CxP Medical Operations Concept of Operations (CONOPS)

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CONSTELLATION

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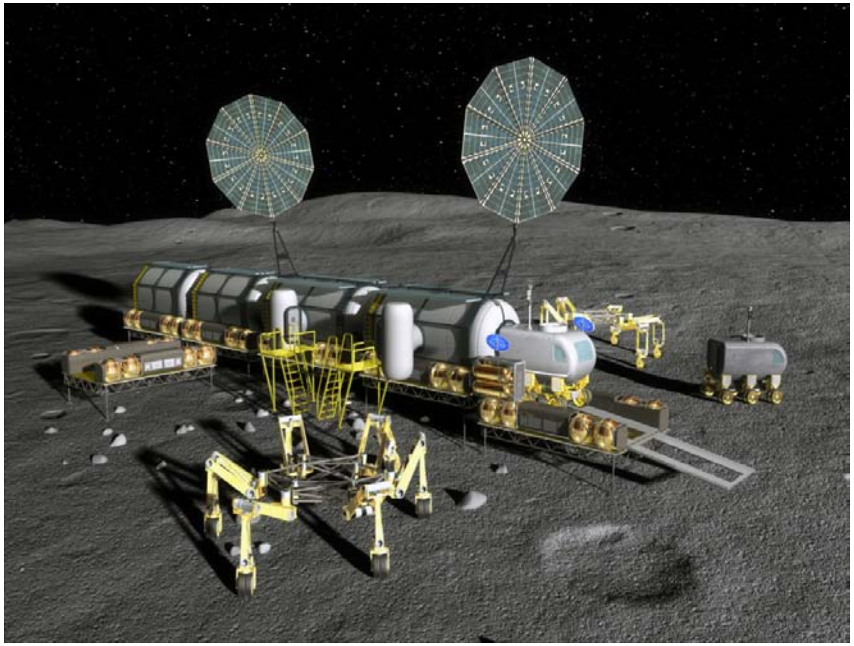
- **Exploration Medical Capability Team**
  - David Baumann, Sharmi Watkins, MD, Eric Kertsman, MD, Yael Barr, MD, Jimmy Wu

Objectives

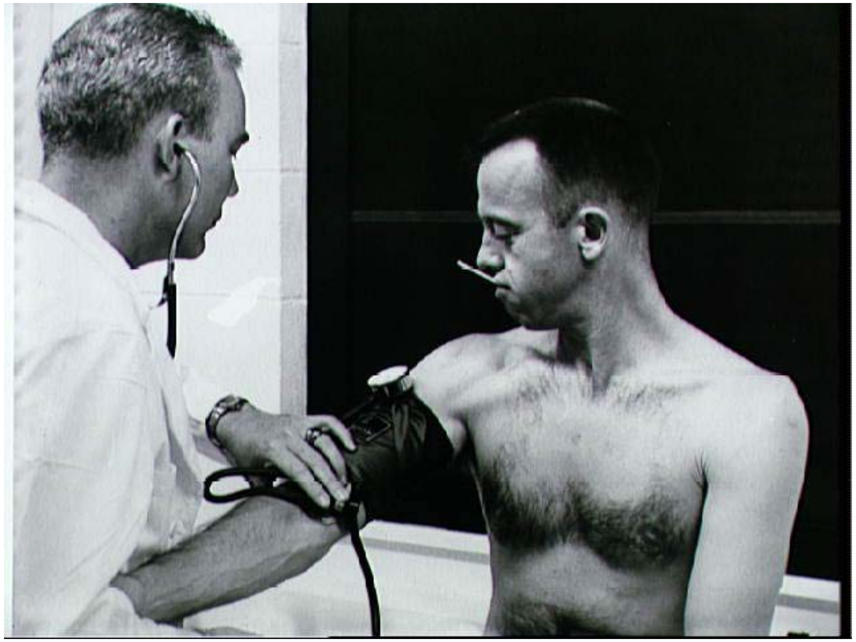
- **Provide insight into the NASA medical operations CONOPS for Constellation**
  - Medical hardware development
  - Telemedicine
  - Training
  - Risk estimation
  - Medical procedure development



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.

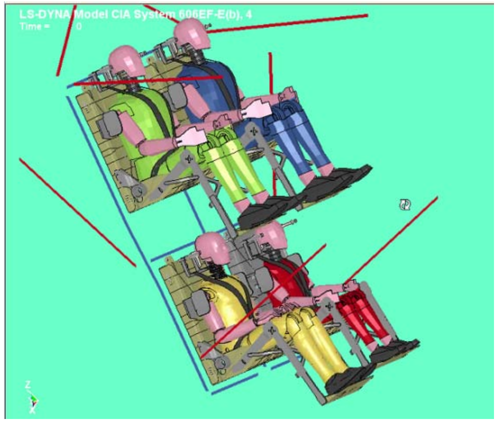
Medical Concept of Operations for Exploration

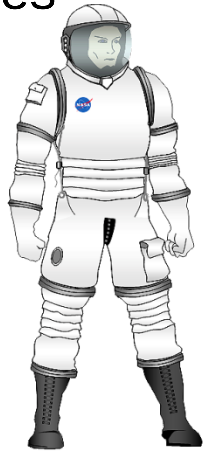


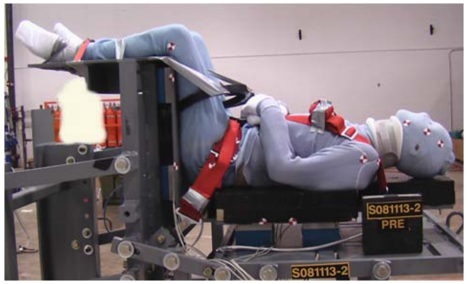
- **_Our mandate:_**
  - **_Optimize crew health and performance to ensure mission success_**
  - **_Return the crew safely to Earth_**

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[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

[1]Scheuring RA, et al. In-flight musculoskeletal injuries in US astronauts. Aviat Space Environ Med, 2009.
[2]Johnson SL, Campbell M, Scheuring RA. Herniated nucleus pulposis in US astronauts. Aviat Space Environ Med, 2009, (In press).

Medical Operational Concept[3]

♦ Lifecycle Phase: Pre-Mission

- Crew selection/retention standards will be used to minimize ... ons ... n.

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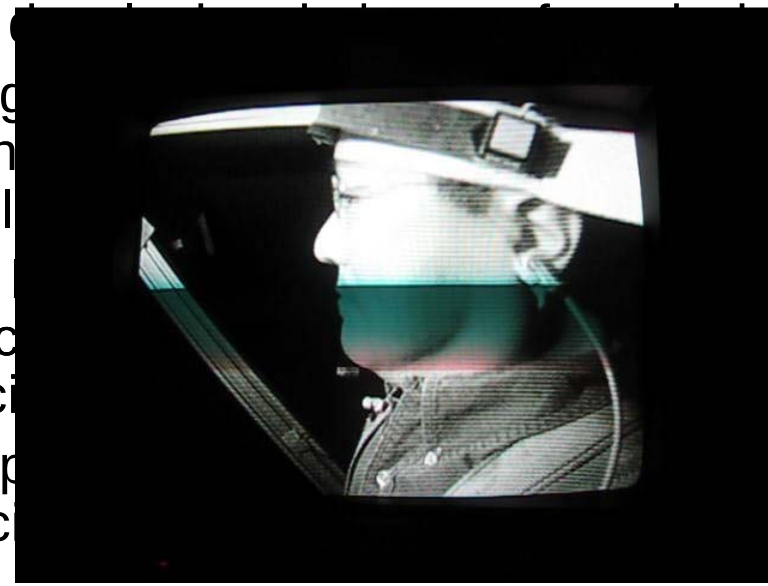


♦ Lifecycle Phase: Launch

- 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[4,5]

Table-1: Levels of Care is matched to mission duration and destination.

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

[4]NASA-Std-3001.

