



# Korean Aerospace Medical Association



Injured Lunar Astronaut. Painting by Pat Rawlings

## *Space Medicine Issues & Healthcare Systems for Space Exploration Medicine*

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*Richard A. Scheuring, DO, MS and Jeff Jones, MD,*

NASA/JSC Space Medicine and Health Care Systems  
Exploration Medical Operations  
Space and Life Sciences Directorate



# Overview

- ◆ **Spaceflight Medical Concerns**
  - Physiological adaptation to microgravity, partial gravity
  - Summary of medical events during spaceflight
- ◆ **Space Vehicle and Environmental and Surface Health Risks**
- ◆ **Medical Concept of Operations (CONOPS)**
  - Current CONOPS & Medical Hardware for Shuttle (STS) and ISS
  - Planned Exploration Medical CONOPS & Hardware needs
- ◆ **Exploration Plans for Lunar Return Mission & Mars**
- ◆ **Developing Medical Support Systems**
  - Preventative Health Strategy
  - Autonomous Care
  - Analog Sites for Exploration

# ***Our Destiny is to Explore!***



- ◆ **The goals of our future space flight program must be worthy of the expense, difficulty and risks which are inherent to it.**
- ◆ **We need to build beyond our current capability to ferry astronauts and cargo to low Earth orbit.**
- ◆ **Our steps should be evolutionary, incremental, and cumulative.**
- ◆ **To reach for Mars and beyond we must first reach for the moon.**

***A committed and long term lunar effort is needed, and we need to begin that investment now!***

# *Human Experience in Space*



- ◆ **Total space flight time to 23 August 2004: 27,302 crew-days (74 crew-years)**
  - Persons who have flown in orbit: 433 (does not include repeat fliers)
  - As of STS 107 there were **6254 person days** on Shuttle (1981-2003)
- ◆ **Skylab experience – 504 person days**
- ◆ **NASA Mir – 849 person days**
- ◆ **US ISS – 1390 person days**

# *Space Medical Issues- Past & Present*



## ◆ **Physiological Issues in Microgravity**

- Space Motion Sickness (SMS)
- Cardiovascular
- Neurovestibular
- Musculoskeletal
- Immune/Hematologic
- Psychiatric

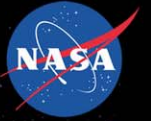


# *Space Motion Sickness (SMS)*



Photo NASA

# Space Motion Sickness



## Causes (possible)

- Neurovestibular
  - otolith mismatch
  - sensory conflicts
- Fluid shift

# Space Motion Sickness Categorization



## ◆ Mild SMS:

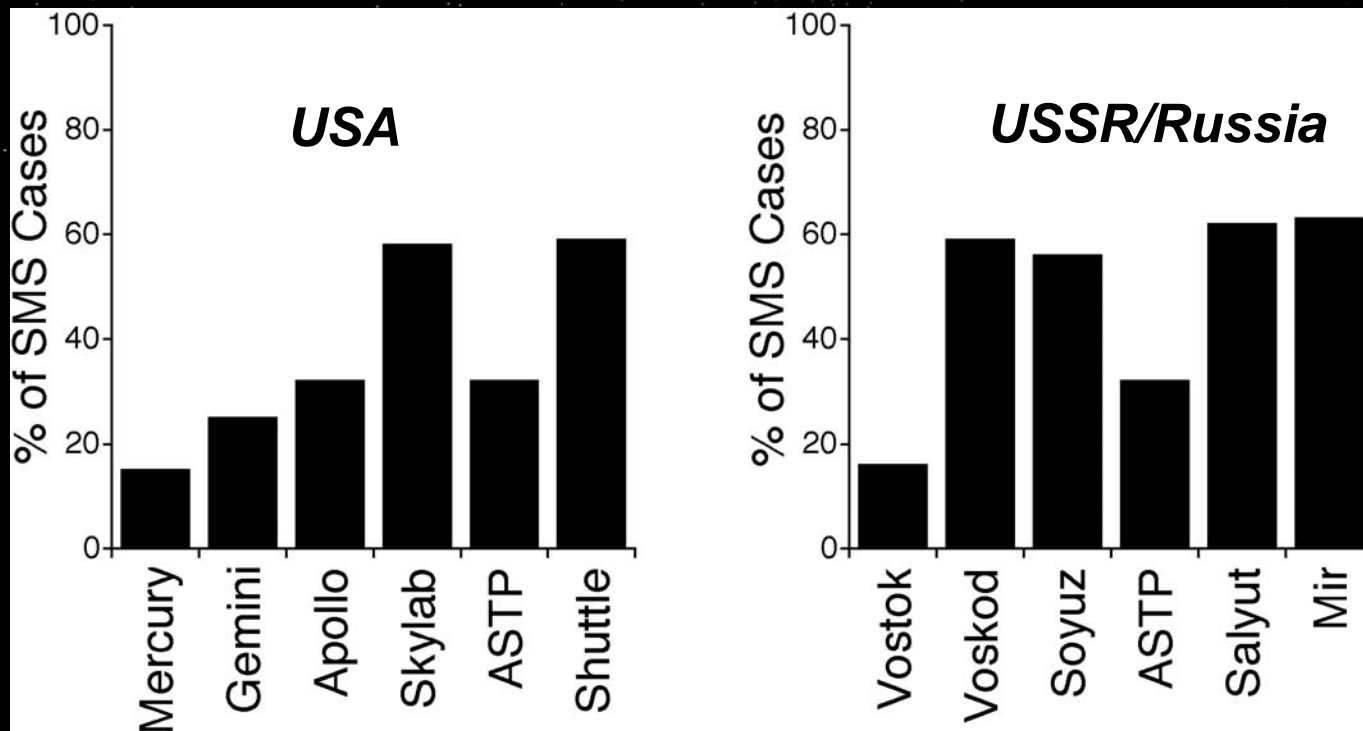
- One to several transient symptoms
- No operational impact
- All symptoms resolved in 36-48 hrs

## ◆ Moderate SMS:

- Several symptoms of a persistent nature
- Minimal operational impact
- All symptoms resolved in 72 hrs

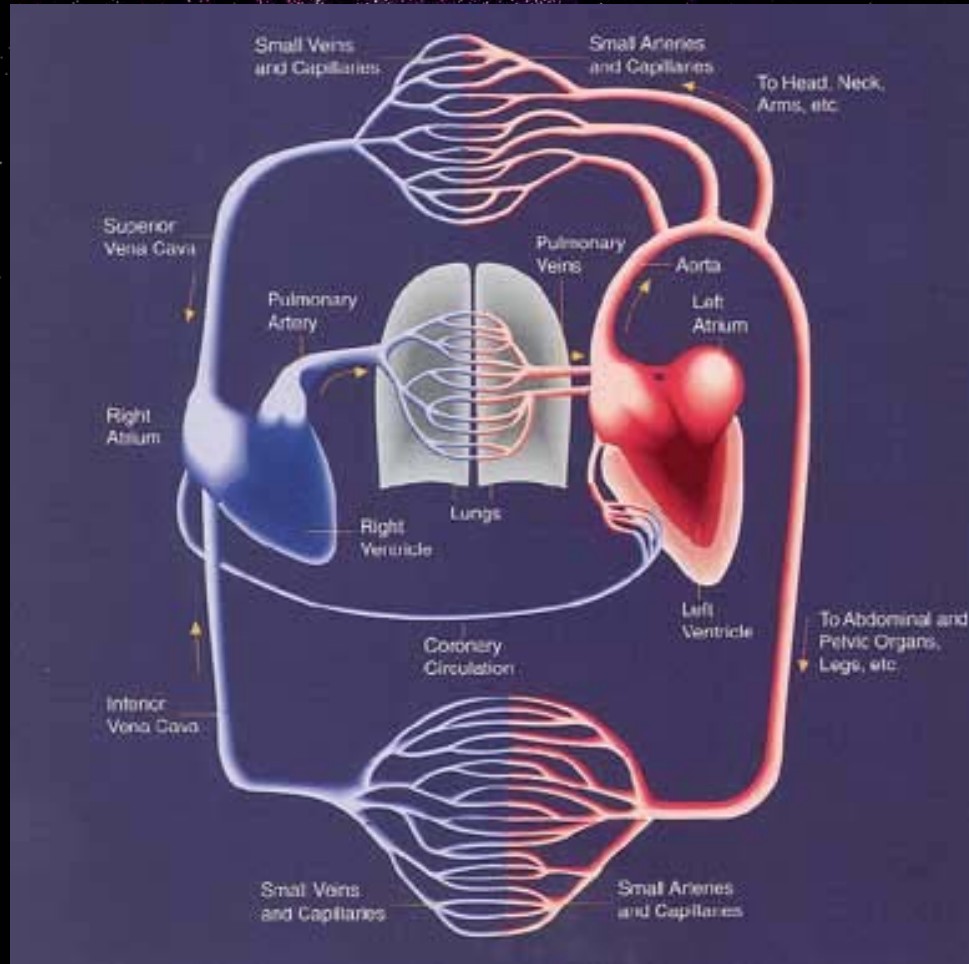
## ◆ Severe SMS:

- Several symptoms of a persistent nature
- Significant performance decrement
- Symptoms persist beyond 72 hrs





# Cardiovascular Effects

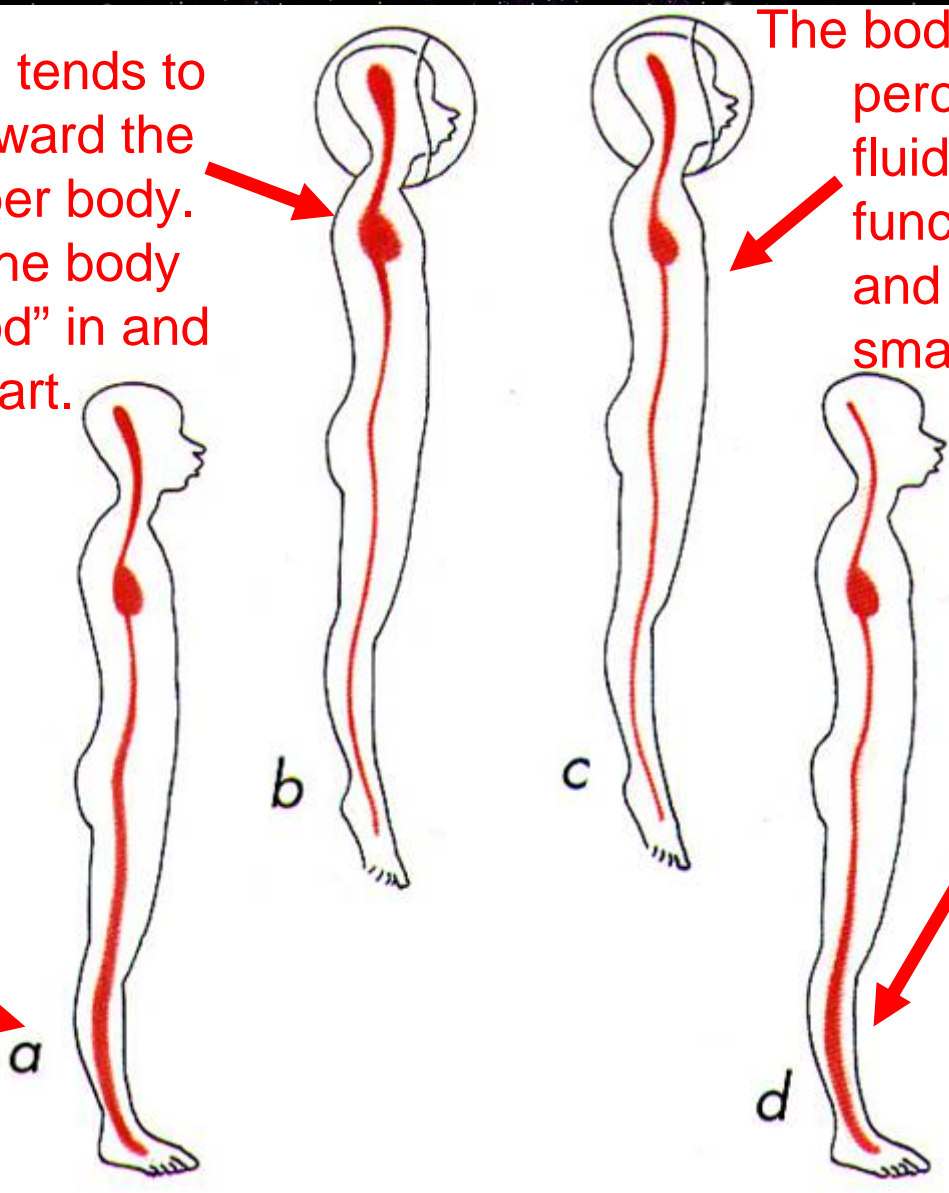


# Fluid Shifts during Space Flight



In space, the fluid tends to redistribute toward the chest and upper body. At this point, the body detects a "flood" in and around the heart.

