NASA/Haughton-Mars Project 2006 Lunar Medical Contingency Simulation

Devon Island, Nunavut, Canadian High Arctic

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NASA/Haughton-Mars Project 2006 Lunar Medical Contingency Simulation

- Mission Purpose/ Overview
- HMP as a Moon/Mars Analog
- Simulation objectives
  - Procedure
  - Results
- Discussion
  - Lessons Learned
- Forward work

Photo courtesy of HMP 2006/R. Scheuring

NASA/Haughton-Mars Project 2006 Lunar Medical Contingency Simulation

- Purpose
  - Evaluate hardware, systems and integration with other elements in an **operational scenario** to develop medical requirements for lunar surface operations

NASA/HMP 2006 Lunar Medical Contingency Simulation

- Mission Overview
  - The operational scenario simulated a lunar EVA by three suited crewmembers
    - One crewmember (EV1) sustains incapacitating injuries requiring extraction from sloped terrain
  - This effort represents the first evidence-based medical contingency simulation in a lunar analog environment
  - Low fidelity simulation

Background research: Medical Contingency Simulation

- Historical data review
- Apollo Medical Operations Summit 7-9 June 2006
- Risk factors for injuries on the lunar surface
  - Navigation into craters >20-26° slope
  - Rover activities
    - CDR vs. LMP
  - Falling from a height
    - Ladder
    - Rim of a crater

Video courtesy of NASA-Apollo archives

Territory of Nunavut, Canadian High A

Devon Island as Analog

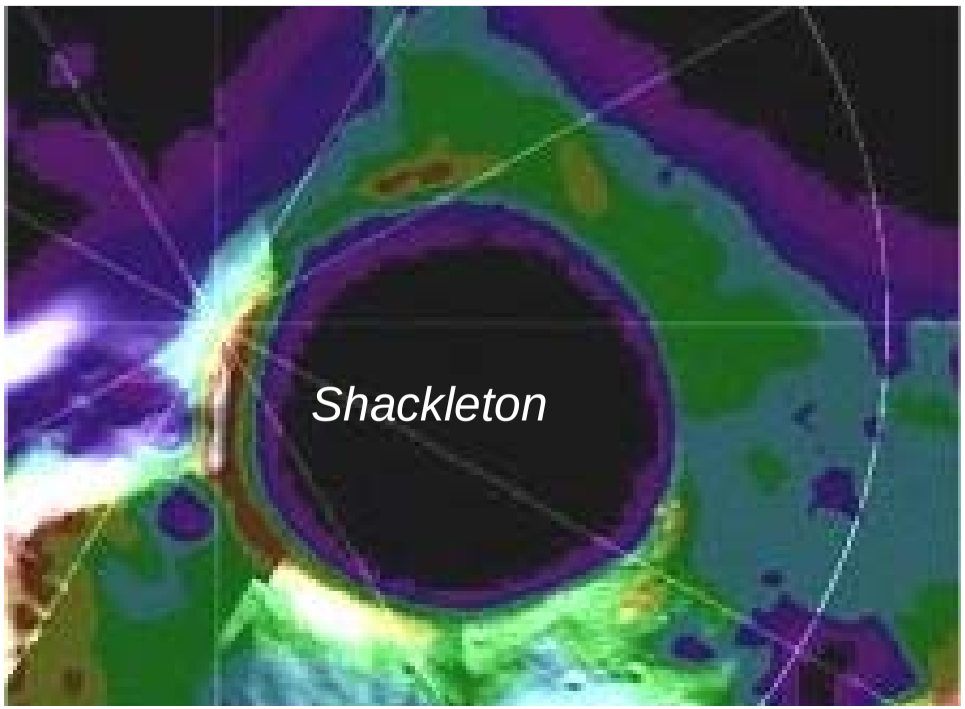
Why is Devon Island a good Moon/Mars Analog?