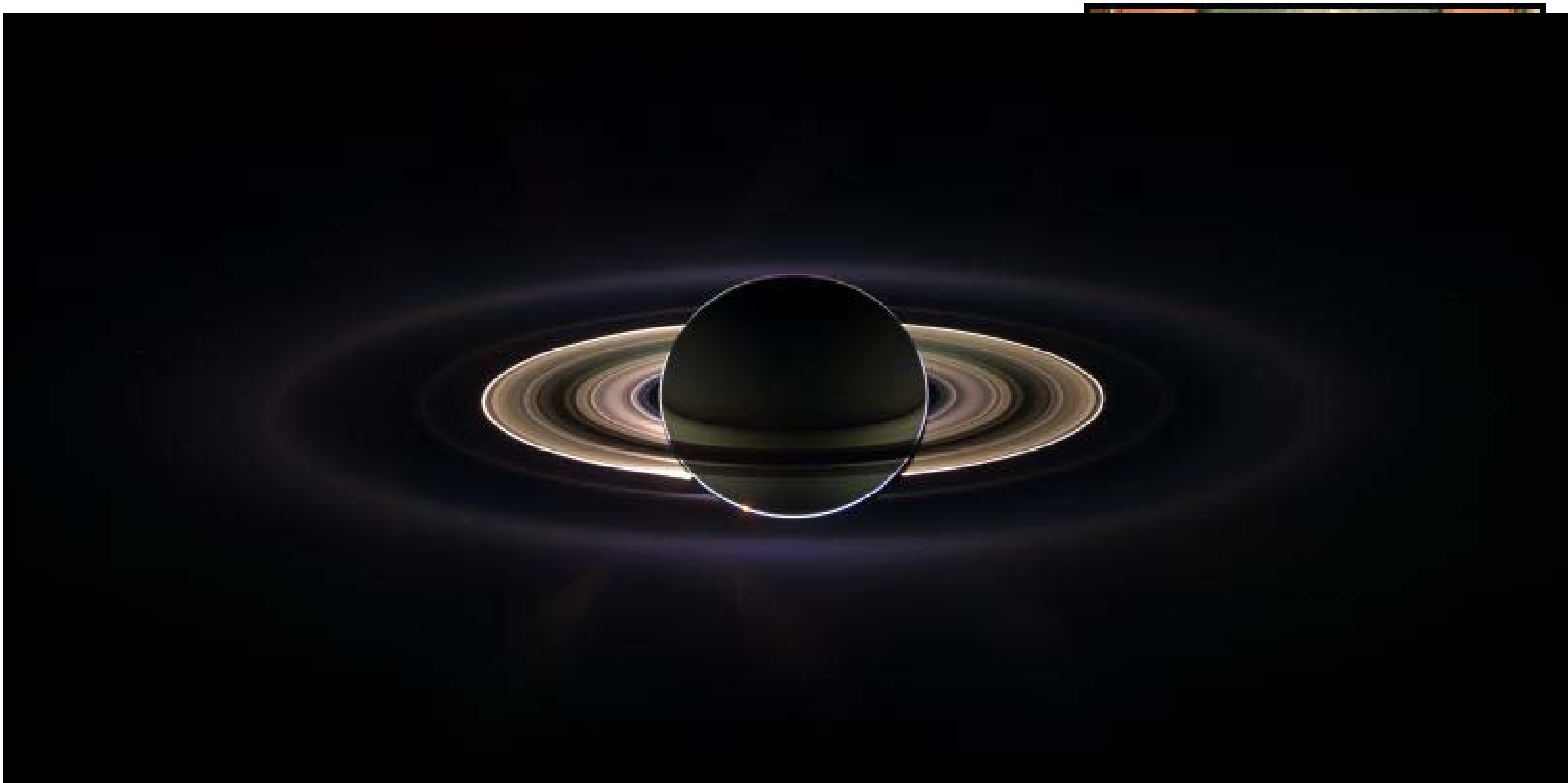
[5]Scheuring RA, Jones JA, Polk JD. Human Spaceflight Health Systems for the Constellation Project. Aviat Space Environ Med. Vol. 78, No.12 Dec. 2007.

Space Medicine Exploration Medical Condition List[6]

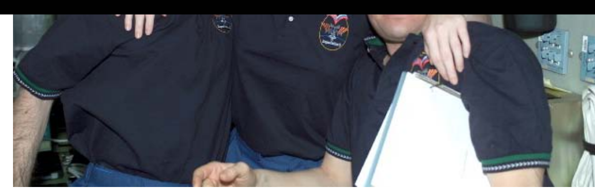
Condition	(Orion↔ISS) Clinical Priority	(Lunar Sortie) Clinical Priority	(Lunar Outpost) Clinical Priority	(ISS Contingency) Clinical Priority	(Sortie Contingency) Clinical Priority	(Outpost Contingency) Clinical Priority	(144 Hour Depress) Clinical Priority
Nasal Congestion - SAS	2 - Shall	2 - Shall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

[6]Space Medicine Exploration Medical Condition List. NASA-JSC, Jul. 2009.

