CxP Medical Operations Concept of Operations (CONOPS)

Rick Scheuring, DO, MS, FAAFP
Constellation Flight Surgeon
NASA-Johnson Space Center

CONSTELLATION
Acknowledgements

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  • Jenn Fogarty, PhD, Tom Hatfield, PhD, Duane Chin, Yamil Garcia, Tara Volpe, Jeff Jones, MD, Pete Bauer, MD, David Alexander, MD, Mike Chandler

♦ Exploration Medical Capability Team
  • David Baumann, Sharmi Watkins, MD, Eric Kertsman, MD, Yael Barr, MD, Jimmy Wu
Objectives

♦ Provide insight into the NASA medical operations CONOPS for Constellation

- Medical hardware development
- Telemedicine
- Training
- Risk estimation
- Medical procedure development
Scope of the Medical Operations CONOPS

♦ Defines the Crew Health Operations Concept (CHOC) for Exploration Class missions beyond Low Earth Orbit and the Orion to ISS transfer missions.

♦ Used by the Space Life Sciences Directorate (SLSD) to bound health care for the various missions, using realistic expectations based on risk, experience from past missions, and limitations due to vehicle or habitat.

♦ Addresses the Constellation
  - launch operations, landing operations (surface operations - land and water)
  - transfer missions (Orion for ISS, Orion for Lunar and Orion for Mars)
  - EVA operations
  - rover operations
  - training for crews
  - medical support personnel and off-nominal situations

♦ Does not include cargo vehicles which could be used to carry crew health equipment and supplies.

♦ Does not address the rescue of the crews in detail, but it does address the transfer from rescue to medical care facilities.
Our mandate:

- Optimize crew health and performance to ensure mission success
- Return the crew safely to Earth
Basic Tenets of Exploration Medicine

♦ **Prevention, Prevention, Prevention!!!!!!**
  - Strict selection criteria
  - Aggressively managed existing medical conditions
  - Maximally prepare crew prior to flight
  - Health maintenance strategy
    - Health checks
    - Countermeasures
    - Early Warning

♦ **Small medical h/w footprint**
  - "Tenets” of space flight guide capabilities
    - Power
    - Mass
    - Volume
    - Time
    - Money
Exploration Medical Management Philosophy

♦ ISS
  • 6-24 hours for medical evacuation
  • Emphasis on stabilization, medical transport and advanced trauma life support capability

♦ Moon: Sortie to Lunar Outpost
  • 6.5-9 days for evacuation (Earth return)
  • CMO for initial missions to physician with some autonomous capability
  • Telemedicine as augmentation

♦ Mars
  • 6 to >12 months for evacuation
  • Broadly trained physician with complete autonomous capability
  • Telemedicine for Tx planning, validation, telesurgery?
Space Medical Issues- Future*

♦ Expected illnesses and problems
  • Orthopedic and musculoskeletal problems\textsuperscript{1,2}
  • 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

♦ 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
Medical Operational Concept\(^3\)

\(\text{♦ Lifecycle Phase: Pre-Mission}\

- Crew selection/retention standards will be used to minimize likelihood of pre-flight medical conditions that could lead to crew debilitation.
- Preflight testing and conditioning of crew will be performed prior to launch to ensure that they are in the best physical and psychological condition prior to launch.
- Crew training will be conducted by medical doctors to provide the crew, especially the Crew Medical Officer, with the best skill set to take care of medical contingencies.
- Behavioral health and family support specialists will work with crew to ensure their psycho-social needs are met.

\(\text{♦ Lifecycle Phase: Launch}\

- Crew launch loads/accelerations are specified to ensure that the crew is not exposed to excessive forces\(^*\)

\(^3\) Crew Health Operations Concept for Constellation Missions. JSC-63566, Mar 2009.