- **Extreme Environmental Conditions**
  - Devon Island is set in the Polar Desert of the High Arctic.
  - Cold climate. Frozen subsurface. High UV flux (Summer only).
- **Relevant Geologic Features & Biological Attributes**
  - Haughton Crater is relatively large & exceptionally well preserved.
  - Cold Climate (Fluvial, Glacial, & Periglacial) Geological Features.
  - Microbial Niche Habitats
- **Remote & Isolated**
  - Arctic Island.
- **No or Limited Infrastructure & Resources**
  - HMP Research Station is only infrastructure.
  - Moon/Mars-Relevant Surface Operations.

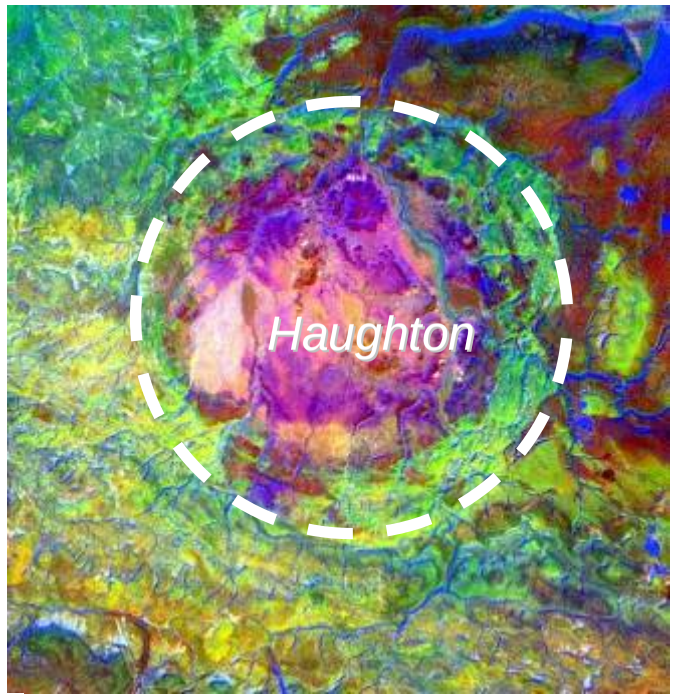
Haughton Crater as Moon Analog

23 km-class Polar Impact Craters

Shackleton Crater at the South Pole of the Moon is 19 km in diameter and might present H_2O ice in surrounding shadowed zones. It is a prime candidate site for human exploration. Haughton Crater, also ~ 23 km in size, is by far the best preserved impact structure of its class on Earth and is located in a H_2O ground ice–rich rocky desert. Haughton may be the best overall ***scientific and operational analog for lunar craters such as Shackleton***.



Map of 19 km Shackleton Crater at lunar South Pole.



ASTER image of 23 km Haughton Crater, Devon Island, High Arctic.