On Earth, gravity exerts a downward force to keep fluids flowing to the lower body.



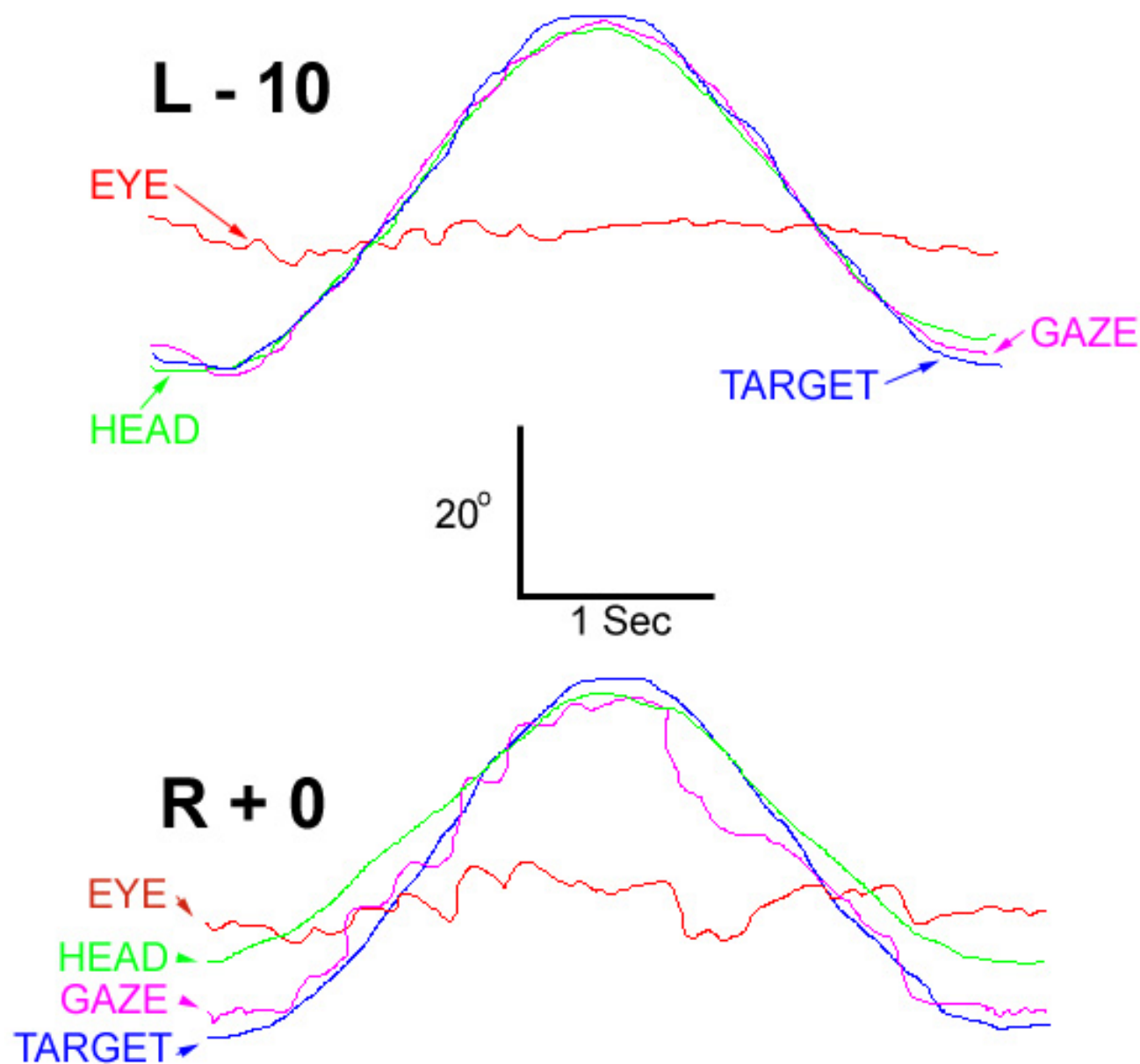
The body rids itself of this perceived "excess" fluid. The body functions with less fluid and the heart becomes smaller.

Upon return to Earth, gravity again pulls the fluid downward, but there is not enough fluid to function normally on Earth.

# Neurovestibular System



# Vertical Pursuit Tracking With Head and Eye



# *Physiological Events and Piloting*



## Landing performance:

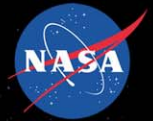
- Initial apparent correlation of length of shuttle mission and landing outside or nearly outside parameters (landing too fast, landing too slow, landing hard)
- Upon further study, correlation not verified (however, there was one very short mission that had bad landing parameters that may have skewed the data considering the small number of data points)
- What is verified is that actual landing performance shows much greater variability than simulator performance parameters
- The implication is that spaceflight has an effect on pilot performance- and now is correlating with post-flight **neurovestibular** measures

# *Physiological Events and Piloting*



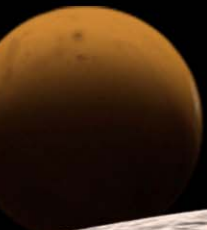
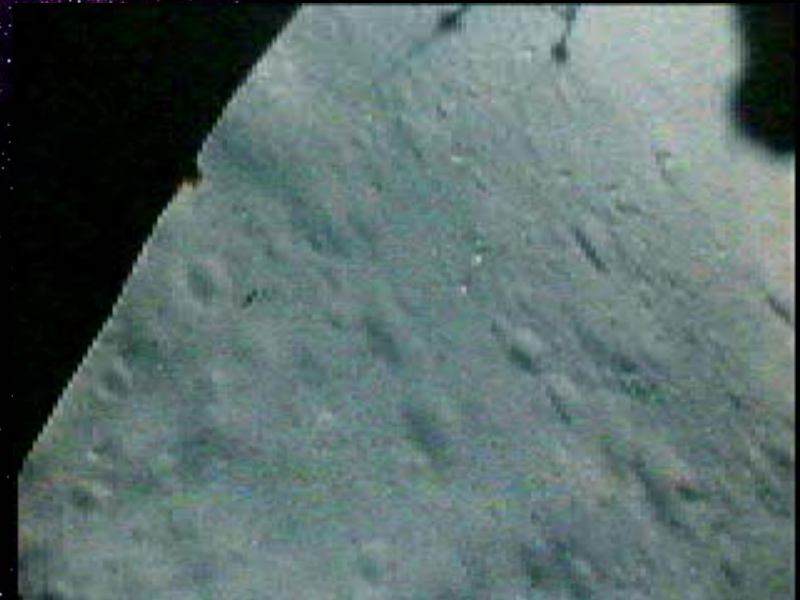
STS 108 Heads Up Display (HUD) on final approach

# Neurovestibular



## ◆ Lunar Surface Operations

- Crews generally felt a little “wobbly” upon stepping on the moon
  - Coordination seemed to improve steadily during first couple of hours on the surface
- Crews denied problems with spatial disorientation on lunar landing





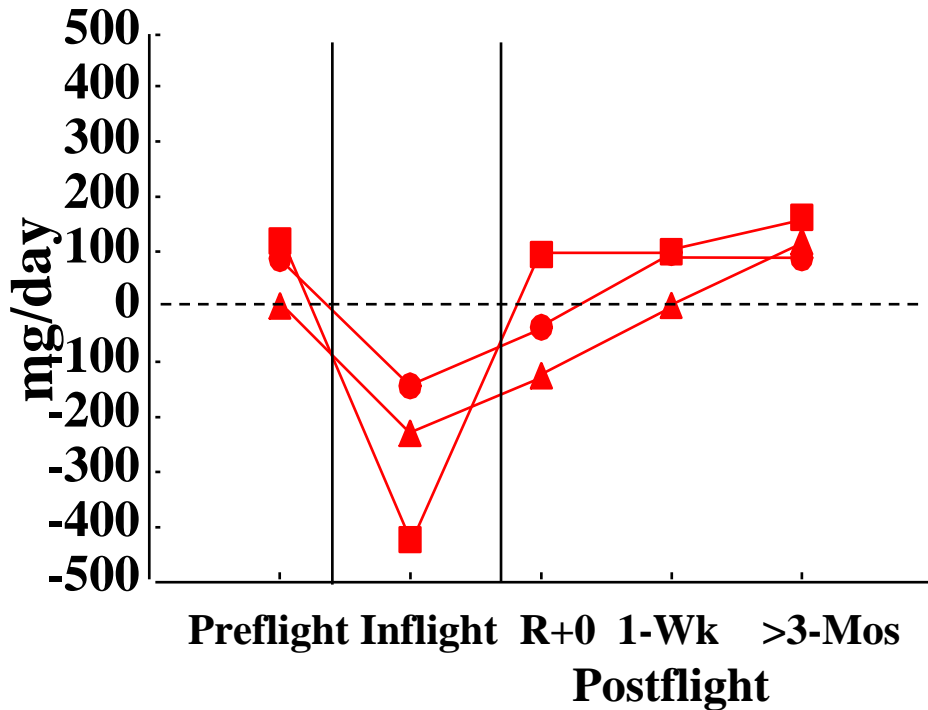
# ***Bone Loss during Spaceflight***

- ◆ **Vostok:** Increased fecal and urinary calcium first noticed
- ◆ **Gemini:** Loss of approximately 2-4% of bone mass in heel after 4-11 days of spaceflight
- ◆ **Apollo:** 3-5% decrease in bone mass after 10 days
- ◆ **Soyuz:** 8-10% decrease in bone density
- ◆ **Skylab:** 1-3% per month loss in bone mineral
- ◆ **Mir:** 10% loss of trabecular bone from lumbar spine in one cosmonaut after a 1-year mission
- ◆ **Shuttle-Mir:**
  - With countermeasures: 5.4% decrease in bone density in tibia. Did not return to preflight level in some individuals
  - Without countermeasures: 1.3-1.5% **per month** decrease in bone density (worst case: 15-22% total in some bones)
- ◆ **ISS:** Preliminary data similar to Shuttle-Mir



# Bone Health assessments after an early Phase I mission (cont.)

Bone Ca Balance ( $V_{o+} - V_{o-}$ )



**Bone Ca Loss** ~ 250 mg/d

**Bone Ca Gain** ~ 100 mg/d

**Recovery: 2-3 x mission**

Smith et al., 1999

# Musculoskeletal System Loss and Potential Complications/ Countermeasures



## ◆ Treatment for Acute Symptoms

- Stretching
- Exercise
- Penguin Suits
- Fetal Position Sleep Strap
- Medications: e.g. NSAID- Rx for discomfort