\(^*\) E.g. Thrust oscillations
# Levels of Care based on Mission Duration

<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.**

<table>
<thead>
<tr>
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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

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<table>
<thead>
<tr>
<th>Condition</th>
<th>(Orion+ISS) Clinical Priority</th>
<th>(Lunar Sortie) Clinical Priority</th>
<th>(Lunar Outpost) Clinical Priority</th>
<th>(ISS Contingency) Clinical Priority</th>
<th>(Sortie Contingency) Clinical Priority</th>
<th>(Outpost Contingency) Clinical Priority</th>
<th>(144 Hour Depress) Clinical Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nasal Congestion - SAS</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
<td>0 - Not Concerned</td>
<td>0 - Not Concerned</td>
<td>0 - Not Concerned</td>
<td>1 - Should</td>
</tr>
<tr>
<td>Nausea / Vomiting</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
</tr>
<tr>
<td>Neck Injury</td>
<td>0 - Not Concerned</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
<td>0 - Not Concerned</td>
<td>0 - Not Concerned</td>
<td>0 - Not Concerned</td>
<td>0 - Not Concerned</td>
</tr>
<tr>
<td>Neurogenic Shock</td>
<td>0 - Not Concerned</td>
<td>0 - Not Concerned</td>
<td>0 - Not Concerned</td>
<td>0 - Not Concerned</td>
<td>0 - Not Concerned</td>
<td>0 - Not Concerned</td>
<td>0 - Not Concerned</td>
</tr>
<tr>
<td>Nosebleed - SAS</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
<td>0 - Not Concerned</td>
<td>0 - Not Concerned</td>
<td>0 - Not Concerned</td>
<td>0 - Not Concerned</td>
</tr>
<tr>
<td>Paresthesias (post-EVA)</td>
<td>0 - Not Concerned</td>
<td>1 - Should</td>
<td>1 - Should</td>
<td>0 - Not Concerned</td>
<td>0 - Not Concerned</td>
<td>0 - Not Concerned</td>
<td>0 - Not Concerned</td>
</tr>
<tr>
<td>Radiation Sickness</td>
<td>0 - Not Concerned</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
<td>0 - Not Concerned</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
<td>2 - Not Concerned</td>
</tr>
<tr>
<td>Seizure</td>
<td>0 - Not Concerned</td>
<td>0 - Not Concerned</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
</tr>
<tr>
<td>Shoulder Dislocation</td>
<td>0 - Not Concerned</td>
<td>0 - Not Concerned</td>
<td>0 - Not Concerned</td>
<td>0 - Not Concerned</td>
<td>0 - Not Concerned</td>
<td>0 - Not Concerned</td>
<td>0 - Not Concerned</td>
</tr>
<tr>
<td>Skin Abrasion/Laceration</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
<td>0 - Not Concerned</td>
<td>0 - Not Concerned</td>
<td>0 - Not Concerned</td>
<td>0 - Not Concerned</td>
</tr>
<tr>
<td>Skin Rash</td>
<td>1 - Should</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
<td>0 - Not Concerned</td>
<td>0 - Not Concerned</td>
<td>0 - Not Concerned</td>
<td>1 - Should</td>
</tr>
<tr>
<td>Smoke Inhalation</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
<td>2 - Not Concerned</td>
</tr>
<tr>
<td>Space Motion Sickness - SAS</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
<td>2 - Not Concerned</td>
</tr>
<tr>
<td>Sprain/Strain/Overuse Syndromes</td>
<td>1 - Should</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
<td>0 - Not Concerned</td>
<td>0 - Not Concerned</td>
<td>0 - Not Concerned</td>
<td>1 - Should</td>
</tr>
<tr>
<td>Sudden Cardiac Arrest</td>
<td>0 - Not Concerned</td>
<td>0 - Not Concerned</td>
<td>1 - Should</td>
<td>1 - Should</td>
<td>0 - Not Concerned</td>
<td>1 - Should</td>
<td>0 - Not Concerned</td>
</tr>
<tr>
<td>Toxic Exposure</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
<td>2 - Not Concerned</td>
</tr>
<tr>
<td>Upper Extremity Fracture</td>
<td>0 - Not Concerned</td>
<td>0 - Not Concerned</td>
<td>1 - Should</td>
<td>0 - Not Concerned</td>
<td>1 - Should</td>
<td>1 - Should</td>
<td>1 - Should</td>
</tr>
<tr>
<td>Urinary Incontinence - SAS</td>
<td>1 - Should</td>
<td>1 - Should</td>
<td>1 - Should</td>
<td>0 - Not Concerned</td>
<td>0 - Not Concerned</td>
<td>0 - Not Concerned</td>
<td>0 - Not Concerned</td>
</tr>
<tr>
<td>Urinary Retention - SAS</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
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<td>2 - Shall</td>
<td>2 - Shall</td>
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</tbody>
</table>