Haughton Impact Crater

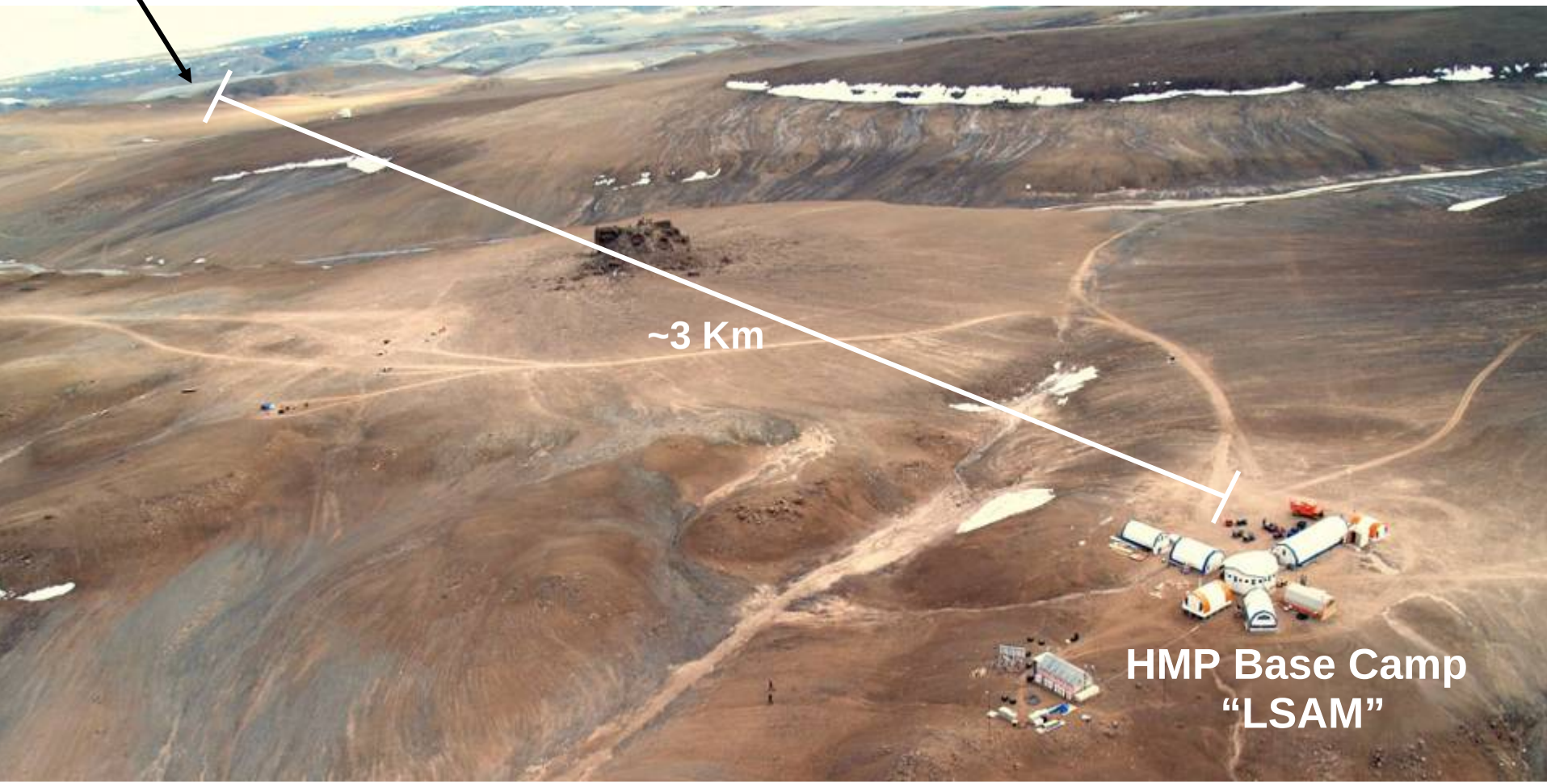


Photo courtesy of HMP 2006/P. Lee

Objectives: Medical Contingency Simulation

1. Develop an effective management strategy for a planetary EVA medical/field contingency

Photo courtesy of HMP 2006/N. Wilkinson

Procedure: Medical Contingency Simulation

- Scenario
  - EV1 is conducting LSA in the crater when the call comes from CEV (ISS) that a SPE has been detected
    - Sustains a lower extremity injury
    - Blunt abdominal trauma
  - Plausible event
    - Stabilization and transfer of an ill or injured crewmember will require dedicated resources and training

Photo courtesy of HMP2006/N. Wilkinson

Results: Medical Contingency Simulation

- The management strategy for dealing with crew injury was established
  - A number of areas were identified that will need refinement
- Field medical assessments are possible but limited
- A physician CMO greatly reduced the dependence on the console flight surgeon and back room support
- Acute radiation sickness?
  - Immediate erythematic response, possible G.I. prodromal symptoms within hours of exposure

Results: Medical Contingency Simulation

- This was the first opportunity to apply the Space Radiation Analysis Group (SRAG) simulation tool into an integrated simulation
  - Demonstration of tool functionality for evaluation of exploration radiation operational rules
- Real time events facilitated a realistic dialog between SRAG/Surgeon/Flight
- The crew did not understand the full impact of the SPE from MCC-Houston
  - No active dosimetry was available on the surface

Objectives: Connectivity

2. Demonstrate the ability to communicate between multiple international control centers, the CEV (ISS), and the EVA crew while conducting EVA operations on an extra-planetary surface.