Behavioral/Psycho-Social

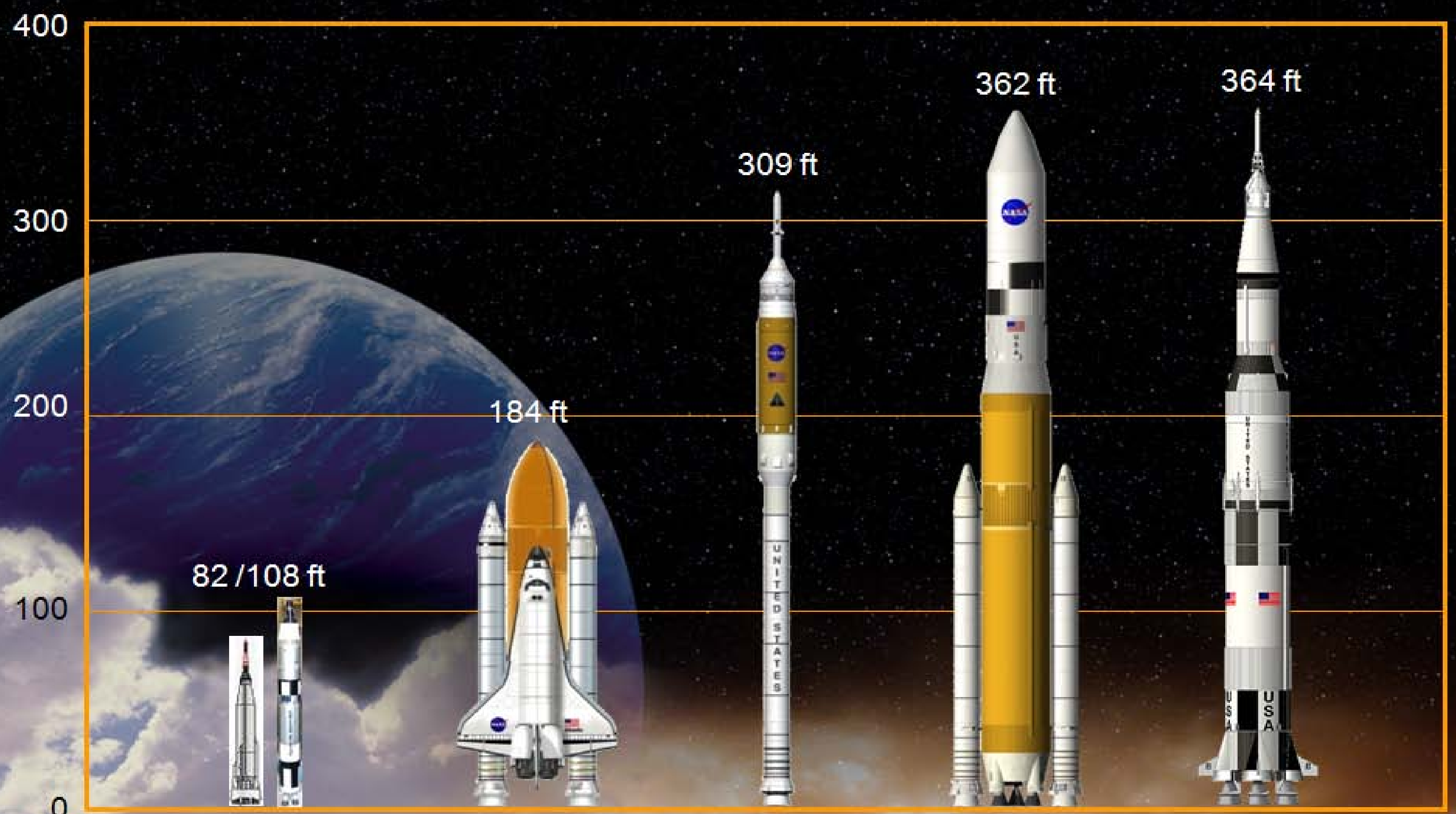


- Diet
- Lack of family contact



♦ **Treatment - Treat causes**

NASA Launch Vehicle Comparison



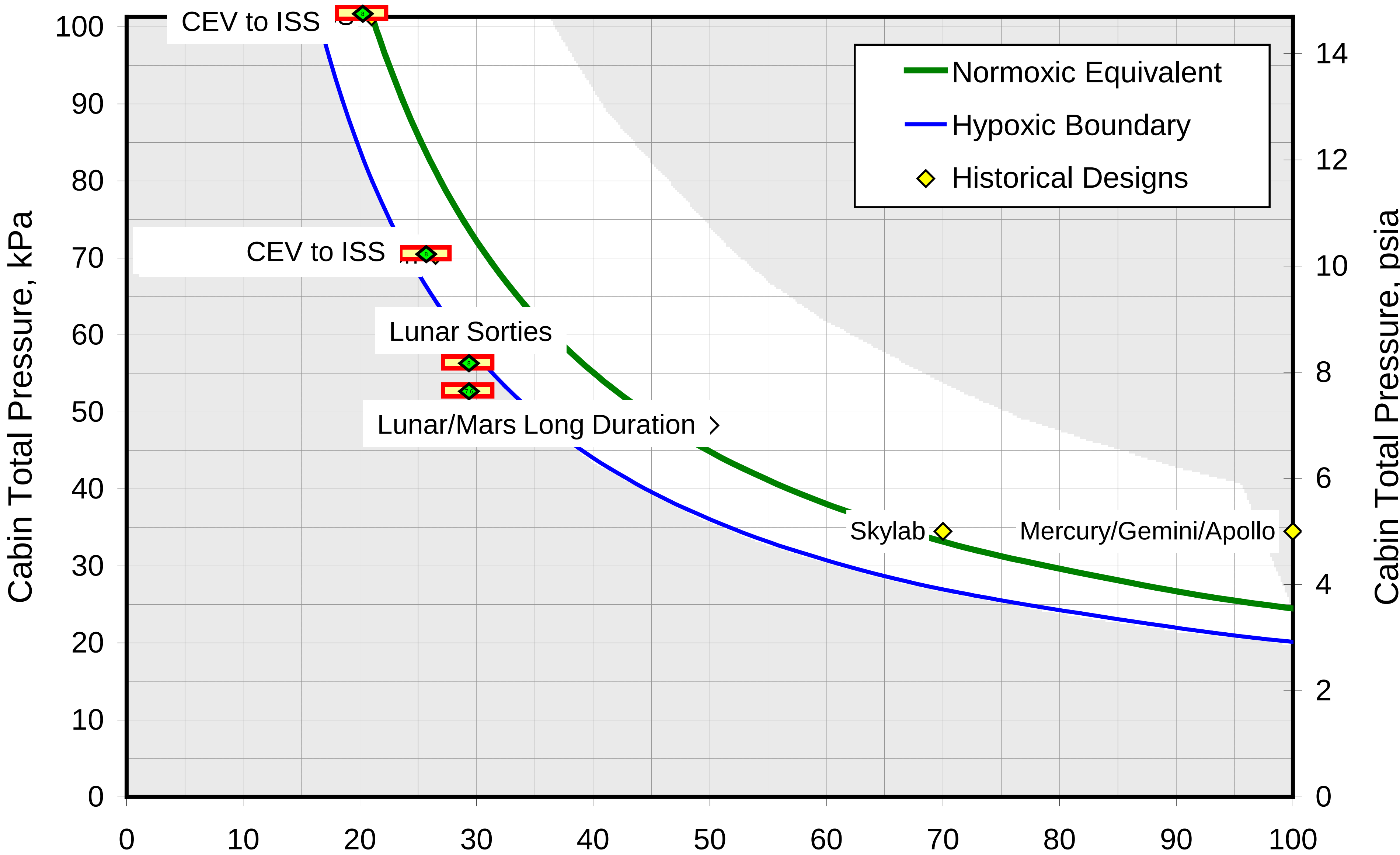
	Atlas-D/Titan II	Space Shuttle	Ares I	Ares V	Saturn V
LEO Payload	3,000/8,000 lbm	53,700 lbm	55,000 lbm	300,000 lbm	262,000 lbm
Max Thrust	308/430 klbf	6.4 Mlbf	3.5 Mlbf	10 Mlbf	7.75 Mlbf
Max Acceleration	< 6g	3.0 g	3.8g	3.8g	3.9g
Thrust Oscillation	0.25 g-RMS	0.2 g-RMS	0.3-0.4 g-RMS	0.2-0.3 g-RMS	< 0.6 g-RMS

Crew Exploration Vehicle

- **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

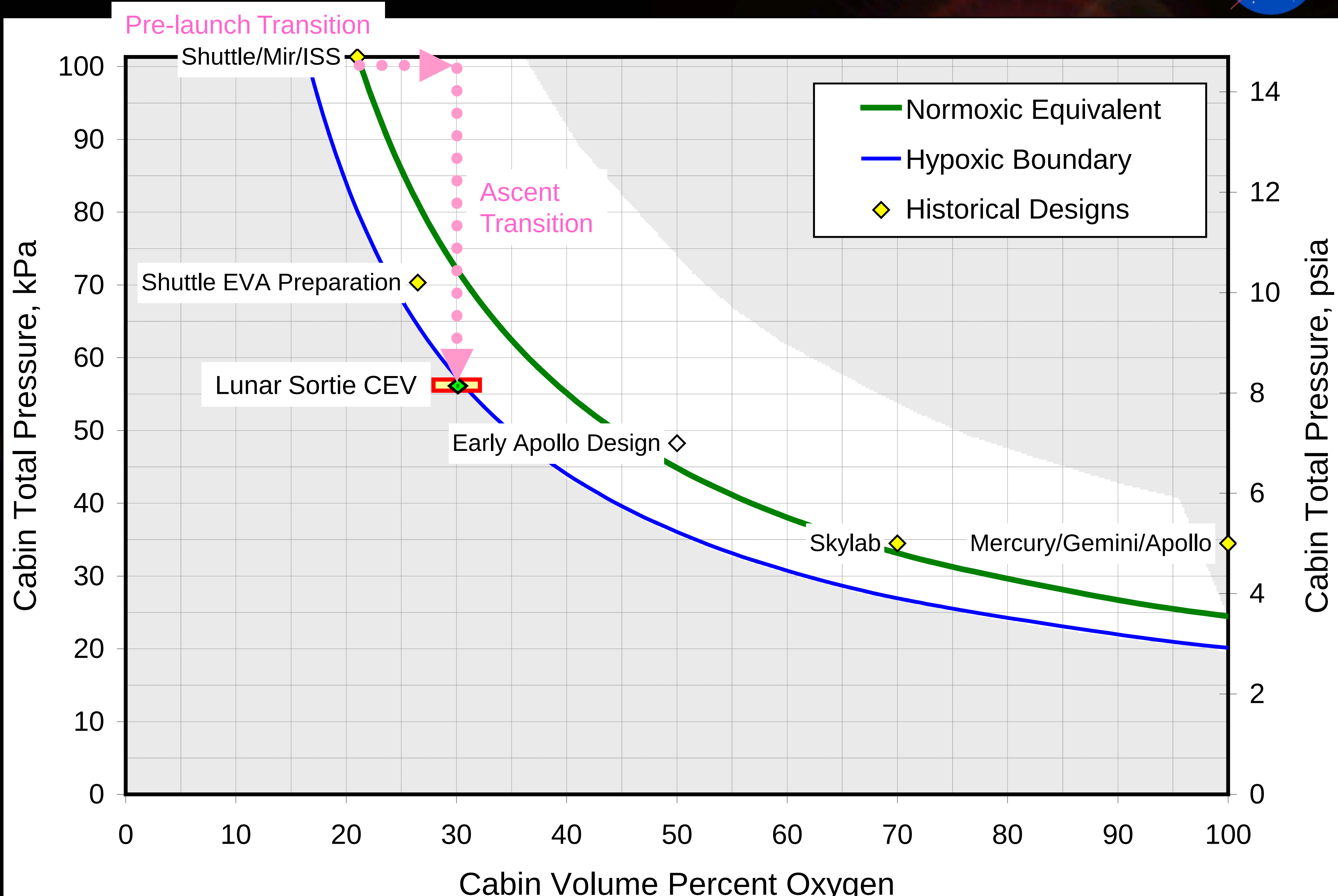
- **5.0 meter diameter capsule – (scaled from Apollo)**
  - Significant increase in volume
  - Reduced development time and risk
  - Reduced reentry loads, increased landing stability, and better crew visibility