Behavioral/Psycho-Social

- Changes in crew mood, morale, and circadian rhythm
- Incidence - Affects all crewmembers to some degree
- Symptoms - Fatigue and irritability
- Time course - Depends on flight plan
- Causes
  - Work load
  - Sleep habits and facilities; chronobiology
  - Crew personalities and "crew space"
  - Temperature
  - Noise
  - Odors
  - Atmosphere
  - Diet
  - Lack of family contact

◆ **Treatment** - Treat causes
NASA Launch Vehicle Comparison

- **Atlas-D/Titan II**
  - LEO Payload: 3,000/8,000 lbm
  - Max Thrust: 308/430 klbf
  - Max Acceleration: < 6g
  - Thrust Oscillation: 0.25 g-RMS

- **Space Shuttle**
  - LEO Payload: 53,700 lbm
  - Max Thrust: 6.4 Mlbf
  - Max Acceleration: 3.0 g
  - Thrust Oscillation: 0.2 g-RMS

- **Ares I**
  - LEO Payload: 55,000 lbm
  - Max Thrust: 3.5 Mlbf
  - Max Acceleration: 3.8g
  - Thrust Oscillation: 0.3-0.4 g-RMS

- **Ares V**
  - LEO Payload: 300,000 lbm
  - Max Thrust: 10 Mlbf
  - Max Acceleration: 3.8g
  - Thrust Oscillation: 0.2-0.3 g-RMS

- **Saturn V**
  - LEO Payload: 262,000 lbm
  - Max Thrust: 7.75 Mlbf
  - Max Acceleration: 3.9g
  - Thrust Oscillation: < 0.6 g-RMS
A blunt body capsule is the safest, most affordable and fastest approach

- Separate Crew Module and Service Module configuration
- Vehicle designed for ISS transfer and lunar missions with 4 crew
  - Can accommodate up to 6 crew for Mars
- System also has the potential to deliver pressurized and unpressurized cargo to the Space Station if needed

5.0 meter diameter capsule – (scaled from Apollo)
- Significant increase in volume
- Reduced development time and risk
- Reduced reentry loads, increased landing stability, and better crew visibility
Atmospheric Conditions for Exploration Vehicles

Cabin Total Pressure, kPa vs. Cabin Volume Percent Oxygen

- CEV to ISS
- Hypoxic Boundary
- Normoxic Equivalent
- Historical Designs

CEV to ISS, Lunar Sorties, Lunar/Mars Long Duration, Skylab, Mercury/Gemini/Apollo

CEV Atmosphere Transition on Earth Ascent

- Pre-launch Transition
- Shuttle/Mir/ISS
- Shuttle EVA Preparation
- Lunar Sortie CEV
- Early Apollo Design
- Skylab
- Mercury/Gemini/Apollo
- Normoxic Equivalent
- Hypoxic Boundary
- Historical Designs
Servicing the International Space Station

- NASA will invite industry to offer commercial crew and cargo delivery service to and from the Station (Initial Capability)

- The CEV will be designed for lunar missions but, if needed, can service the International Space Station.

