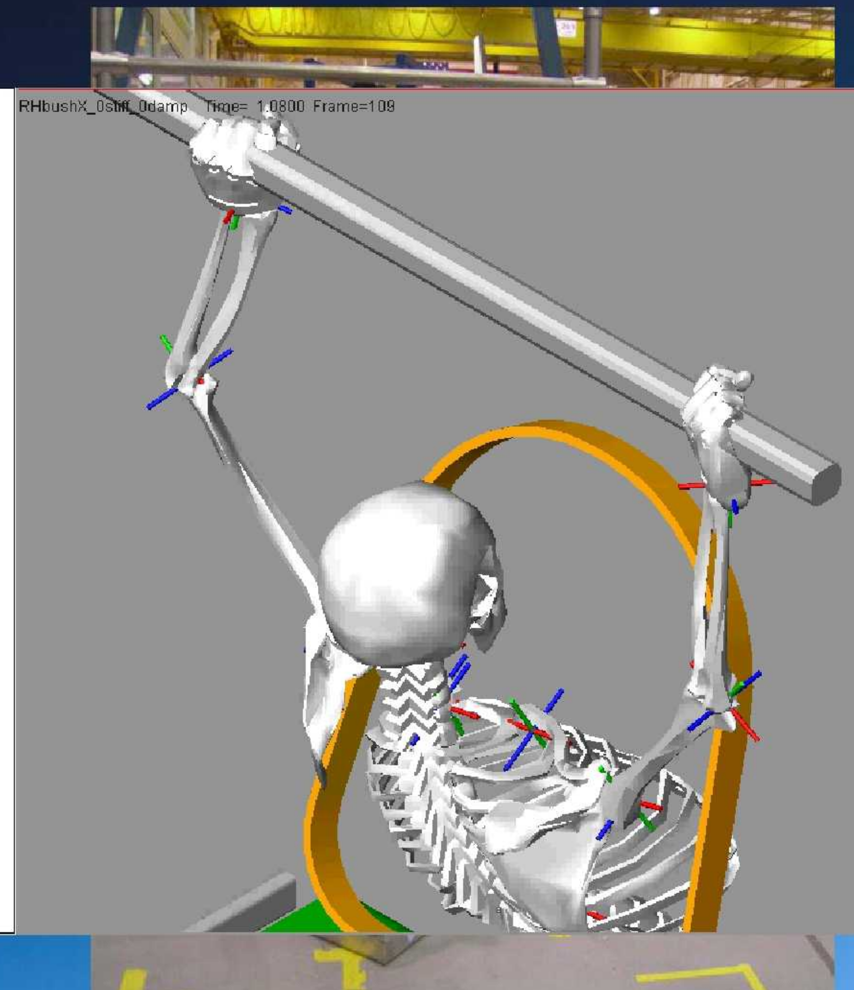
Lunar Electric Rover

- 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**





Space Medicine in the Human Systems Integration Process

Verification

Were requirements met?

- Analog testing of medical hardware, procedures, and concepts

Analog Function Characteristics Mapped to Sites


Haughton-Mars 1


H. Remote Scien 2


DesertRATS 3


Mars Desert R. 4


Flashline Arctic 5 S.

Characteristics	1	2	3	4	5	6	7	8	9	10	11
Physical space for infrastructure setup	HI	Lo	HI	HI	HI	Lo	HI	Lo	HI	HI	HI
Physical space for an Outpost configuration (at lease 0.5 sq km)	HI	Lo	HI	HI	HI	Lo	Med	Lo	Med	HI	HI
Extended physical space for long distance testing (able to traverse up to 100 km)	Med	Lo	HI	HI	HI	Lo	Lo	Lo	Med	HI	Med
Regolith Handling	HI	Lo	HI	HI	HI	Lo	Med	Lo	Med	Med	HI
Power source (electricity via generators or grid connection)	Med	HI	Med	Med	Med	HI	HI	Med	HI	Med	Med
Full Internet access to remote locations	Med	HI	Med	Med	Med	HI	HI	Med	HI	Med	Med
Good vista (not too many man made objects or vegetation in sight, looks like the Moon or Mars)	HI	Lo	Med	Med	HI	Lo	Lo	Lo	Lo	HI	HI
High Temperature extremes (> 100 degrees F)	Lo	Lo	Med	HI	Lo	Lo	Lo	HI	Med	Lo	Med
Low Temperature extremese (< 32 degrees F)	HI	Lo	Med	Lo	HI	Lo	Lo	HI	Lo	HI	Med
Zero-G capability	Lo	Lo	Lo	Lo	Lo	Med	Lo	HI	Lo	Lo	Lo
Partial -G	Lo	Lo	Lo	Lo	Lo	HI	Lo	Lo	Lo	Lo	Lo
Site Diversity	Med	Lo	HI	Lo	Lo	Lo	Lo	Lo	Lo	Lo	HI
Access for large equipment	Lo	HI	HI	Med	Lo	Lo	HI	Lo	HI	Lo	Med
Access for People	Lo	HI	HI	Med	Lo	Lo	HI	Lo	HI	Lo	Med
Cost of working there	$$	$	$$	$$	$$$	$$	$	$$$$	$	$$$	$$
Partnerships/Shared Costs	HI	Med	Lo	Lo	Med	HI	Med	Lo	Med	Med	Med