## ◆ Countermeasures in Practice

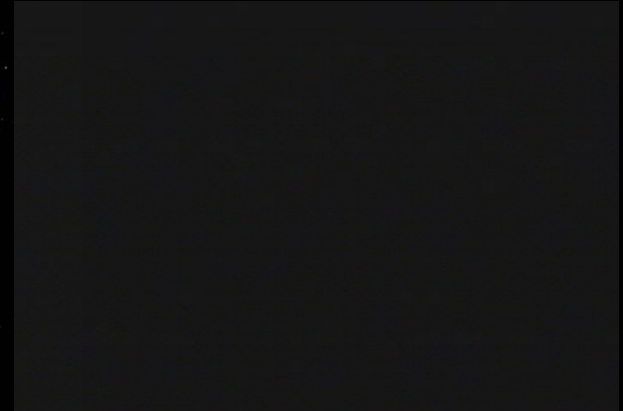
- For Muscular strength and endurance preservation
  - Resistive exercise
  - NAC and other supplements/pharmacologics
- For cardiovascular system and aerobic capacity maintenance
  - Cycle/treadmill/rower, other whole body exercise capability
- For Reduced bone strength/ Increased Injury or Fracture Risk:
  - 1) Resistive exercise hardware
  - 2) Pharmacologic- e.g. Bisphosphonates

## ◆ For Urinary Calcium Excretion- Risk of Calculi

- 1) Fluid Intake
- 2) Resistive exercise
- 3) Pharmacologic- e.g. inhibitor  $K^+$  Citrate or  $K^+Mg$  Citrate
- 4) Contingency Management Strategy

## ◆ Countermeasures under consideration/ preparation

- 1) Artificial gravity in transit
- 2) PTH, Peptides





# *Immune System*

- ◆ **Among the possible causes of space flight-induced alterations in immune responses are**
  - exposure to microgravity
  - exposure to stress
  - exposure to radiation
  - and many more as yet undetermined causes

Sonnenfeld G. The immune system in space and microgravity. *Med Sci Sports Exerc.* 2002 Dec;34(12):2021-7.

# Hematopoietic system

## ◆ Reduction in Circulating Red Blood Cell mass

- “Space Flight Anemia”

Udden MM, Driscoll TB, Leach-Huntoon CS, Alfrey CP. *Decreased production of red blood cells in man exposed to microgravity.* *New England Journal of Medicine*, 1994.

Lawrence Rice, Clarence P. Alfrey. *Modulation of red cell mass by neocytolysis in space and on Earth.* *Pflugers Arch- Eur. J. Physiol.*, 441 (Suppl):R91-R94, 2000.



# Psychiatric

- ◆ 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



# Physiological Issues in Partial Gravity



- ◆ **Apollo lunar crews adapted quickly to the 1/6g environment**
  - Initial unsteady gait related to EVA suit CG issues *not* neurovestibular dysfunction
  - Forearm and upper extremity fatigue attributed to glove design
  - Inadequate sleep, dietary caloric intake experienced by most crewmembers
  - Other physiologic function (cardiovascular, bone) unknown
- ◆ **SMS did not recur upon return to microgravity**





# Health-Impact Events in Flight

- ◆ Medical Evacuation
  - 3 Russian medical-induced vehicle evacuations
- ◆ Near misses
  - Cardiac event on-orbit, Heart Attack 6 weeks post-flight
- ◆ Medical with mission impact
  - Apollo 13 – Kidney infection during mission
- ◆ Neurologic consequences of Spaceflight
  - Impaired cognitive performance aka “Space Fog” or “Space Stupids”
- ◆ Behavior and performance
  - STS payload specialist despondent when payload experiment failed, crew concerned about potential for dangerous behavior
- ◆ Medication events
  - Excessive medication use prior to EVA
- ◆ Fouled Atmosphere
  - Fire, toxic release, etc.
- ◆ Thermal Issues
  - Hyper- and hypo- thermia

# Medical Symptoms in US Space Program



- ◆ Shuttle program (89 missions) 1981-98:
- ◆ 508 crew (439 men, 69 woman) over 4443 flight days (includes repeat fliers, does not include 1998-2005)
  - No medical evacuations to date, but multiple mission impact events
  - 79% reported space motion sickness
  - 98% reported some medical symptom
    - 67% headache
    - 64% respiratory complaints
    - 58% facial fullness
    - 32% gastrointestinal complaints
    - 26% musculoskeletal complaints
    - 12% injuries
    - 10% genitourinary symptoms



# ***Medical Events in Flight – Medical with Mission Impact***



- Apollo -- EVA rescheduled due to motion sickness
- Apollo – Type 1 DCS in command module pilot
- Apollo – Urinary tract infection during mission
- Apollo – Cardiac irregularity during lunar EVA
- Salyut- Kidney Stone- 1982
- Shuttle -- 4 cases of urinary retention resulting in bladder catheterization
- ISS -- Crewmember pulled from EVA due to cardiac abnormalities



# ***Medical Events in Flight – Near Misses***

- 1 cardiac ischemic event within 3 days of launch (crew changed out)
- 2 cardiac ischemic events inflight, followed by myocardial infarction (MI) postflight
  - Case 1: acute diaphoresis, fatigue and bigeminy on orbit, Myocardial Infarction 2 years post flight
  - Case 2 event treated with ASA and beta blocker, Myocardial Infarction 6 weeks post flight



# ***Medical Events in Flight – Medical Evacuation from Space***

- ◆ **Salyut 5 space station (1976) abandoned 49 days into 54 day mission for intractable headaches following probable combustion event**
- ◆ **Salyut 7 space station (1985) evacuation 56 days into 216 day mission for urinary tract infection**
- ◆ **Mir space station (1987) evacuation 6 months into 11 month mission for heart irregularity**

# ***Health Risk during EVA***

- ◆ Separation from space craft
- ◆ Micrometeoroid/ orbital debris (MMOD)
- ◆ Foreign body Injury (inhalation, ocular)
- ◆ Worksite injury (crush, electrical)
- ◆ Contact with Toxic Substances
- ◆ Hypobaric space suit pressure
- ◆ Life Support System failures
- ◆ Suit leaks in Vacuum
- ◆ Thermal Injuries
- ◆ Light Glare/ Darkness
- ◆ Radiation



# Suit Trauma

- ◆ Existing Space Suits cause significant trauma to crew members
  - Onycholysis-Finger nail damage
  - Shoulder and other orthopedic injuries
  - Bruising, abrasions, parathesias
- ◆ Minimize movement and point loading within suit
- ◆ Ensure suit kinematics are designed in conjunction with human biomechanical considerations
- ◆ Lower operating suit pressures
- ◆ ? Form-fitting, inflate to fit LCVG



# Possible Hazards of Long Duration Space Flight



## ◆ Space Environment

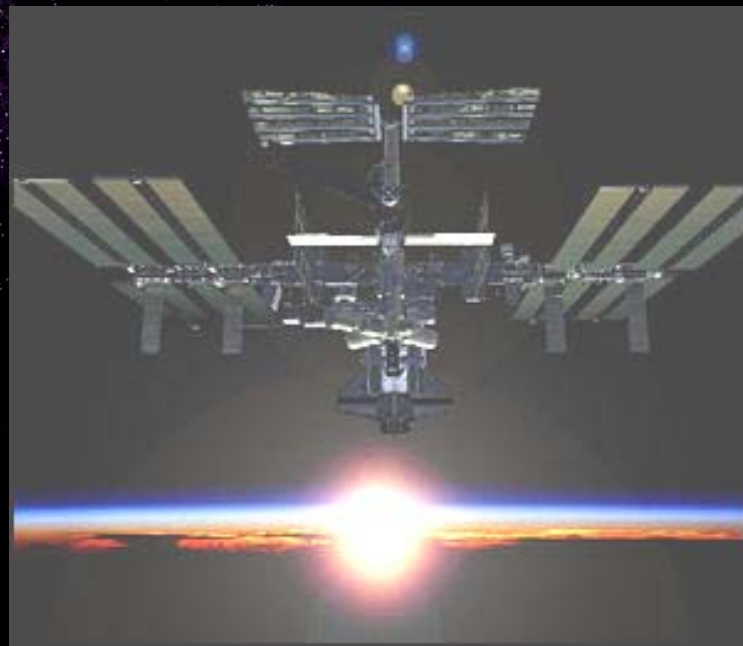
- Reduced or Micro / Zero Gravity
- Radiation (GCR / SPE)
- EVA Extravehicular Activity (Spacewalks)
- Vacuum (Pressure D)- Decompression
- Sickness
- Micrometeoroids / Orbital Debris
- Interplanetary microbial life (??)

## ◆ Space Craft Environment

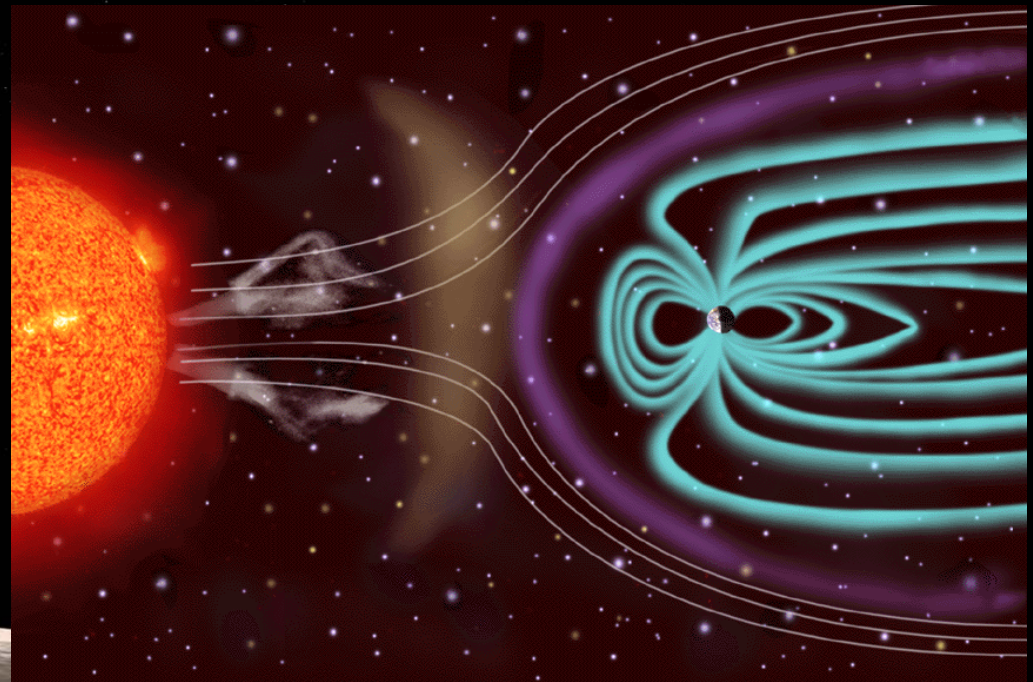
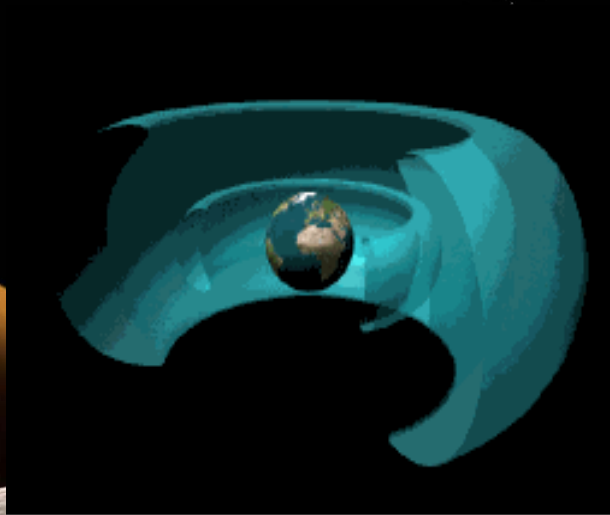
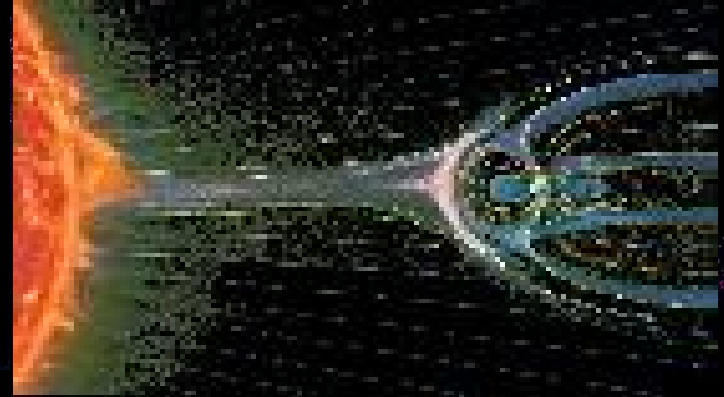
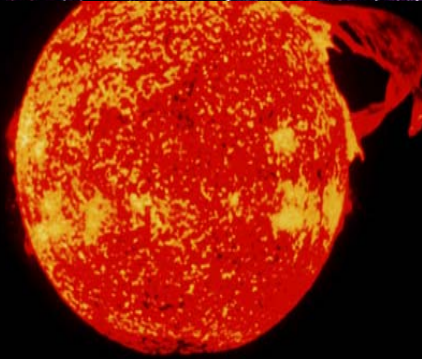
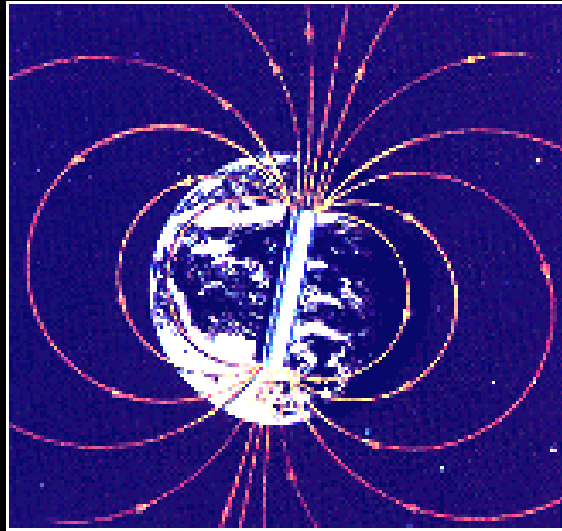
- Toxic Atmosphere
- Impaired Gas Concentration ( O<sub>2</sub>, CO<sub>2</sub>)
- Combustion
- Thermal
- Isolation and confinement
- Noise and Vibration
- Closed loop environment (life support)
- Payloads and construction activities
- Waste production