- The CEV will be able to transport crew to and from the Station and stay for 6 months

- Current timeline targeted for 2015*

Typical International Space Station (ISS) Reference Mission

Orion Control Mass 19.3 mt (42,540 lbm)
Ares-I Delivered Mass 20.4 mt (44,780 lbm)

Crew of 1 to 6
1047 kg (2308 lbm) of crew & equipment

Orion CM Op limit: [9,525kg (21,000 lbm)]

Service Module Expended

Direct Entry Nominal Water Landing

10 min launch window

ISS orbit
407 km (220 nm), 51.6°

-20.4 x 185 km
(-11x100 nm)
70 NM Altitude
8 NM deliv error
51.6°
Medical Operational Concept

Lifecycle Phase: CEV to ISS transfer mission (Initial Capability)

♦ Nominal:

- Minimal medical equipment will be stowed for onboard use for the short mission to/from ISS. {GFE hardware allocation matrix, SRD Table 3-5 mass/volume}
- Two-way private audio/video is required for performing Private Medical Conferences and conferences between the crew and their family {SRD 3.2.2.15.12.1 & 3.3.10, Portable Equipment/Medical I/F Whitepaper}
- The crew will be instructed by the Flight Surgeon in MCC about medication usage and medical prescriptions to manage early flight medical conditions will be communicated to the crew via the CEV comm and data system {SRD 3.4.7.1}

♦ Off-nominal:

- In the event of illness or injury onboard the ISS, advanced life support equipment and medical supplies from ISS may be brought over to the CEV with the ill/injured crewmember for the return trip. Oxygen may be required depending on the crewmember’s condition. The crew’s health would be monitored on the ground by the Flight Surgeon along with the CMO. Power, data, mechanical, and oxygen interfaces will be required {SRD 3.4.7, 3.4.7.1, 3.4.7.2, Portable Equipment/Medical I/F Whitepaper}
- During contingency EVAs, physiological parameters (i.e. oxygen, carbon dioxide, temperature, etc.) will be monitored by the flight surgeon in MCC.
Exploration Medical Kit Capability by Mission

**CEV to ISS**
- Medical Kit: 7 x 6 x 4 in
- Contingency Cleanup Kit: 7 x 7 x 5 in
- Medical Interface Kit: 7.5 x 5 x 5 in
- Environmental Health: 7 x 7 x 7 in

**CEV to Lunar Orbit**
- Contingency Cleanup Kit: 7 x 7 x 5 in
- Environmental Health: 7 x 7 x 7 in
- Medical Kit: 14.5 x 7 x 9.5 in
- Excercise: 9.75 x 16.75 x 9.25 in

**LSAM**
- Medical Interface Kit: 7 x 5 x 5 in
- Airlock EVA Contingency Response: 10 x 11 x 15 in

**ISS Advanced Life Support Pack**
- ISS Advanced Life Support Pack: 26 x 14 x 8 in
- Medical Trauma & Life Support: 32 x 12 x 16 in
The Moon - the 1st Step to Mars and Beyond…

♦ Gaining significant experience operating away from Earth’s environment
  • Space will no longer be a destination visited briefly and tentatively
  • “Living off the land”
  • Human support systems

♦ Developing technologies needed for opening the space frontier
  • Crew and cargo launch vehicles (125 metric ton class)
  • Earth ascent/entry system – Crew Exploration Vehicle (CEV)
  • Mars ascent and descent propulsion systems (liquid oxygen/ liquid methane)

♦ Conduct fundamental science
  • Astronomy, physics, astrobiology, historical geology, exobiology
CEV (Lunar Capability) to Lunar orbit and back

♦ Current timeline for lunar return is 2020
Lunar Sortie - Design Reference Mission

- CEV (lunar capability) and Altair launch separately
- CEV docks with Altair in LEO with TLI after docked
Lunar Lander and Ascent Stage: Altair

- 4 crew to and from the surface
  - Seven days on the surface
  - Lunar outpost crew rotation