Atmospheric Conditions for Exploration Vehicles[7]



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

CEV Atmosphere Transition on Earth Ascent

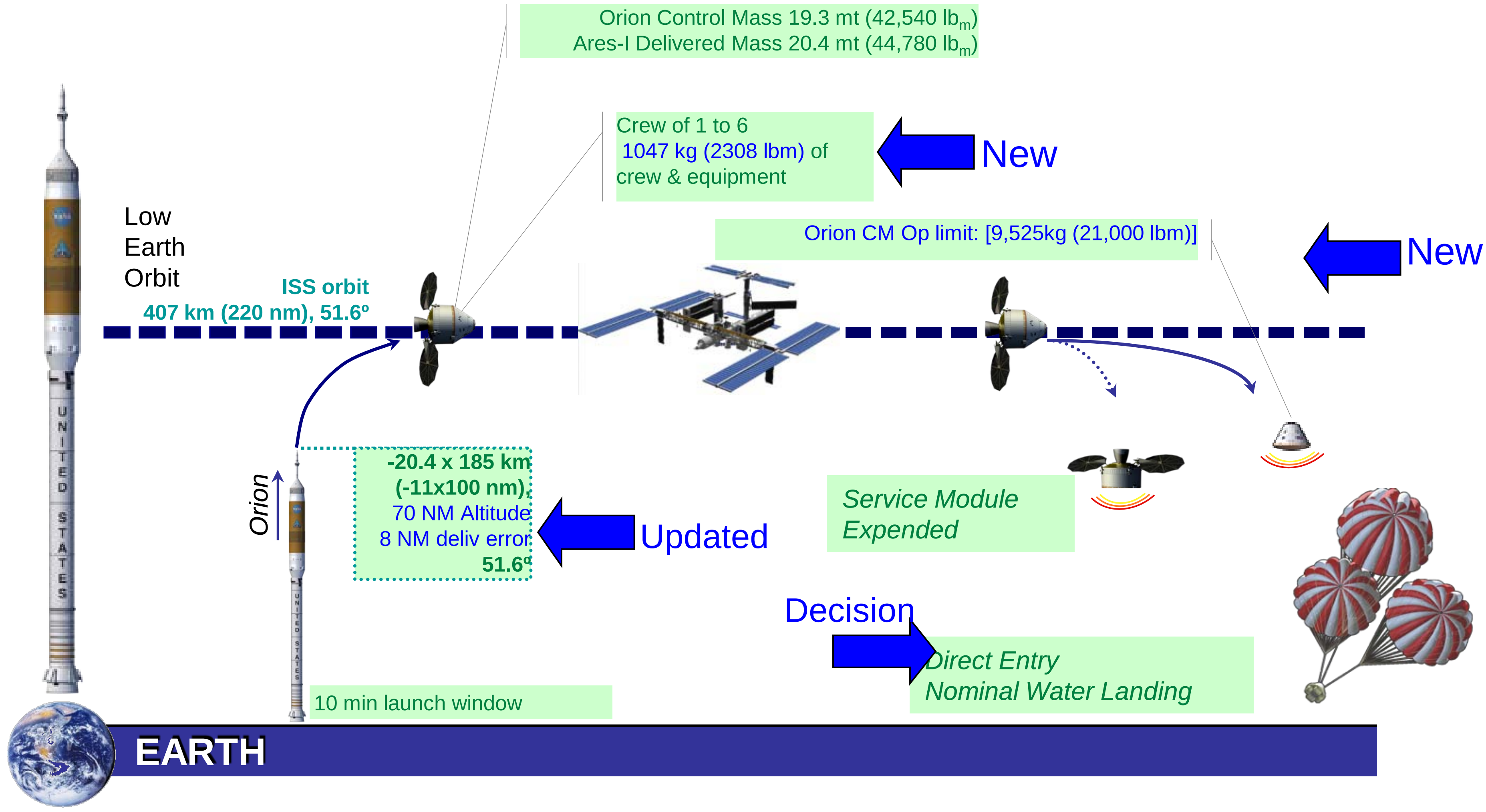


Servicing the International Space Station

- 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*

*Pending outcome of the Presidential review of the Augustine Panel report: http://www.nasa.gov/pdf/396093main_HSF_Cmte_FinalReport.pdf

Typical International Space Station (ISS) Reference Mission



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 7x 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

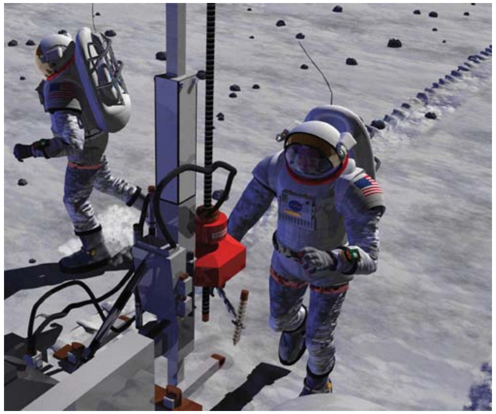
Medical Trauma & Life Support
32 x 12 x 16 in

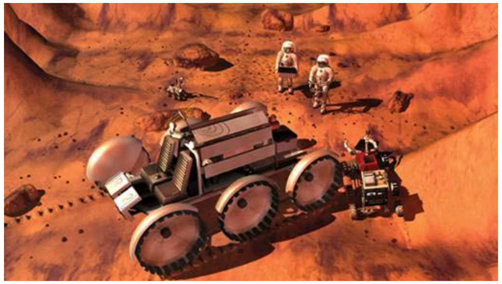
ISS Advanced Life Support Pack

ISS Advanced Life Support Pack
26 x 14 x 8 in

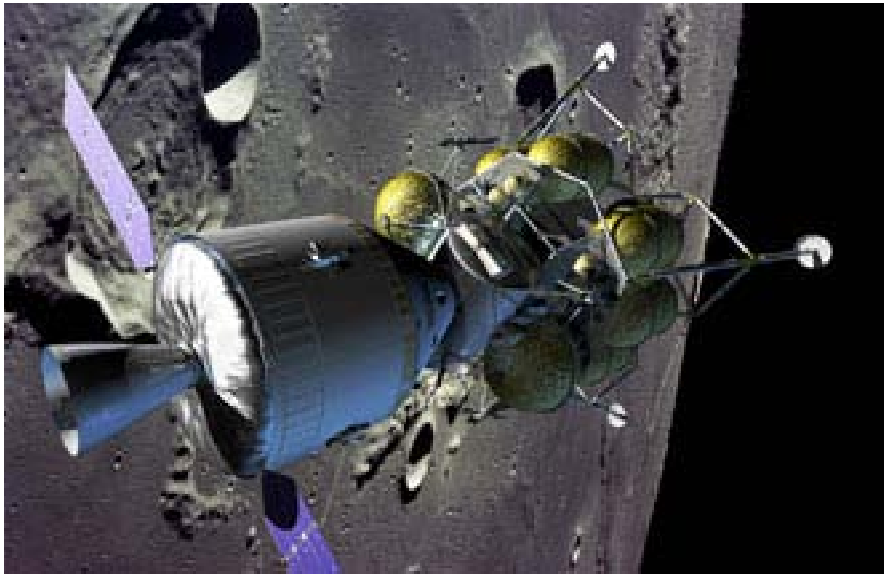
The Moon - the 1st Step to Mars and Beyond…