## ◆ Space Flight

- Remoteness and time passage / communication delay
- Flight activity (propulsion, G-forces, impacts)
- Circadian / Schedule changes



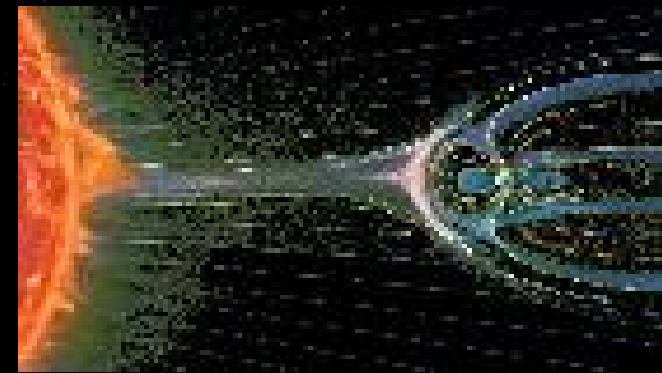
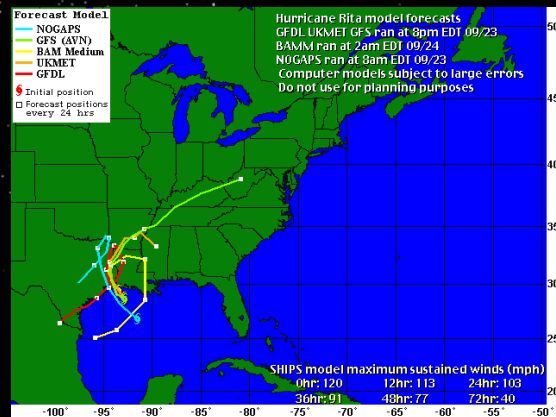
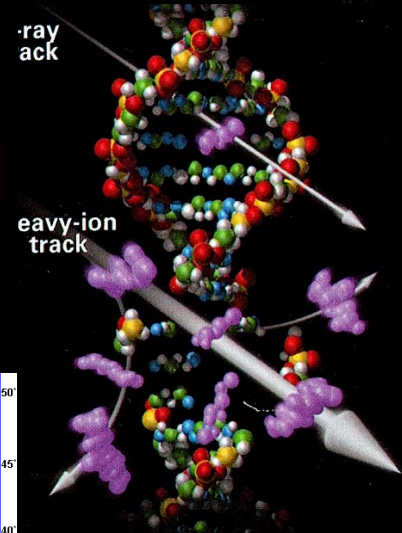
# LEO: Radiation Exposure protection from the Geomagnetosphere, Not on Mars!



# Radiation Safety and Protection



- ◆ **Module dose monitors**
- ◆ **Small, lightweight detectors with EVA teams**
  - Alarms integrated into suit CnW
  - Best on rover vs. PLSS of each suit?
- ◆ **Early warning satellite network**
  - Improved modeling for prediction of progressive events
  - Not all X-ray flares are followed by energetic protons
- ◆ **Deployable shielding**
  - On rover
  - ? Walkback portable shield
- ◆ **Radioprotectants**





# ***Biologic Effects of Radiation Exposure***



## ◆ **Immediate and Delayed Effects**

- Direct
  - Largest cellular target- Nucleic Acids
  - Lethal events (esp. if large track or clustered hits)
  - High, acute dose (overwhelm defenses, often lethal)
  - Chronic, low dose (mutations-cancers)
- Indirect
  - Reactive Oxygen Species
  - Lipid Peroxidation
  - DNA Methylation

## ◆ **How do we quantify the effects: Biodosimetry**

## ◆ **Health Risk associated with exposure**

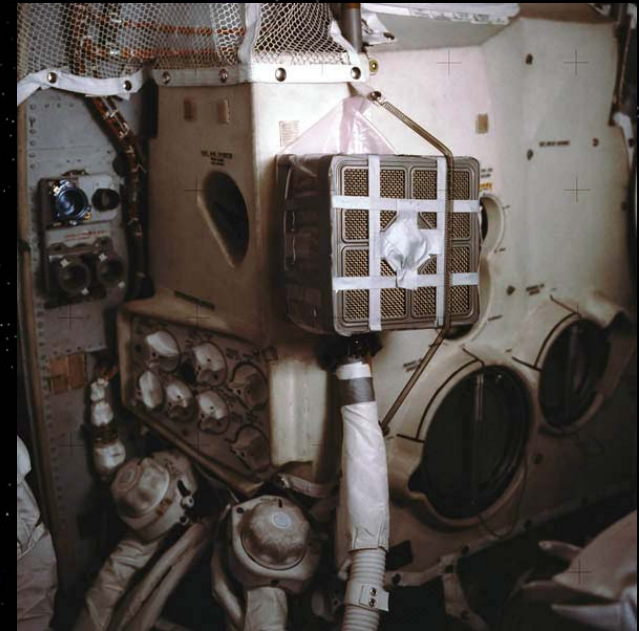
- Based on extrapolations from nuclear accident and weapon exposure data
- Cancer risks have significant uncertainty

# Other Environmental Issues



“Those that do not read and understand history are doomed to repeat it”  
– President Harry S. Truman

- ◆ Apollo 1 fire
  - 100% oxygen at sea level pressure
  - Lack of materials control
- ◆ Apollo 13
  - Critical consumables location
  - Multiple hardware developers
    - CO2 removal
- ◆ Shuttle, Shuttle/Mir, ISS experiences



# Lunar Dust

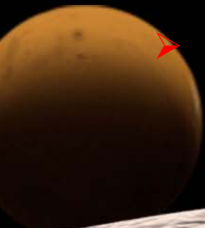
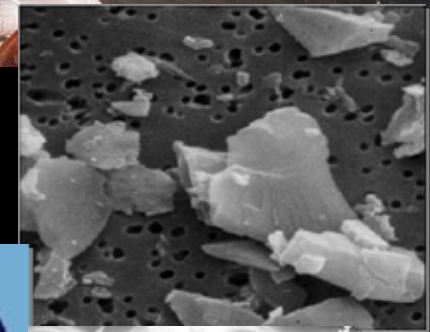
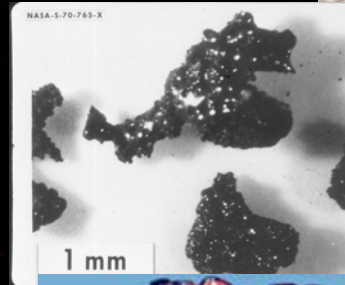


## Why are we concerned?

- Dust particles levitated at the lunar terminator, perhaps due to polarity changes (Criswell '72). 0.16 G at lunar surface, where there is a layer of fine particles that are easily disturbed and placed into suspension. These particles cling to all surfaces and pose serious challenges for the utility of construction equipment, air locks, and all exposed surfaces (Slane '94)
- After lunar EVA the crewmen and the samples they had collected were covered with fine lunar material. Despite attempts at clean-up and packaging in the LM, transfer of crew and materials back to the CM resulted in contamination of the CM atmosphere (Brady et. al, 1975)
- Apollo astronauts were not in the lunar environment long enough to develop the clinically significant, dust-related symptoms. However, during upcoming missions, crews will be on the Moon for months at a time.