- Global access capability*

- Anytime return to Earth**

- Capability to land 21 metric tons of dedicated cargo

- Airlock for surface activities

- Descent stage:
  - Liquid oxygen / liquid hydrogen propulsion

- Ascent stage:
  - Liquid oxygen / liquid methane propulsion

*1 of 10 potential landing sites

**Approximately 6.5-9 days for Earth return from polar landing sites
Medical Operational Concept

Lifecycle Phase: CEV and Altair to lunar orbit (Lunar Capability; LC)

♦ Nominal:
  - Same as Initial Capability CEV but a larger set of equipment/supplies will be stowed in the LC CEV.
  - A subset of this equipment will be taken with the crew in the Altair to support surface operations.
  - A small exercise device (~0.5 MLE) will be stowed for onboard use.
  - The crew will perform exercise in the LC CEV and will require attach points for the exercise device. The details are TBR. (Portable Equipment/Medical I/F Whitepaper). The operational envelope of the crew/exercise device is currently 90 ft³.

♦ Off-nominal:
  - Same as IC CEV but the advanced life support/trauma management equipment will be stowed in the Altair to stabilize crewmembers experiencing lunar surface contingencies and brought into the CEV only in case of a need to transport and ill or injured crewmember.
Lunar Electric Vehicle (LER)
Medical Operational Concept

Lifecycle Phase: Surface Operations – Lunar Sortie

♦ Nominal:

- The crew will bring a subset of the CEV medical equipment and the exercise device (TBR) into the Altair to support nominal surface operations
- Advanced life support/trauma management equipment will be stowed in the Altair.
- The flight surgeons in MCC will monitor physiological parameters (i.e. heart rate, oxygen, carbon dioxide, etc.) during surface EVAs via telemetry data down-linked to the ground.
- Flight surgeons will be able to monitor EKG real-time during intravehicular (IVA) operations
- Two-way private audio/video is required for performing Private Medical Conferences especially pre/post EVA. The two-way communication will also support Private Family Conferences (PFC) at least weekly between the crew and their family, and Private Psychological Conferences (PPC) as required.

♦ Off-nominal:

- An EVA Contingency Response Kit will be stowed in the Airlock which will contain a Contamination Kit (brushes, bags, wipes), DCS treatment, fluids, and anti-inflammatory medication for the crew to use.
- The medical equipment brought from the CEV and stowed in the Altair will be used to treat ill/injured crewmembers per instructions from the flight surgeons. Data from the medical monitoring devices will be communicated to the ground for further diagnostic purposes. Power will be required for the medical equipment. Pressurized oxygen may be required for certain medical conditions for the ill/injured crewmember.
- A significant illness or injury will be stabilized using Altair-based medical equipment in preparation for ascent and transfer to CEV.
- Two-way private audio/video is required for performing Private Medical Conferences with the flight surgeon in MCC to ensure optimization of medical care via the Crew Medical Officer.
**Medical Hardware for Initial Lunar Missions**

**Table 2: Example hardware and mass/volume allocation for support of lunar missions**

<table>
<thead>
<tr>
<th>Item for Lunar Sortie</th>
<th>Mass</th>
<th>Size</th>
<th>Development Concept</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medical Kit</td>
<td>10 lbs</td>
<td>10x7x6 in</td>
<td>COTS</td>
</tr>
<tr>
<td>Medical Contingency Kit</td>
<td>30 lbs</td>
<td>32x12x16 in</td>
<td>Modified COTS</td>
</tr>
<tr>
<td>EVA Contingency Response Kit</td>
<td>16 lbs</td>
<td>16x16x8.5 in</td>
<td>Modified COTS</td>
</tr>
<tr>
<td>Environmental Health Kit</td>
<td>7.5 lbs</td>
<td>7x7x9 in</td>
<td>Modified COTS</td>
</tr>
<tr>
<td>Exercise Equipment</td>
<td>5-20 lbs</td>
<td>TBD</td>
<td>Technology Development Required</td>
</tr>
</tbody>
</table>