- **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



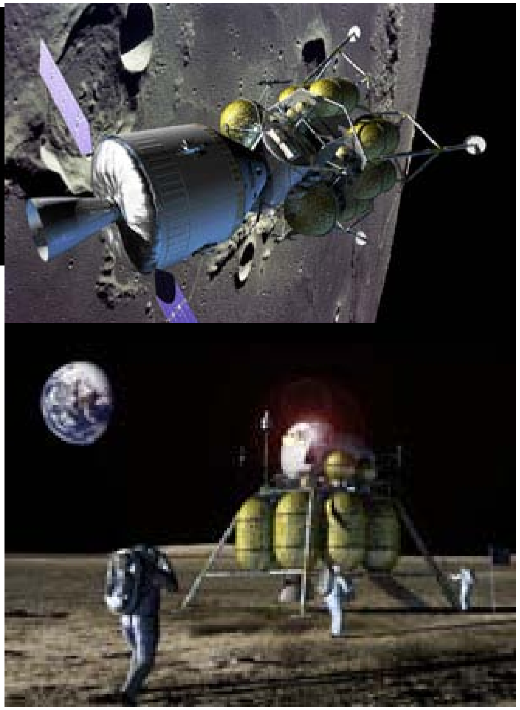


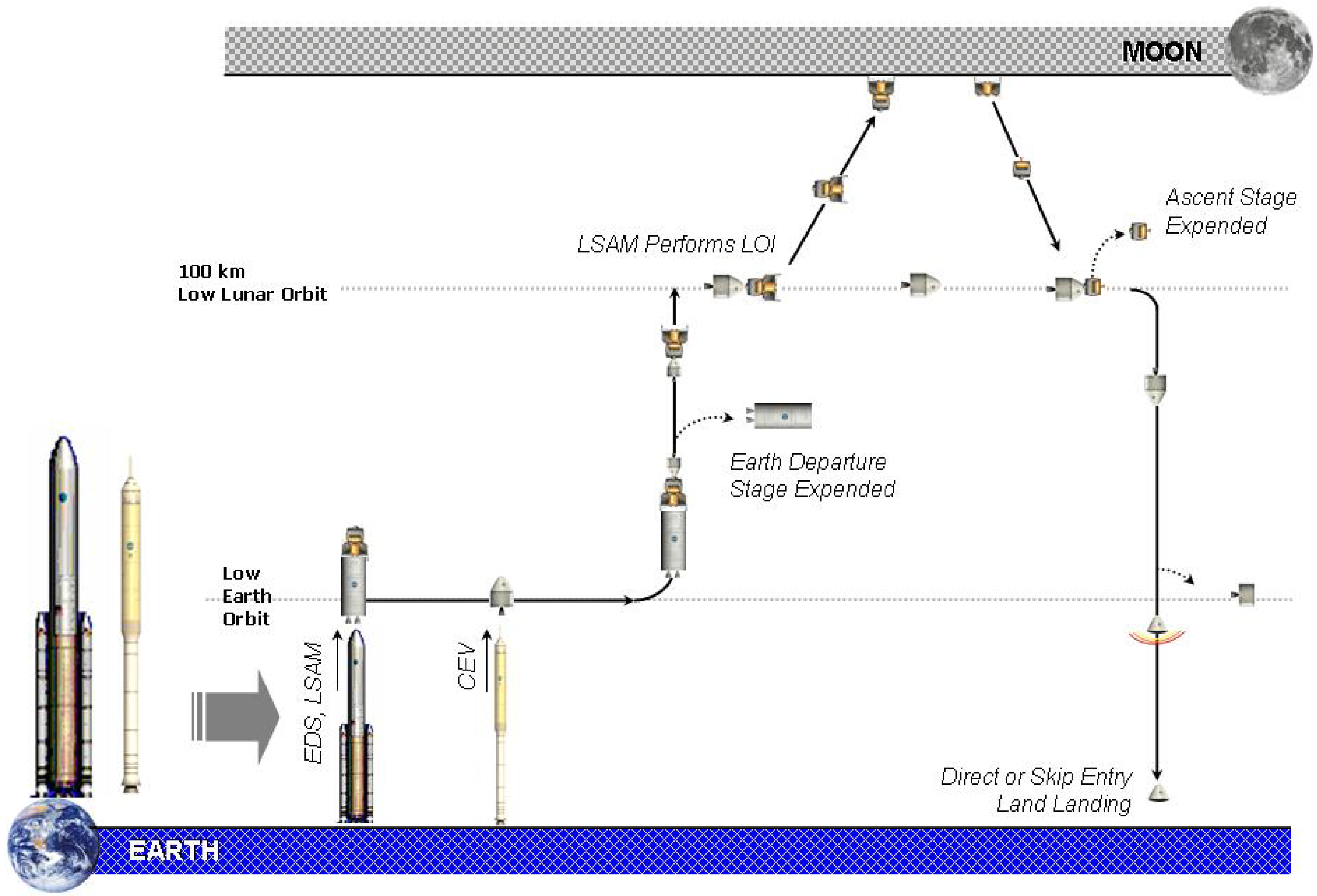
CEV (Lunar Capability) to Lunar orbit and back



- **Current timeline for lunar return is 2020**

Lunar Sortie- Design Reference Mission

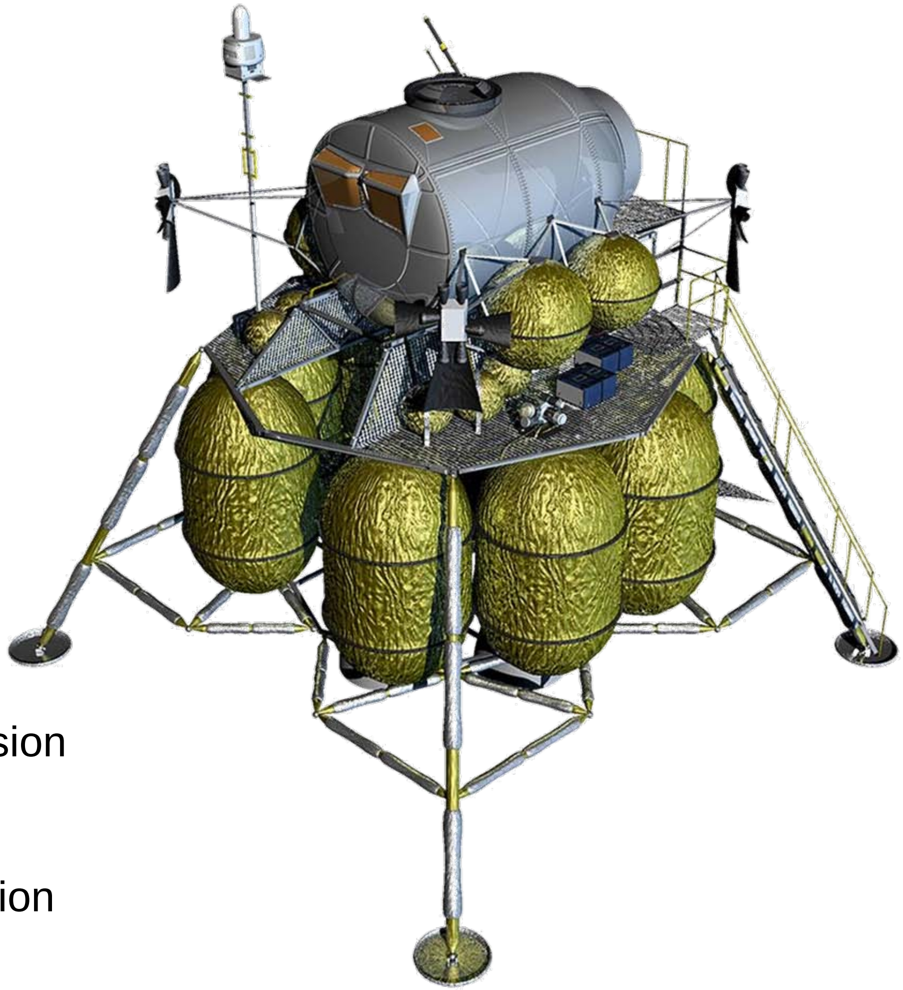




- CEV (lunar capability) and Altair launch separately
- CEV docks with Altair in LEO with TLI after docked

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**
- **<u>Airlock</u> for surface activities**
- **Descent stage:**
  - Liquid oxygen / liquid hydrogen propulsion
- **Ascent stage:**
  - Liquid oxygen / liquid methane propulsion