## Properties

- Size, shape, lack of weathering
- Possible reactivity- volatiles, solar protons



# Space Medical Issues- Future Concerns



- ◆ **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
- ◆ **Chronic diseases**
  - Radiation-induced problems
  - Responses to dust exposure
  - Presentation or acute manifestation of nascent illness



# ***Medical Concept of Operations for Exploration (CONOPS)***

- ◆ ***Our mandate:***
  - ***Optimize crew health and performance to ensure mission success***
  - ***Return the crew safely to Earth***



# Medical Operational Concept

## ◆ Prevention is Key

- Crew selection/retention standards will be used to minimize likelihood of medical conditions developing during or after mission.
- 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



Technology Assessment



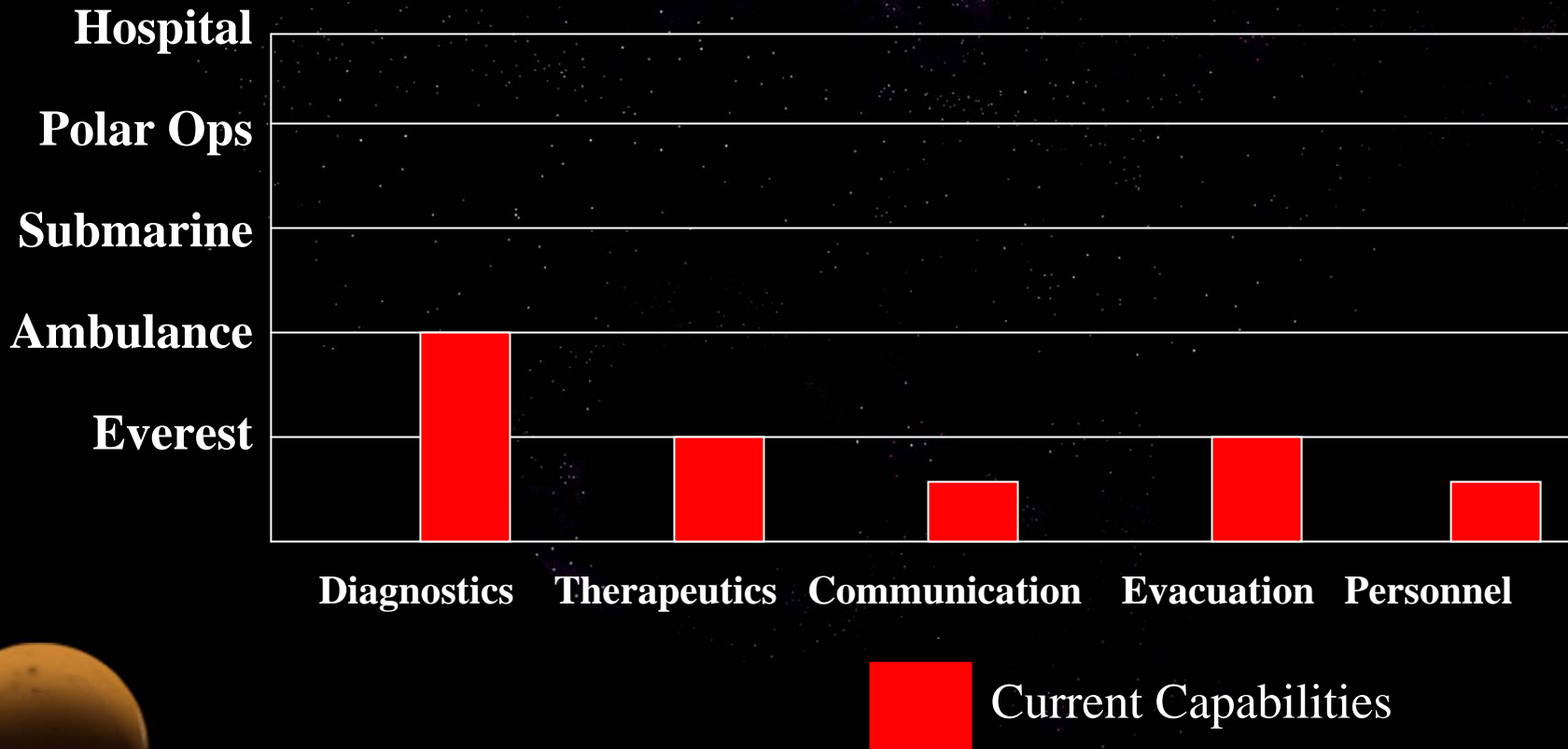
# **Guiding Philosophy:** **Prevention; Prevention; Prevention** **(with a little Prophylaxis mixed in)**

- ◆ **Revised selection and mission medical standards**
- ◆ **Improved pre-flight medical readiness program**
  - Fitness
  - Optimization of health
  - Crew rest???
- ◆ **Better system design to reduce crew overhead**
  - Reduce fatigue
- ◆ **Emphasis on safety**
  - Vehicular components
  - Mission Planning, esp. EVA
  - Flight Rules
- ◆ **Maintenance of Performance**
  - EVA
  - Re-entry
  - Recovery

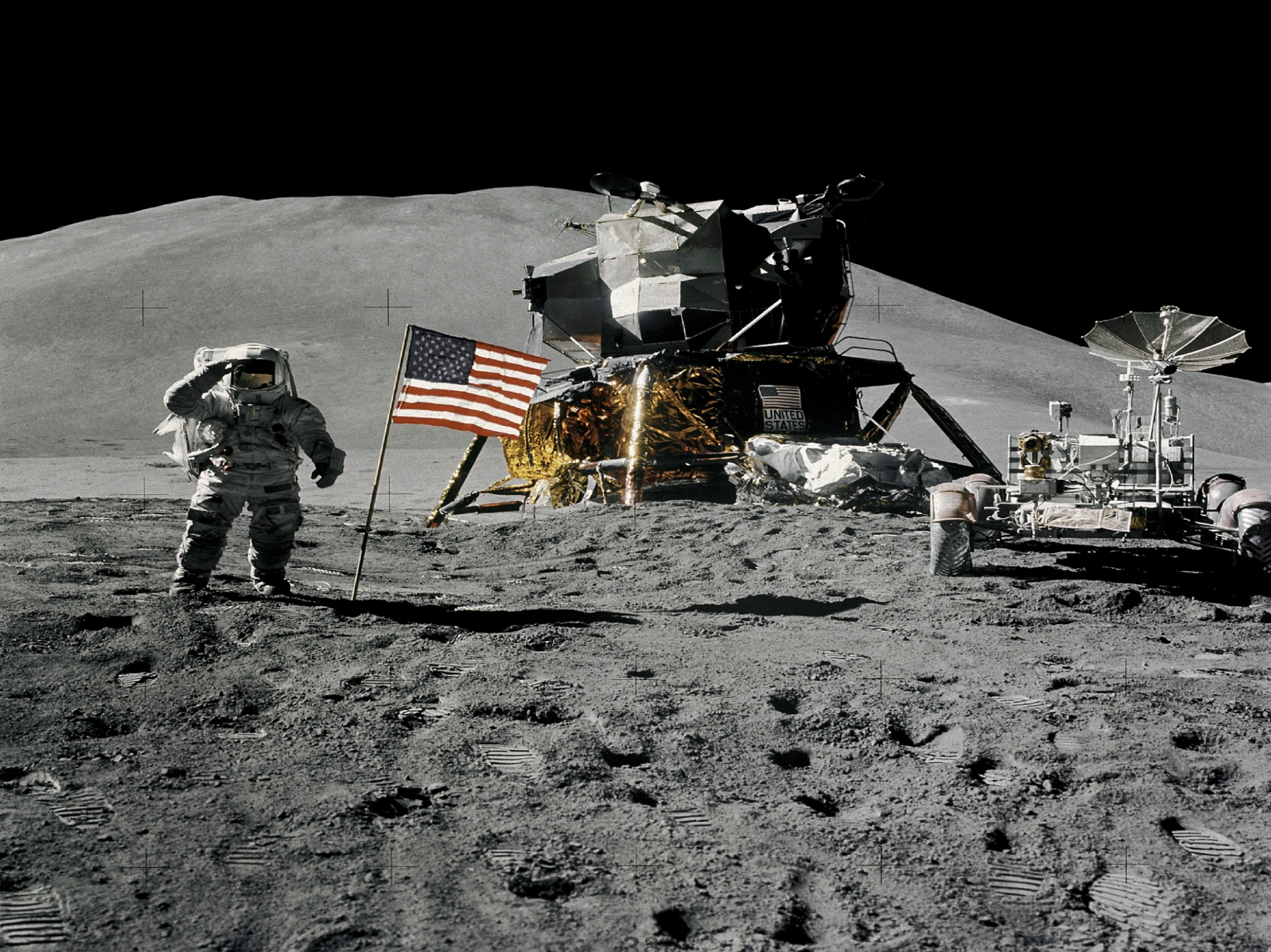




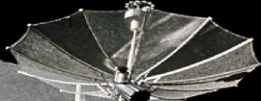
# Current Medical Capabilities Comparison







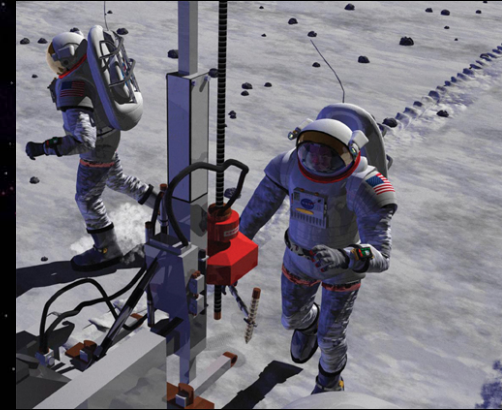
UNITED STATES



# *The Moon - the 1st Step to Mars and Beyond....*



- ◆ **Gaining significant experience in 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
  - Mars ascent and descent propulsion systems (liquid oxygen / liquid methane)
  
- ◆ **Conduct fundamental science**
  - Astronomy, physics, astrobiology, historical geology, exobiology

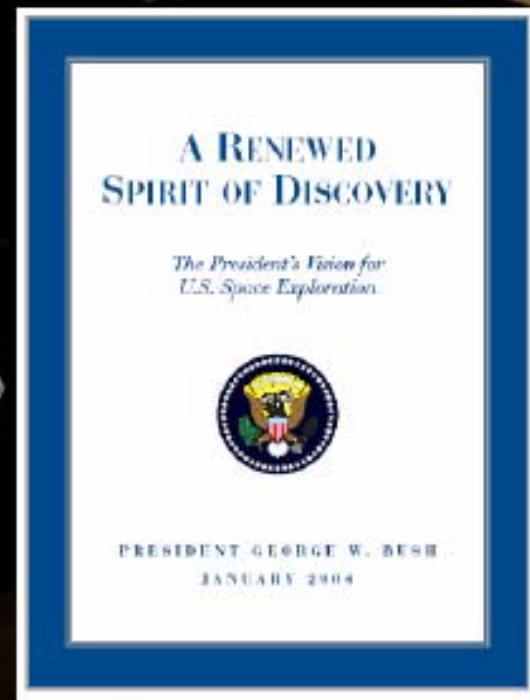


***Next Step in Fulfilling Our Destiny As Explorers***

# A Bold Vision for Space Exploration, Authorized by Congress



- Complete the International Space Station
- Safely fly the Space Shuttle until 2010
- Develop and fly the Crew Exploration Vehicle no later than 2014 (goal of 2012)
- Return to the Moon no later than 2020
- Extend human presence across the solar system and beyond
- Implement a sustained and affordable human and robotic program
- Develop supporting innovative technologies, knowledge, and infrastructures
- Promote international and commercial participation in exploration



## NASA Authorization Act of 2005

The Administrator shall establish a program to develop a sustained human presence on the Moon, including a robust precursor program to promote exploration, science, commerce and U.S. preeminence in space, and as a stepping stone to future exploration of Mars and other destinations.