HMP-Devon Island (LSAM)

PTOC-Montreal (MCC backroom support)

ISU-Strasburg (MCC backroom support)

ExPOC-Houston (MCC)

ISS-LEO (CEV)

Results: Connectivity

- Real-time delivery of audio/visual and BIOMED data across multiple centers was achieved
- Integration between radio systems and network infrastructure was successful – a unique first

Devon Island

PTOC

ExPOC

ISU

Results: Connectivity

- Loss of communications for EV2 not planned.
  - Scenario very realistic in the context of a SPE. Need to develop 'Loss of Communication' protocol for medical contingencies during planetary EVA
- Communications blackouts occurred
  - Primarily between suit and network infrastructure
    - Full multi-layer network communications re-initializing caused extensive times of no end-to-end connectivity

Objectives: Extraction of Ill/Injured Crewmember

3. Demonstrate the ability to conduct field (possibly high-angle) rescue operations for an incapacitated EVA crewmember on an extra-planetary surface

Procedure: Extraction of Ill/Injured Crewmember

- The slope angle varied from 16 degrees at the point of patient loading to 21 degrees mid-slope
- Standard mountain rescue equipment was used
- Technique used was different than what had been worked out in the procedures
  - The winch was anchored to the front bumper of the HUMVEE via nylon webbing straps.

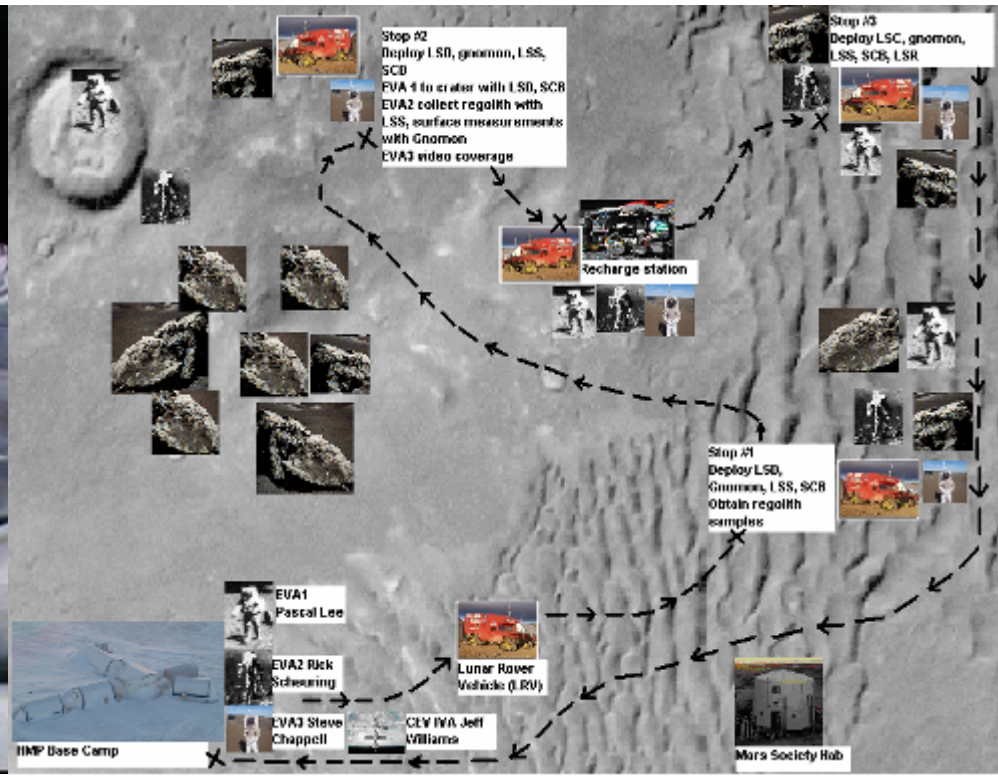
Photo courtesy of HMP 2006/R. Scheuring

Results: Extraction of Ill/Injured Crewmember

- An anchor to provide stable support for the winch is considered key to the success of the technique
- Litter design promoted build up of dirt at the head making extraction difficult
- The leg splint effectively immobilized the limb
- The technique of assisting the injured crew member into the litter was effective