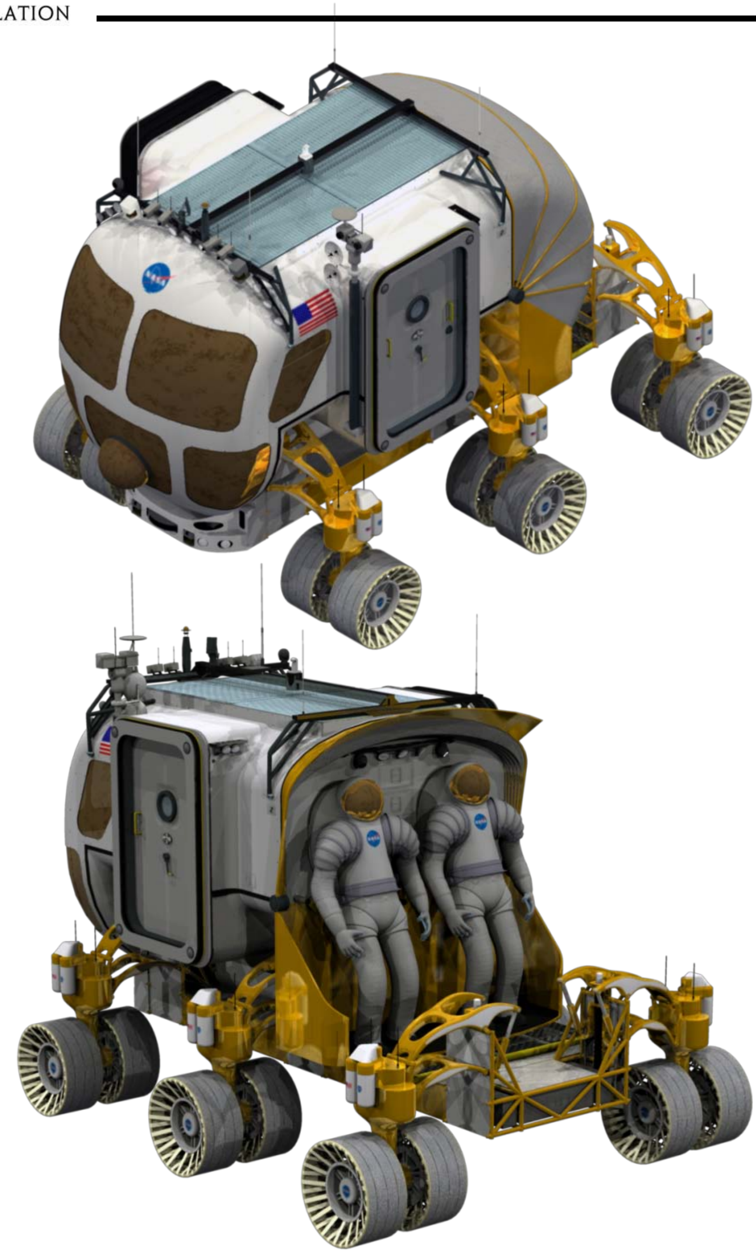
*1 of 10 potential landing sites
**Approximately 6.5-9 days for Earth return from polar landing sites

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[4,5]

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

Item *for* ***Lunar Sortie***	Mass	Size	Development Concept
Medical Kit	10 lbs	10x7x6 in	COTS
Medical Contingency Kit	30 lbs	32x12x16 in	Modified COTS
EVA Contingency Response Kit	16 lbs	16x16x8.5 in	Modified COTS
Environmental Health Kit	7.5 lbs	7x7x9 in	Modified COTS
Exercise Equipment	5-20 lbs	TBD	Technology Development Required

COTS= Commercial Off-The-Shelf

[4]NASA-Std-3001.

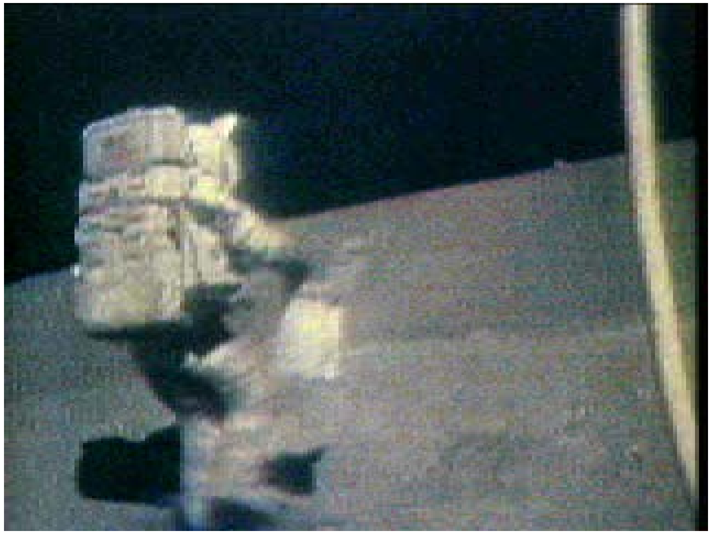
[5]Scheuring RA, Jones JA, Polk JD. Human Spaceflight Health Systems for the Constellation Project. Aviat Space Environ Med. Vol. 78, No.12 Dec. 2007.

Medical Issues to Manage for Lunar EVA

♦ Lunar Surface EVA issues

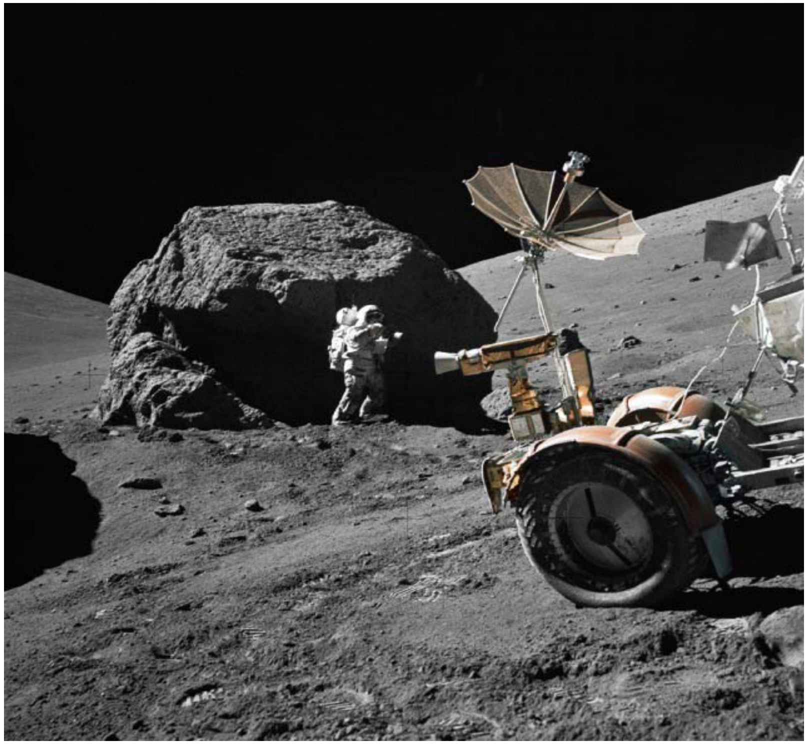
- LSS: Oxygen/Carbon Dioxide
- Thermal Loading
- Metabolic Loading
- Wear-ability/Comfort
- Injury Prevention
- Decompression Sickness
- Dust Toxicity
- Radiation Protection*

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



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

[8]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.

Injury Prevention

- **Suit Factors:**
  - Mobility/Agility
  - Balanced CG
  - Vision
- **Operational Prevention:**
  - Lunar Surface Ops Plan/Rules
  - Communication

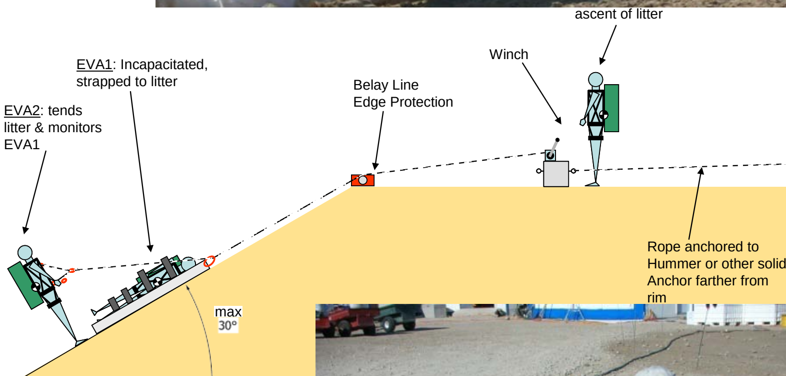
Apollo 16 Astronaut on rim of Plum Crater (30-m), which is on the rim of Flag Crater (300-m in diameter, 50-m deep).