# NASA Exploration Lunar Activities addressing Themes



Human Civilization



Global Partnerships



Scientific Knowledge



Economic Expansion

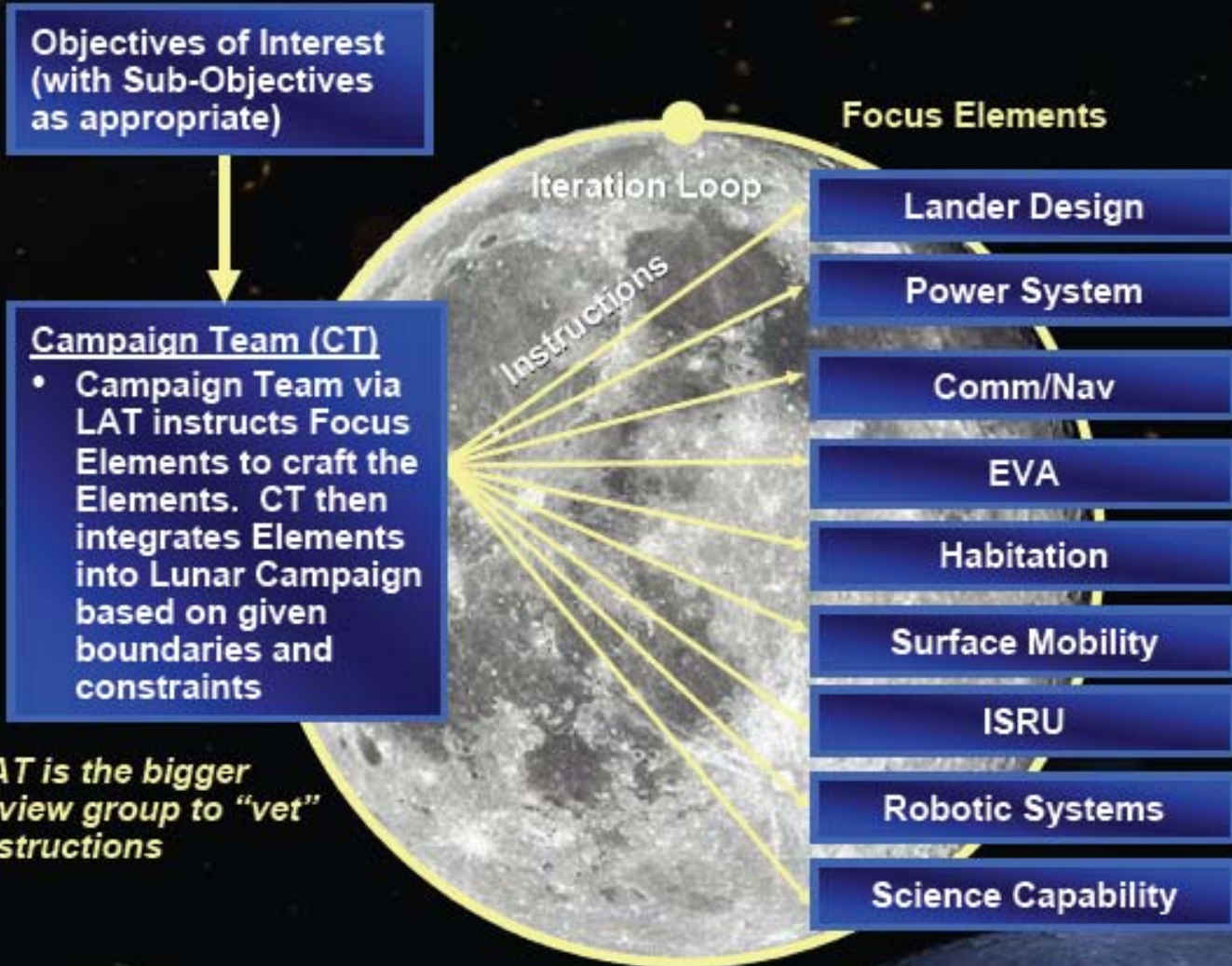


Exploration Preparation



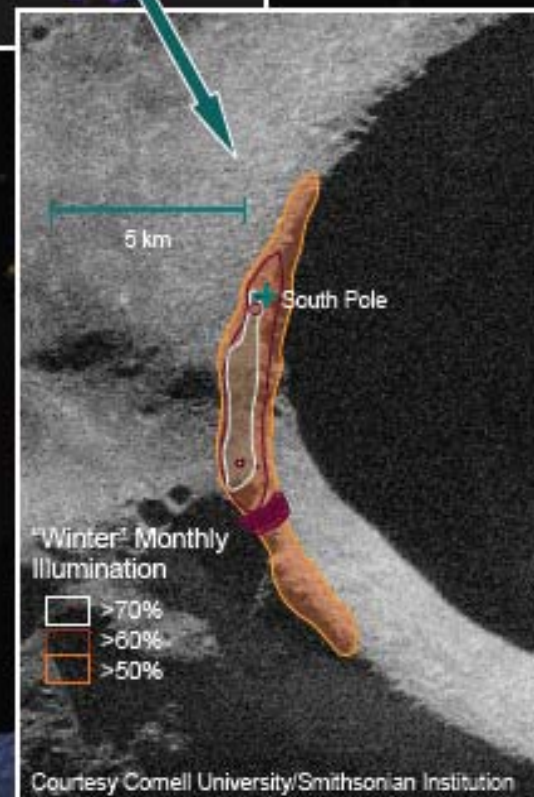
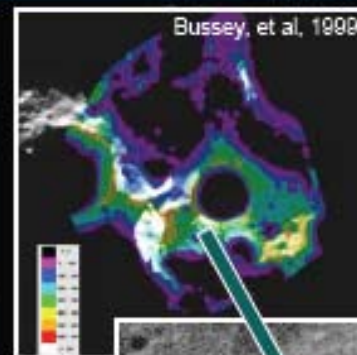
Public Engagement

# Lunar Architecture Development Process



# Key Decisions: *Sortie vs. Outpost*

- **First: What is the fundamental lunar approach?**
- LAT concluded outpost first is best approach
- **Top 2 Themes – “Exploration Preparation” and “Human Civilization” drive to outpost**
- Enables global partnerships
- Allows development and maturation of ISRU
- Results in quickest path toward other destinations
- Many science objectives can be satisfied at an outpost



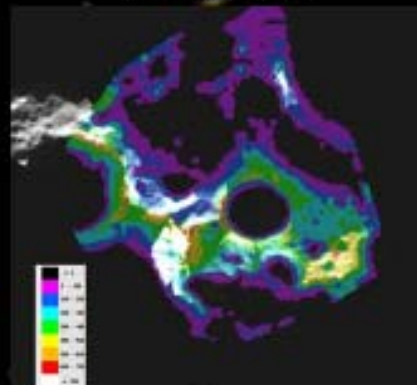
# Outpost Site Location



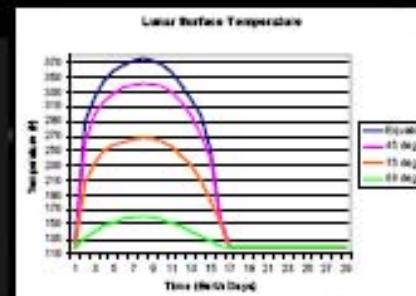
## Outpost Site: Polar

- **Safe**
  - Thermally Moderate
- **Cost Effective**
  - High percentage of sunlight
  - Allows use of solar power
  - Least Delta V required
- **Resources**
  - Enhanced hydrogen (possibly water)
  - Potentially other volatiles
  - Oxygen
- **Flexibility**
  - Allows incremental buildup using solar power
  - Enhanced surface daylight ops
  - One communication asset (with backup)
  - More opportunities to launch
- **Exciting**
  - Not as well known as other areas
  - Offer unique, cold, dark craters

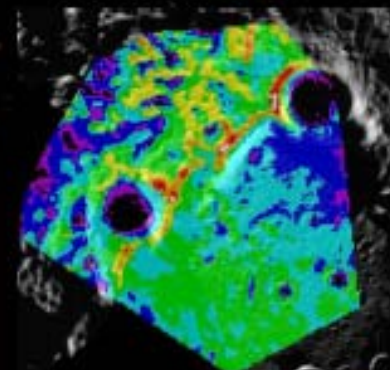
### South Pole



Data obtained during southern winter (maximum darkness)



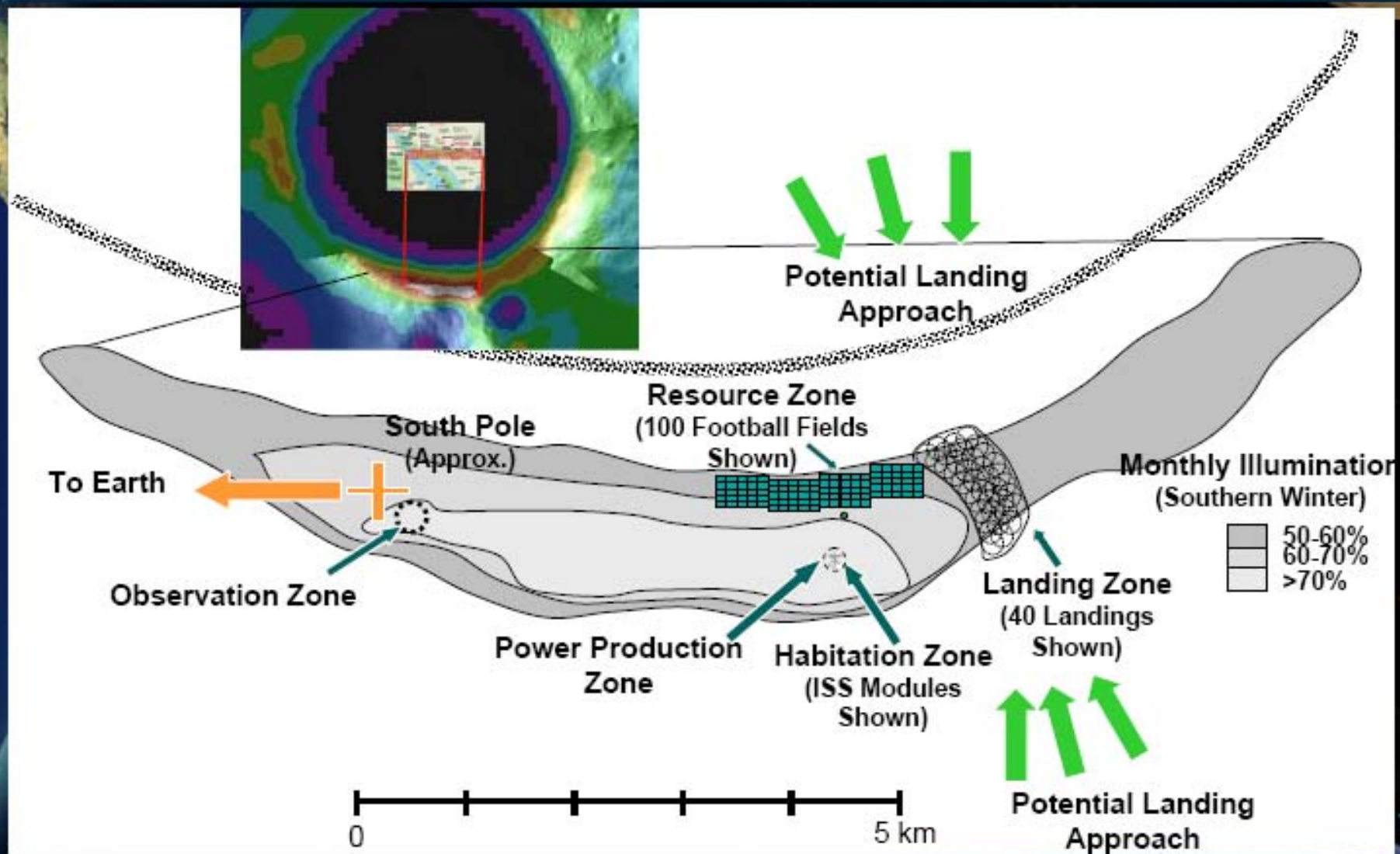
### North Pole



Data obtained during northern summer (maximum sunlight)