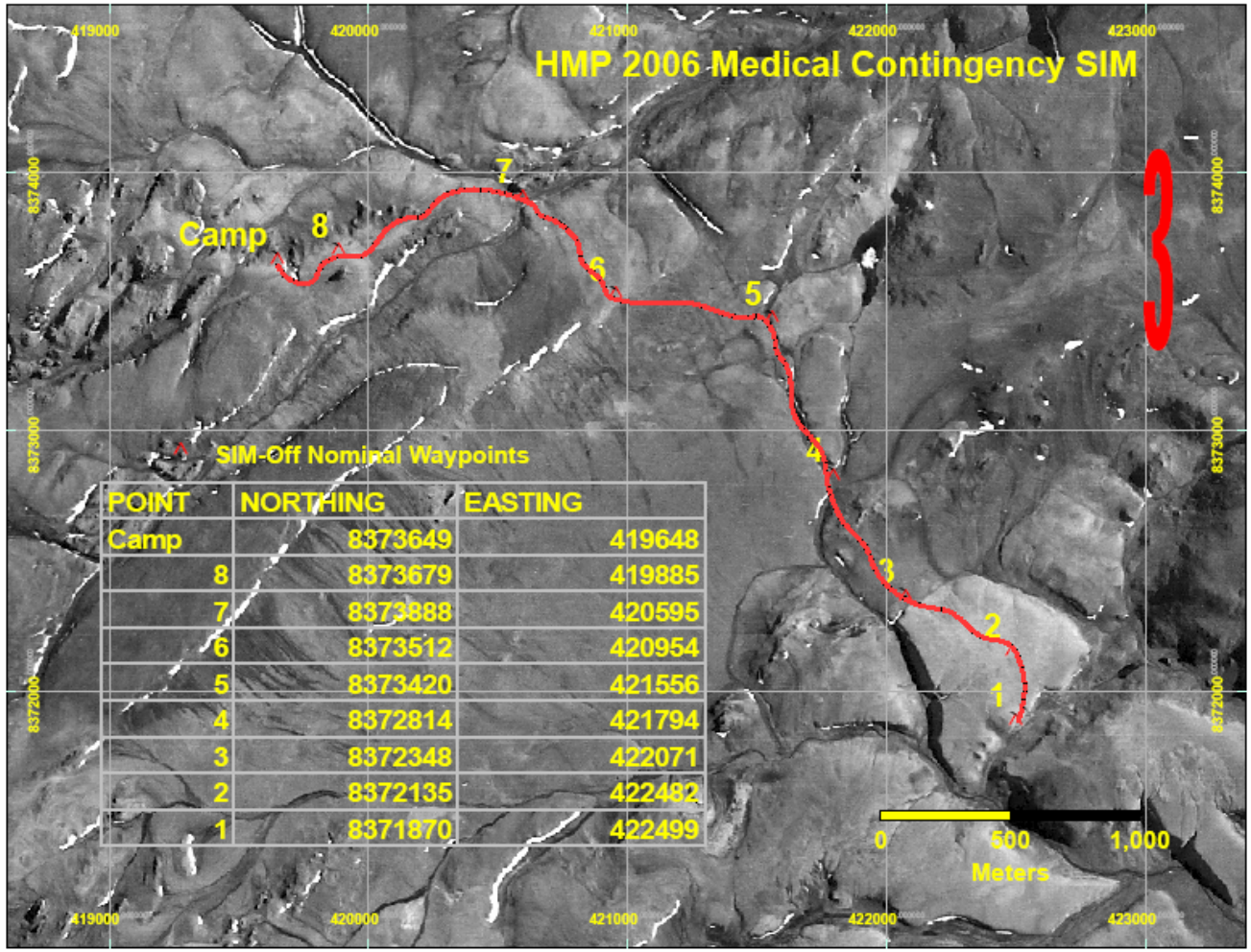
Objectives: Traverse navigation

4. Develop management strategy for off-nominal rover traverse navigation



Results: Traverse navigation

- Predetermined waypoints called to the multiple MCC's in UTM worked very well for simulation purposes