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



Medical Operational Concept

Lifecycle Phase: Return transfer mission

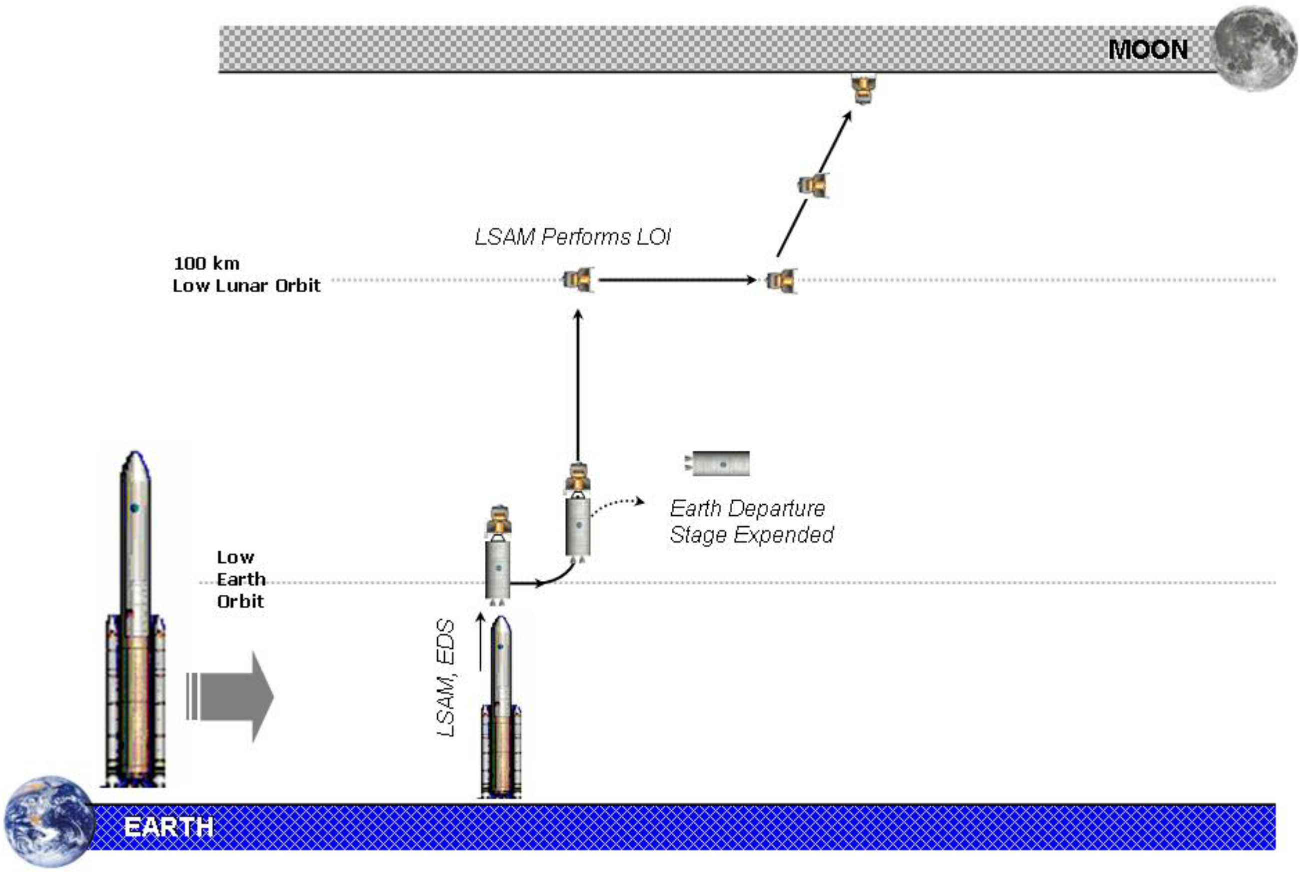
- Nominal:
  - The crew will perform daily exercise in the CEV in preparation for return to 1g.
  - Private two-way audio/video communication will allow a Pre-entry PMC.
- Off-nominal:
  - If illness or injury on the lunar surface occurs, the Altair required hardware will be transported back with the 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[9]
  - ???

[9] Scheuring RA, Van Baalen M, Jones JA, Vasquez M, et. al. Management of acute radiation exposures on the lunar surface for exploration missions. Aviat, Space, Environ Med , 2008.

Lunar Outpost- DRM: Habitat Pre-positioned

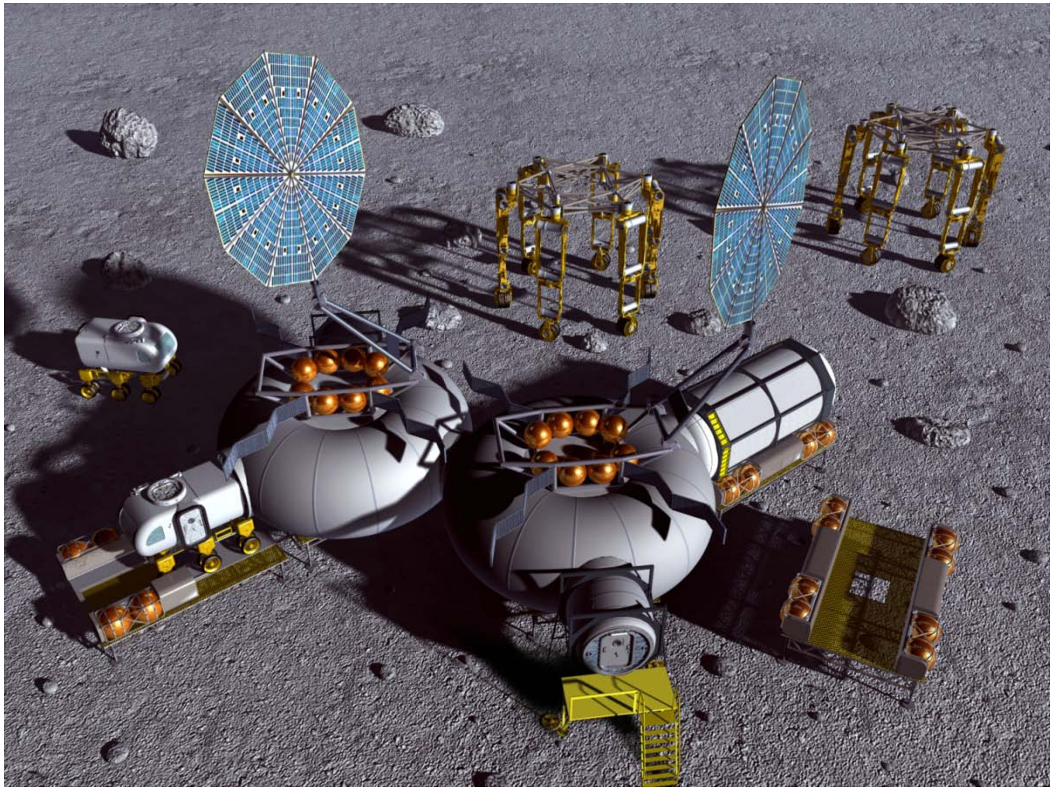


Concept

- **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**

Lunar Outpost

- Medical Kits
  - Volume – 1 ISS ISO rack stowage bin equivalent (approx. 0.5-0.75 M^3)
- Exercise
  - Volume 0.5 CTBE (1/2 Shuttle mid-deck locker) approx. 0.01 M^3
  - Mass 10 kg (22 lbs.)
  - Use envelope: 2.57 M^3 (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