# Shackleton Crater Rim with Notional Activity Zones



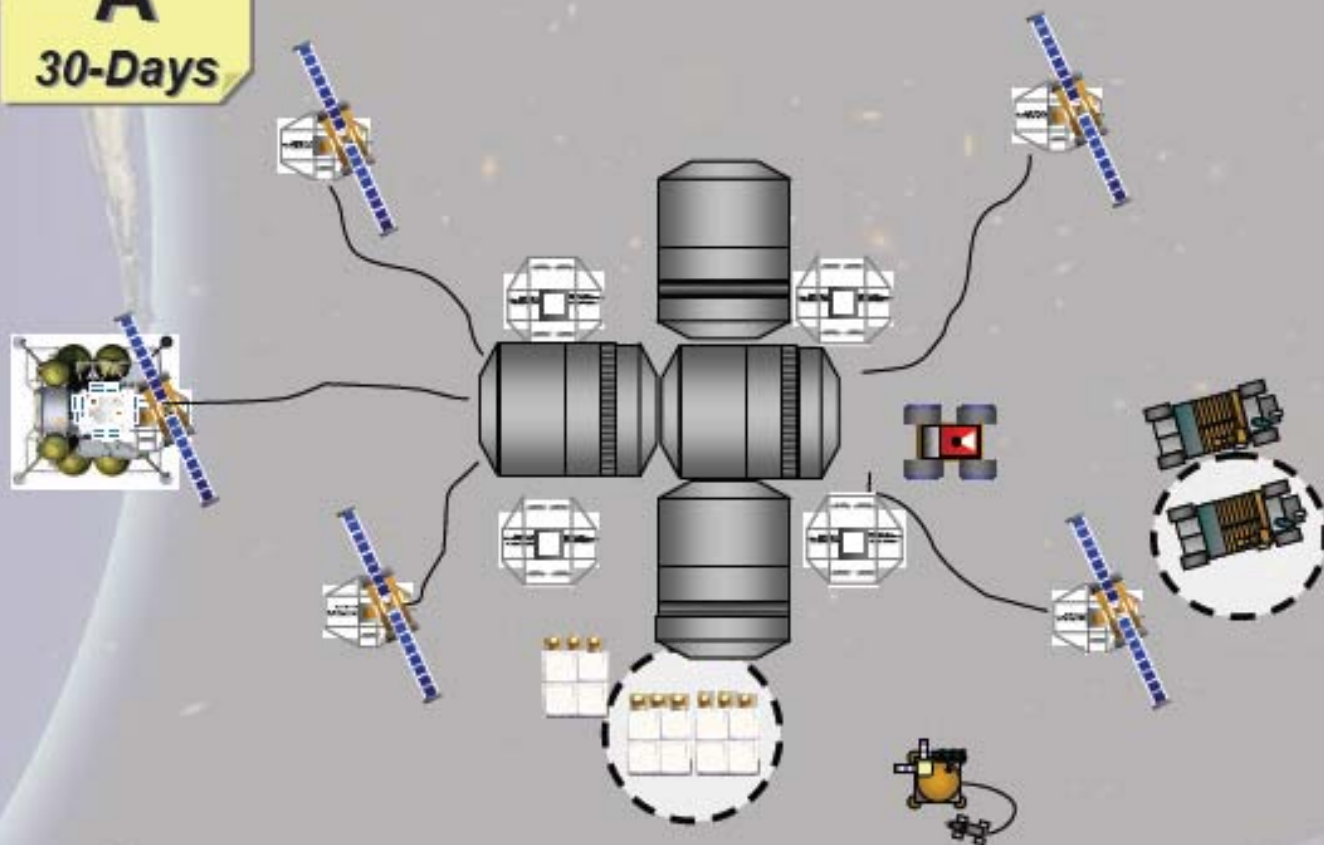


# Key Points: Outpost Build up



**2024**  
**A**  
**30-Days**

2024B Starts 6 month increments



## KEY

-  Crew/Cargo Lander
-  Solar Power Unit
-  Unpressurized Rover
-  Surface Mobility Carrier
-  Habitation
-  Power Storage Unit
-  Logistics
-  ISRU Module
-  Pressurized Rover (2027)

# Key Points: Lander Basic Architecture

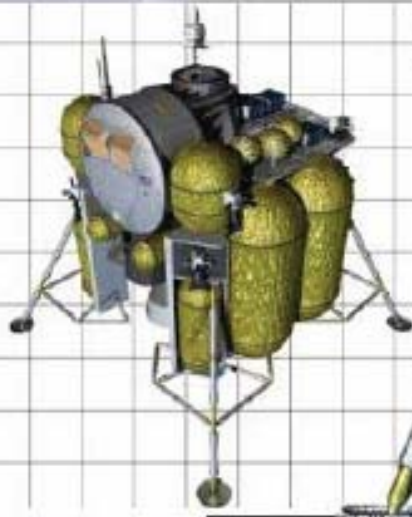


Ascent Module  
(minimized for  
mass)

Landed Mass  
(Cargo, Habitat,  
Mobility, etc –  
Maximized for Mass)

- Design Goals
  - Minimize Ascent Module mass
  - Minimize Descent Module mass
  - Maximize landed "payload" mass
  - Simplify interfaces
  - Move functions across interfaces when it makes sense

Descent Module  
(minimized for  
mass)



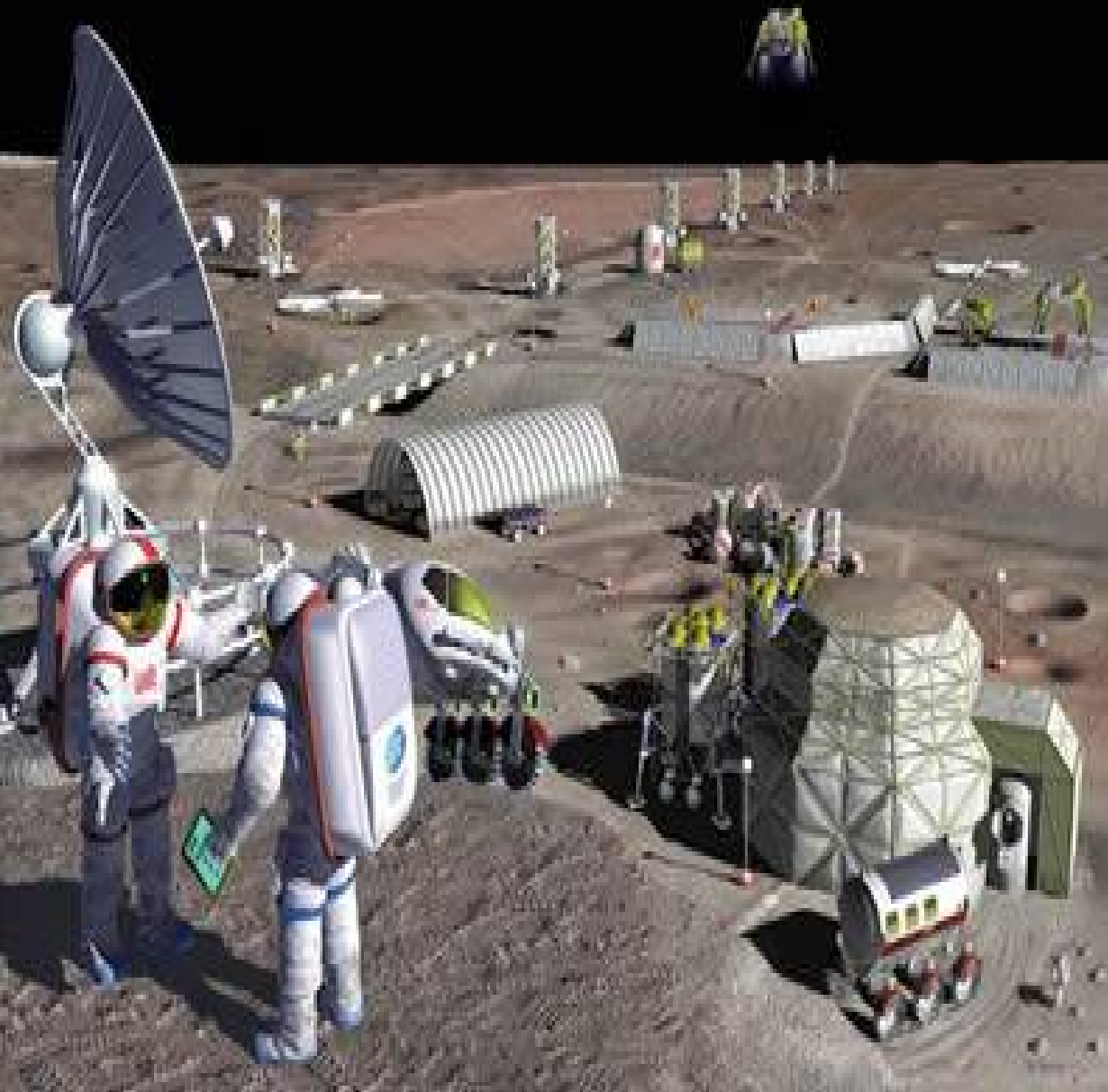
# Medical System- Hardware Elements

## Lunar Sortie- Lander:

- Ambulatory Medical Kit (Routine symptom response: HA,
- Medical Contingency Kit (Trauma management; O2 concentrator, AED)
- Environmental Response Equipment
  - Airlock EVA Contingency Response (Contamination Clean-up, PPE and Contamination or Decompression Sickness Medical Kit)
  - Contingency Breathing Apparati (4-portable or umbilical-based devices)
  - Eyewash (system to flush contaminants from crew)



# Lunar Outpost- Long duration Habitat: Medical



- ◆ **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 kit**
  - Dental
  - Laceration repair
  - Acute Care pack

# Medical/Exercise/Environmental Monitoring System Mass and Volume Allocation-GFE



## Lunar Outpost Outpost- Long duration Habitat:

Periodic Health Status via Telemedicine WS

Exercise/Fitness station

Improved autonomy for Contingency Response

Environmental Contingency Response

Medical h/w and supplies to outfit the HabiTank:

Telemedicine Workstation  
Diagnostic Capability

Portable Imager (U/S)

Advanced Life Support/

Trauma stabilization kit

Medical procedure kit

Dental

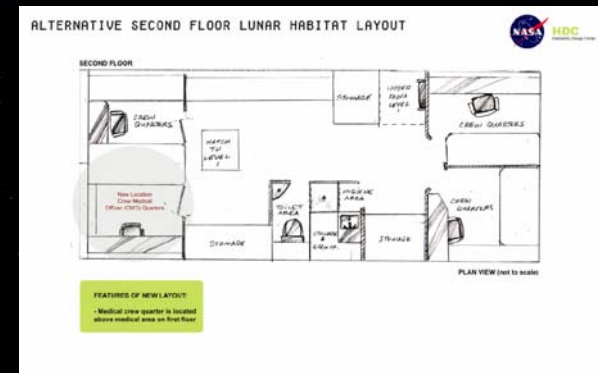
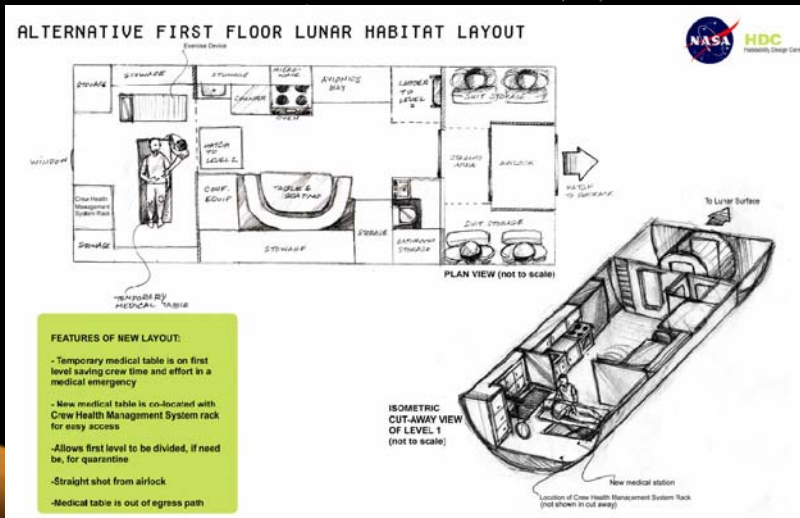
Laceration repair

Acute Care pack

Size- Approx. ISS ISO Rack: 0.5-0.75 M2

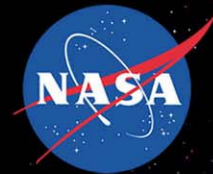
Volume TBD 0.5-0.75 CTBE

Mass 10-20 kg



# ***Biomedical and Crew Performance Aspects of the Exploration EVA system: EVA Physiology, Systems and Performance Project***