DRAFT


NEEMO 6


Integrity 7


Intl. Space Station 8


Mars Yard/Chamber 9


Antarctic/desert 10


PISCES 11

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**

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

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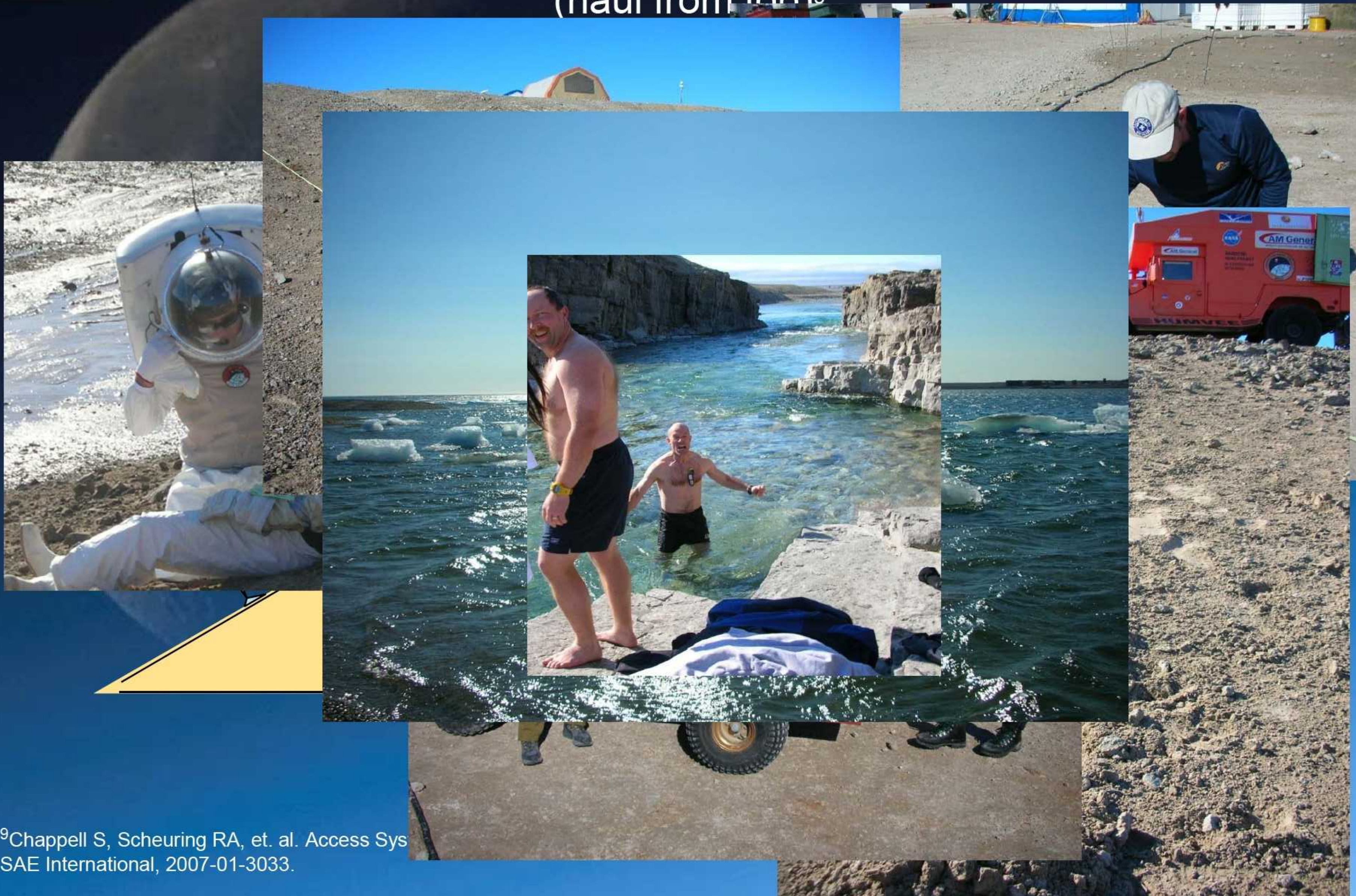
Apollo Medical Operations Recommendations

- **Analog environments**
  - Remote location, not easily accessible
  - Operationally focused- multiple “E
    days/week

3rd Party Assisted Rescue on Sloped Terrain (haul from top)[9]



[9]Chappell S, Scheuring RA, et. al. Access Sys
SAE International, 2007-01-3033.

DVD-Video
PLAY

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[10]

[10]Jones H. Integrated Systems Testing of Spacecraft. NASA-ARC-2007-01-3144.

Space Medicine in the Human Systems Integration Process

- **Questions?**