Objectives: EVA Contingencies

5. Develop response plan for unexpected EVA suit/navigation traverse contingencies

Apollo EVA suit concerns

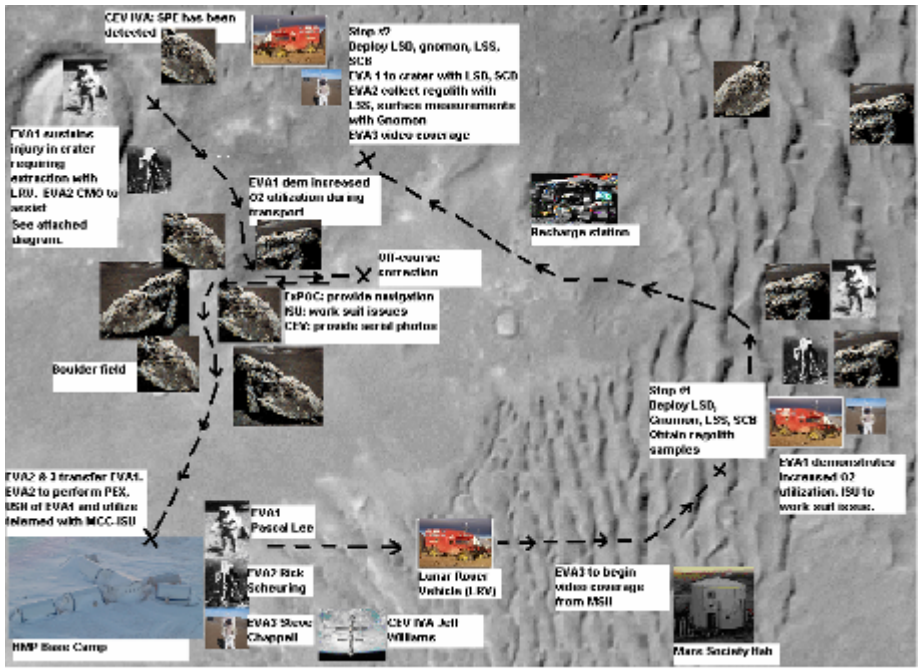
- Puncture
- Visor – Fogging, Scratches (A17)
- Consumable usage

Procedure: EVA Contingencies

- Increased suit O_2 utilization
  - Suit leak vs. increased metabolic rate?
    - Occurred during LSA at work station #1
    - Occurred following injury event at work station #2
- An algorithm for predicting metabolic rate from sensor parameters was developed for the sim
  - This allowed for accurate diagnosis
  - However, often there was no suit consumables data available or it was limited and not coming in quickly enough

Photo courtesy of HMP 2006/N. Wilkinson

Procedure/Results: Traverse contingency



- Course deviation during traverse back to habitat
  - The flight controllers were able to quickly and accurately detect course changes and re-route the EVA crewmembers to the desired route

Objectives: Telemedicine

6. Demonstrate the ability to conduct remote patient medical diagnosis of an ill/injured EVA crewmember using telemedicine (including ultrasound) techniques

Results: Telemedicine

- Standard telemedicine protocol followed
  - Ultrasound FAST exam
- The video quality of the U/S was poor
  - However, this hardware capability has been tested and proven in previous analog simulations
- Having a physician CMO was disorientating to the flight controllers
  - Dependence on MCC-H console support was markedly reduced during real-time operation
- MCC-H unable to provide info on EV1's radiation dose

Objectives: Student Familiarization and Training with MCC Operations

7. Familiarize students with mission control center operations; communications protocols; flight controller responsibilities
8. Students are to have an interactive role functioning as back room flight controllers for EVA, ECLS, Surgeon, SRAG and Traverse- with responsibilities to work issues real-time with the ExPOC-designated front room controllers

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Discussion

- How realistic was the 1g analog scenario to a 1/6g Lunar environment?