Landing 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

Apollo 12 landing, 1970

♦ Off-nominal recovery

- Crew may be in the ocean up to 24 hours before recovered

PORT 1 , 2009

Summa Foundation 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

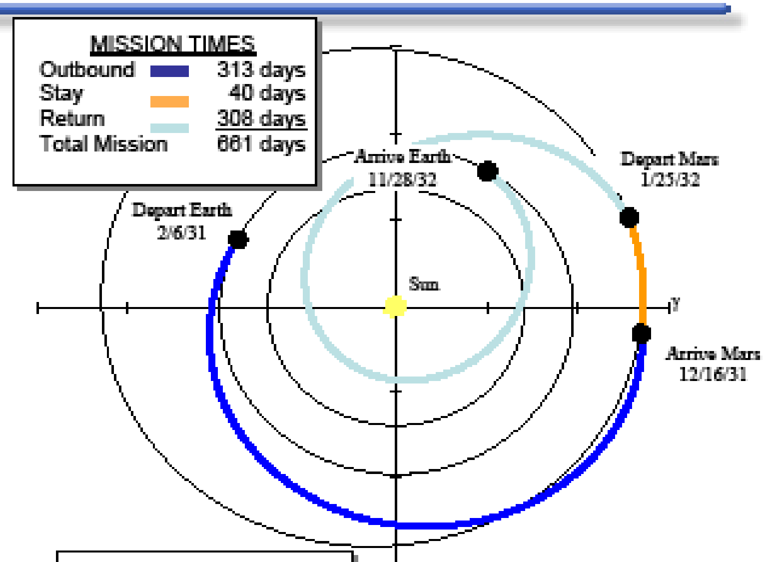
- USAARL/US stethoscope
- USAISR/LTM
- GRC/IVGEN
- JSC/IMM
- GRC/IMM modeling
- JSC/Assisted Medical Procedures
- GRC/O2 Concentrator Development
- GRC/Consumables tracking
- GRC/Injectables
- GRC/Medical Imaging Integration
- ARC/Lunar Lab Analysis
- GRC/Reusable Laboratory Capability
- ARC/Biomedical Sensors
- JSC/Guideview

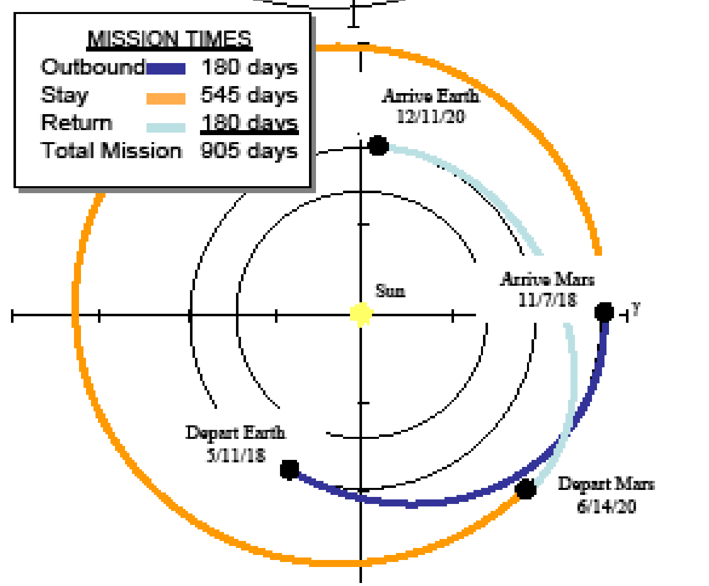
CEV- to Mars Orbit or likely to Mars Transit Vehicle and back

- **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

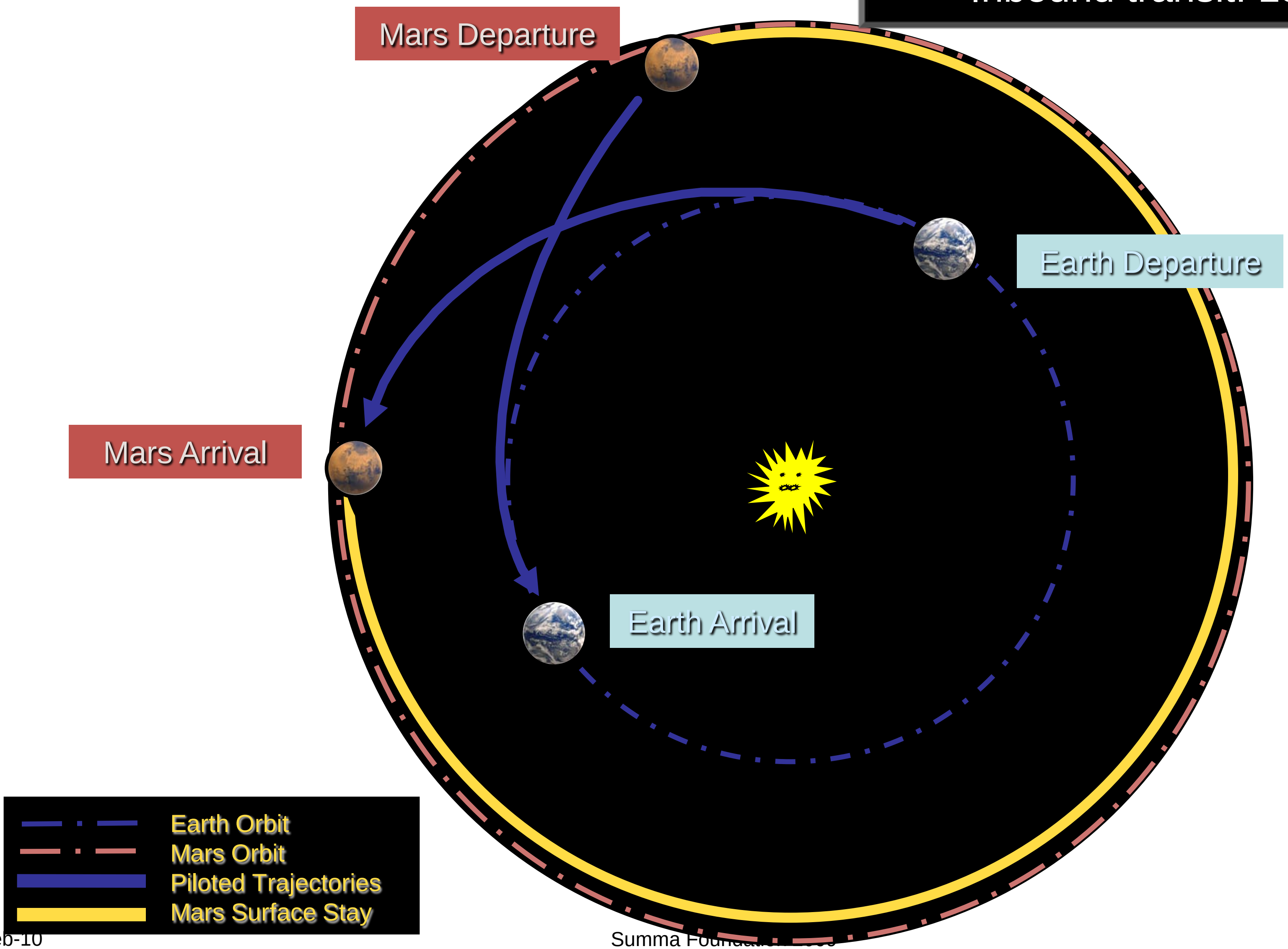
- **Even assuming advanced propulsion technology, Mars missions "driven" by orbital mechanics**
- **"Short-stay" ("Opposition-Class")**
  - High-propulsive requirements
  - Venus swing-by or deep-space Maneuvers
  - Close perihelion passage
  - 1½ to 2 year mission duration
  - Majority (90+%) of crew 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



Assumed Mission Characteristics

Factor	Long Stay Mission Conjunction-class	Short Stay Mission (2037 opportunity) Opposition-class
Outbound transit to Mars	6 months	6 months
Inbound transit to Earth	6 months	13 months
Total transit (deep space) time (% total mission duration)	12 months (40%)	19 months (95%)
Surface stay time (% total mission duration)	18 months (60%)	1 month (5%) (2 months = 10%, 3 months = 15%)
Total Mission Time	30 months	20 months
Closest solar approach • Without Venus swing-by • With Venus swing-by	• 1 AU • n/a	• ~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