*COTS= Commercial Off-The-Shelf*

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Medical Issues to Manage for Lunar EVA

*Lunar Surface EVA issues*
- LSS: Oxygen/Carbon Dioxide
- Thermal Loading
- Metabolic Loading
- Wear-ability/Comfort
- Injury Prevention
- Decompression Sickness
- Dust Toxicity
- Radiation Protection*
Were injuries common on the Moon?
Injury Prevention

♦ Lunar Surface Operations\(^8\)
  - 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

Injury Prevention

♦ Suit Factors:
  • Mobility/Agility
  • Balanced CG
  • Vision

♦ Operational Prevention:
  • Lunar Surface Ops Plan/Rules
  • Communication

Apollo 16 Astronaut on rim of Plum Crater (30-m), which is on the rim of Flag Crater (300-m in diameter, 50-m deep).
Injury contingency management

I’ve fallen and can’t reach my slide rule

Medical contingencies plans for EVA injury management must be developed for low likelihood transport and stabilization
Injury contingency management

- EVA1: Incapacitated, strapped to litter
- EVA2: Tends litter & monitors EVA1
- Winch
- Belay Line
- Edge Protection
- Rope anchored to Hummer or other solid anchor farther from rim
- ascent of litter

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Medical Operational Concept

Lifecycle Phase: Return transfer mission

♦ Nominal:
  • The crew will perform daily exercise in the CEV in preparation for return to 1g.
  • Private two-way audio/video communication will allow a Pre-entry PMC.

♦ Off-nominal:
  • If illness or injury on the lunar surface occurs, the Altair required hardware will be transported back with the crewmember to ensure a stabilized condition is maintained.
  • Two-way private audio/video is required for performing Private Medical Conferences with the flight surgeon in MCC to ensure optimization of medical care via the Crew Medical Officer.
Lunar Outpost- Long duration Habitat

- Concept: Medical h/w and supplies to launch in rack (must meet launch mass constraints) ALS/Trauma stabilization kit
  - Portable Imager (U/S)
  - Telemedicine Workstation
  - Medical procedure/monitoring/treatment kit
    - Dental
    - Laceration repair
    - Extremity splinting devices
    - Acute radiation exposure monitoring devices and countermeasures
  - ???

---

Lunar Outpost- DRM: Habitat Pre-positioned

Concept

♦ Up to 20 Metric Tonnes to Surface
♦ Crew launches at later time on separate vehicles
♦ Lunar habitat functionality checked-out via telemetry
♦ ISRU/Power/LSS support
Medical/Exercise/Environmental Monitoring System Mass and Volume Allocation-GFE

♦ Lunar Outpost

- Medical Kits
  - Volume – 1 ISS ISO rack stowage bin equivalent (approx. 0.5-0.75 M³)
- Exercise
  - Volume 0.5 CTBE (1/2 Shuttle mid-deck locker) approx. 0.01 M³
  - Mass 10 kg (22 lbs.)
  - Use envelope: 2.57 M³ (6.5 x 4.2 x 3.3 ft.)
  - No power or data interface
- Environmental Monitoring
  - Volume TBD 0.5-0.75 CTBE
  - Mass 10-20 kg
Landings Recovery

♦ Nominal recovery
  • Water is prime for landing
    – Land is a contingency launch abort scenario
    – Crew will remain in vehicle with two-way communication until SAR forces arrive

♦ Off-nominal recovery
  • Crew may be in the ocean up to 24 hours before recovered

Apollo 12 landing, 1970

PORT 1, 2009
Medical Capabilities Envisioned to Support Exploratory Class Space Flight Implications for the Future