Video courtesy of NASA

Discussion

- The sim rescue (extraction from a > 20 degree slope) on Earth **generally requires 4-6 litter bearers and at least 4 additional** personnel for anchor establishment and haul system operation.
- The evacuation would have greatly benefited from establishing the anchor prior to its need by decreasing the overall time from injury to rover.

Discussion

Photos courtesy of HMP 2006/R. Scheuring

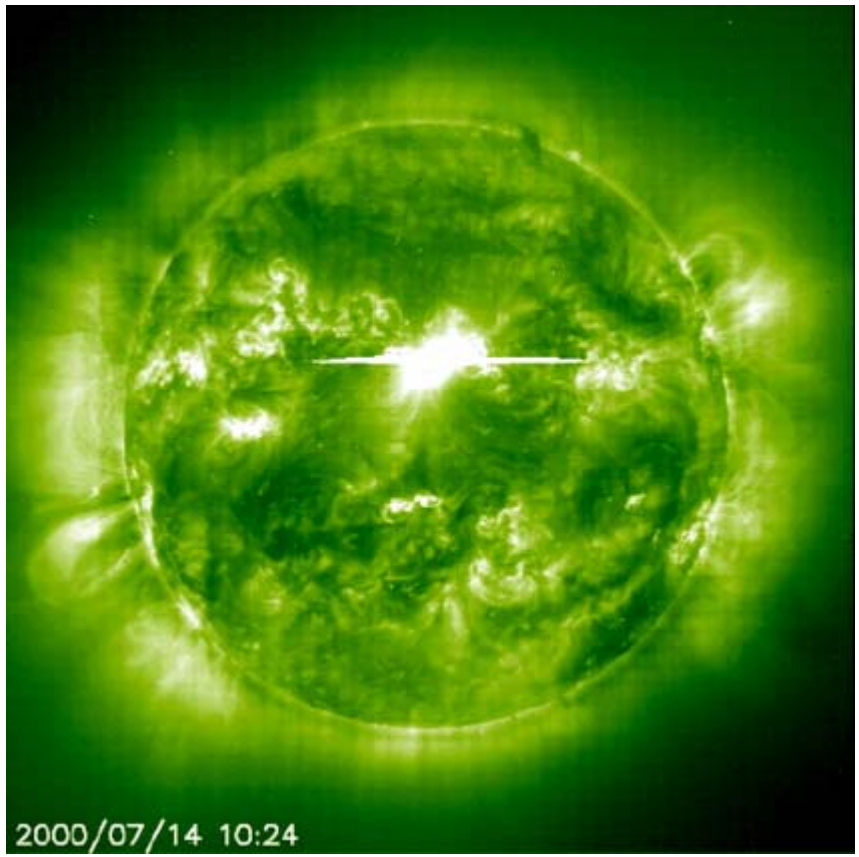
- The extraction method and technique practiced at HMP was not the recommended choice due to schedule and budget constraints.
  - The recommended method was to have a wheeled litter or cart to evacuate the astronaut up the slope.

Discussion

- Radiation Monitoring
  - Reliable SPE prediction capability is nonexistent
  - Real-time event severity uncertain
- Countermeasures
  - Radioprotectant drugs may have been used in the field but does not target all tissues and no metrics for efficacy
  - EVA suit shields only low-kinetic-energy events; must seek shielding immediately. Vehicle/habitat shielding almost always highly to moderately effective.

Discussion

- ISS operational rules were used for event definition, but clearly rules specific to CEV translunar or lunar operations will need to be developed and assessed.