✦ Small steps needed for diagnostic imaging upgrade/miniaturization
✦ Still need a giant leap for the autonomous medical system to support Lunar Colonies and Mars Exploration
✦ Plenty of work for all that are interested in Medical Technology Development
✦ Medical Suite in Habitat and Rover
✦ Remote/ Automated Diagnostics
  - Vital Signs
  - Imaging
  - Laboratory
✦ Non-Invasive monitors/sensors
✦ Telemedicine
  - Enhanced TIP for consultation to Earth
  - Telerobotics
  - Computer-based diagnostic and treatment algorithms; virtual consultant
Medical Hardware Development Collaborations

- USAARL/US stethoscope
- USAISR/LTM
- GRC/IVGEN
- JSC/IMM
- GRC/IMM modeling
- JSC/Assisted Medical Procedures
- GRC/O2 Concentrator Development
- GRC/Consumables tracking
- GRC/Injectables
- GRC/Medical Imaging Integration
- ARC/Lunar Lab Analysis
- GRC/Reusable Laboratory Capability
- ARC/Biomedical Sensors
- JSC/Guideview
Concept to have access to a Mars transit vehicle after TMI until Mars descent

Concept pre-position Mars habitat on surface and conduct check-out

? ISRU/Power/LSS support

Preventive Medicine station
  • PEx, Labs, Countermeasures

Contingency Management
  • Portable Imager (U/S)
  • Telemedicine Workstation
  • Medical procedure kit

Mars Surface
  • Autonomous Medical Prevention and Care
  • ? Surgical Capability
Human Mars Mission Classes

- Even assuming advanced propulsion technology, Mars missions “driven” by orbital mechanics
  - “Short-stay” ("Opposition-Class")
    - High-propulsive requirements
    - Venus swing-by or deep-space Maneuvers
    - Close perihelion passage
    - 1½ to 2 year mission duration
    - Majority (90+%) of crew time spent in deep-space environment
  - “Long-Stay” ("Conjunction-Class")
    - Lower-propulsive requirements
    - All missions > 1 A.U.
    - Short transits separated by long-surface mission
    - 2½ year mission duration
    - Majority (60+%) of crew time spent on Mars
Mars Long-Stay Mission Overview

Outbound transit: 180 days
Mars surface stay: 540 days
Inbound transit: 180 days

Earth Orbit
Mars Orbit
Piloted Trajectories
Mars Surface Stay

Earth Departure
Mars Departure
Mars Arrival
Earth Arrival
## Assumed Mission Characteristics

<table>
<thead>
<tr>
<th>Factor</th>
<th>Long Stay Mission</th>
<th>Short Stay Mission (2037 opportunity)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Conjunction-class</td>
<td>Opposition-class</td>
</tr>
<tr>
<td>Outbound transit to Mars</td>
<td>6 months</td>
<td>6 months</td>
</tr>
<tr>
<td>Inbound transit to Earth</td>
<td>6 months</td>
<td>13 months</td>
</tr>
<tr>
<td>Total transit (deep space) time (% total mission duration)</td>
<td>12 months (40%)</td>
<td>19 months (95%)</td>
</tr>
<tr>
<td>Surface stay time (% total mission duration)</td>
<td>18 months (60%)</td>
<td>1 month (5%) (2 months = 10%, 3 months = 15%)</td>
</tr>
<tr>
<td>Total Mission Time</td>
<td>30 months</td>
<td>20 months</td>
</tr>
</tbody>
</table>

**Closest solar approach**
- Without Venus swing-by
  - 1 AU
  - n/a
- With Venus swing-by
  - ~0.75 AU
  - ~0.5 AU (3+ months ≤0.75 AU)
  - 2 or 3-month stay: ~0.35 AU (<3 months ≤0.75 AU)
Medical Issues

♦ Long-stay (shorter transits)
  • Longer overall mission duration, more exposure to mission risks, including surface trauma; less total radiation exposure due to less time in interplanetary space and to perihelion = 1 AU

♦ Short-stay (longer transits)
  • Shorter overall mission duration, less exposure to overall mission risks, including surface trauma; however more acute radiation exposure due to more time in interplanetary space and to perihelion ≤ 0.7 AU