Discussion

- Presence of physician CMO had significant impact on the outcome of the simulation
  - *"A physician crewmember would increase the comfort level among the crewmembers and can be cross-trained to do other activities"*

    Apollo Med Ops Recommendation

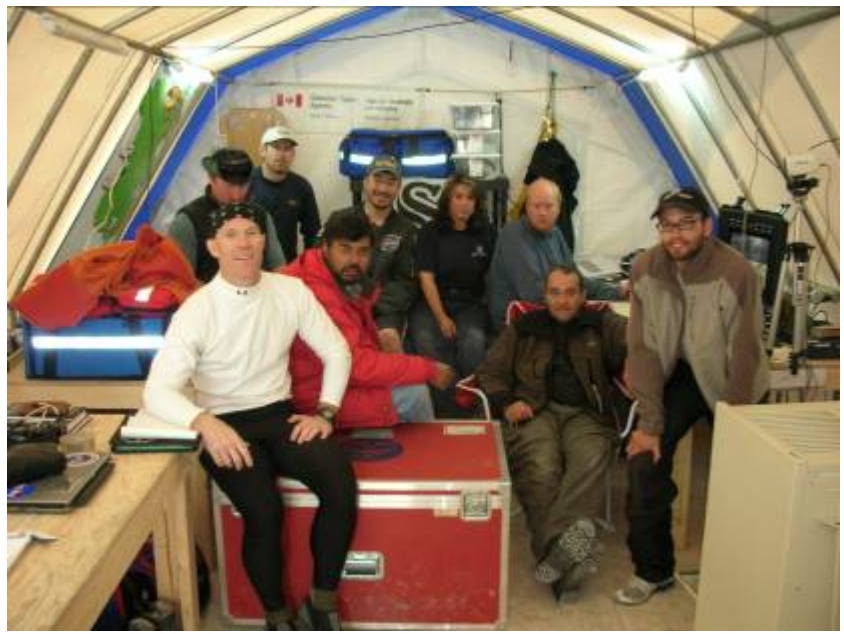


Photo courtesy of HMP 2006/N. Wilkinson

Discussion

- Psychological/Crew dynamics
  - 24 hours of sunlight
  - Physiological factors
  - Work schedule
  - Limited resources
  - Timeline constraints of working with multiple centers

Lessons learned

- Extensive pre-season fully integrated tests of the communications systems would have quickly identified the connection problems
- The team as a whole needs to be aware of the complexity of the simulation
- Series of sims should be planned with increasing complexity
  - First develop medical requirements without additional contingencies then stack up failures
- Participation of sim specialists at Devon would be beneficial

Forward Work

- Develop a strategic plan for testing hardware, procedures, and integration with other elements for each analog site
- Establish improved sensor requirements for metabolic assessment
- The metabolic rate algorithm is under refinement / development to be used for future EVAs
- Radiation Health Working Group
  - Real-time space weather monitoring is crucial
  - EVA requires active dosimetry for immediate response of unshielded crew
  - Develop flight rules to define threshold values to direct crew response on the lunar surface
  - Ground Support needs to develop real-time response models of potential mission & medical impacts and report these to flight director and flight surgeon

Forward Work

- HMP 2007 Lunar Med Contingency Sim Goals
  - Develop the radiation hazard mitigation strategy
  - Continue investigation of field rescue systems
  - In-suit testing of metabolic rate algorithm
- Pre-sim development
  - Communications/connectivity
  - Radiation gaps in knowledge
    - In-suit dosimetry
  - BIOMED development and integration
  - Extraction equipment/technique

Conclusion

- The simulation scenario performed at Devon gave us the experience and perspective to move forward with developing lunar surface medical operations requirements

Photo courtesy of NASA

NASA/HMP 2006 Lunar Medical Contingency Simulation Team

Photo courtesy of HMP 2006/R. Scheuring

Questions?

Injured Lunar Astronaut. Painting by Pat Rawlings

Photo courtesy of HMP 2006/N. Wilkinson/P. Lee