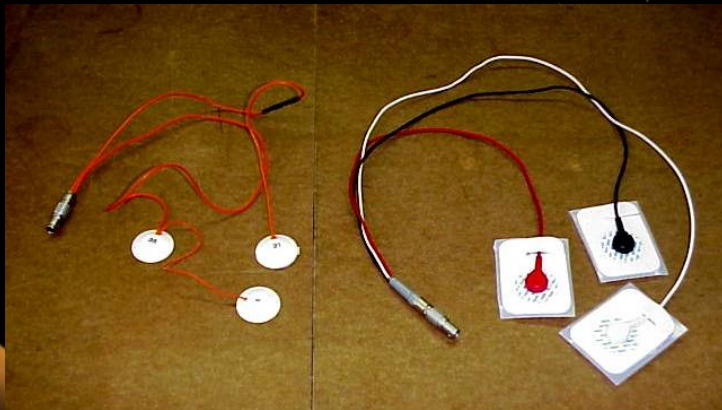
**Mike Gernhardt/Jeff Jones (JSC- CB;SK/ SD)  
Kevin MacNeil; Jennifer Jadwick (Wyle)**

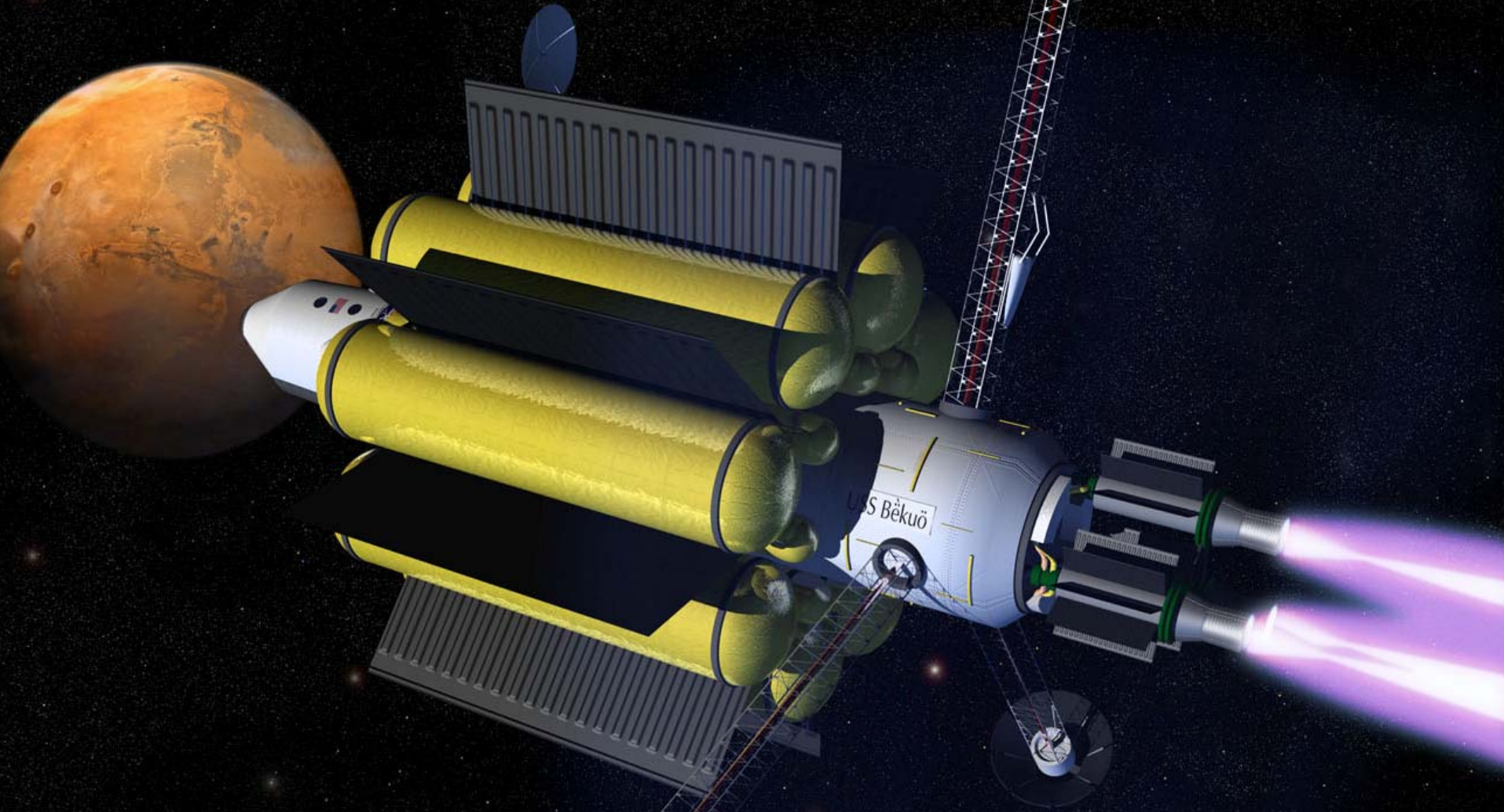


# ***Biomedical and Crew Performance Aspects of the Exploration EVA System***



- ◆ Goal to provide the biomedical data to drive suit design decisions that optimize human performance and minimize suit induced trauma
- ◆ Predictive models of metabolic costs and biomechanical parameters based on gravity levels, suit weight and mass, kinematics, pressure and center of gravity
- ◆ No overhead biomedical harness- built into thermal garment/LCVG





VaSIMR (Variable Specific Impulse Magnetoplasma Rocket) engines do not use chemical reactions to produce rocket thrust. Instead the hydrogen is turned into plasma, a super hot gas at temperatures higher than the interior of the Sun. The plasma is created by electromagnetic waves in a magnetic chamber and expelled through a magnetic nozzle. Advanced superconducting magnets generate the strong fields required by the engine.

**Getting there faster is the best countermeasure medical could hope for!!!!**



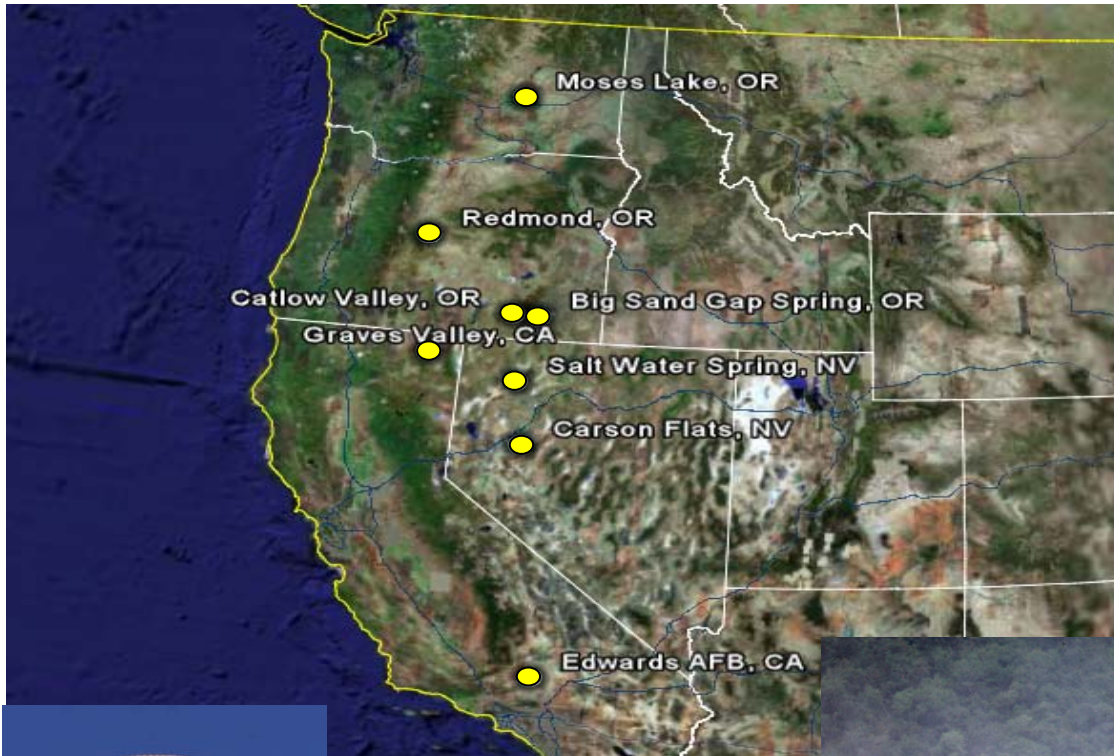
# ***CEV to Mars Orbit or likely to Mars Transit Vehicle and back***

- ◆ **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



# POTENTIAL CEV LANDING AREAS: CONUS and PACIFIC (from M. Chandler, et al)

## Nominal Potential Landings



# *Developing Medical Support Systems*



## ◆ Preventative Health Strategy

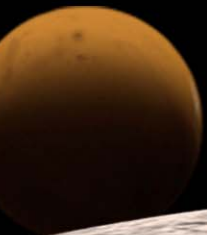
- Countermeasures: Exercise, Pre-breathe, Pharmacologic, Artificial Gravity

## ◆ Autonomous Care

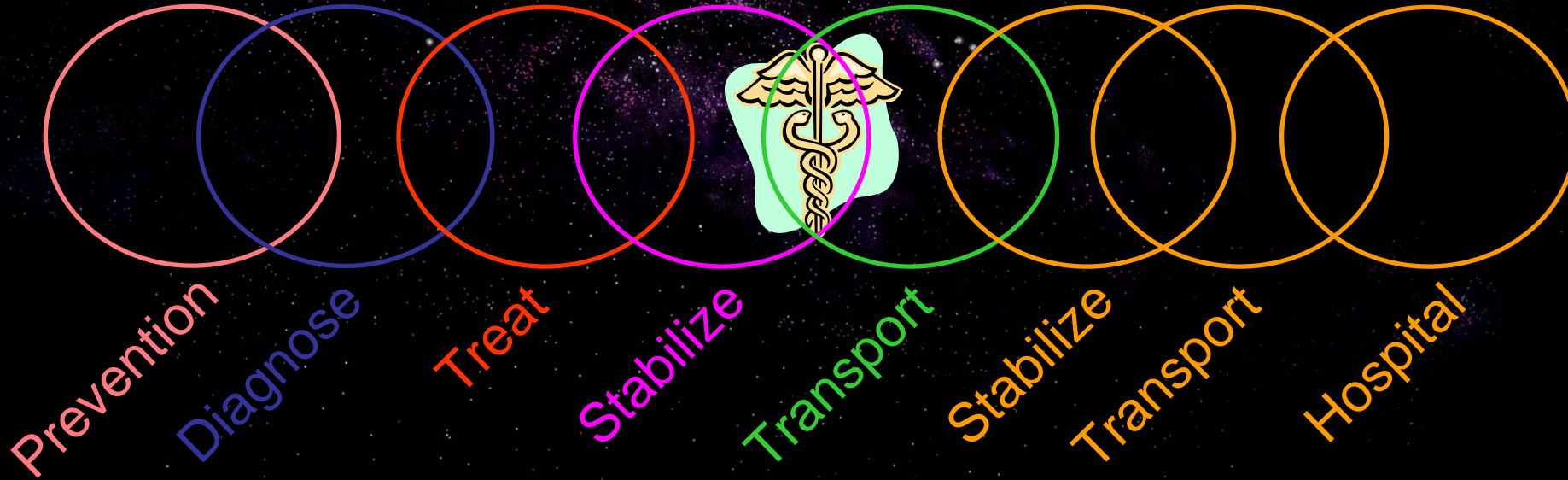
- Smart Systems with Decision Support
- Microbiology/Synergy with Astrobiology
- Telemedical Augmentation

## ◆ Analog Sites- Devon Island, HMP

- Lessons Being Learned



# Chain of Care



Prevention: pre- and in-flight medical screening, health stabilization, and in-flight countermeasures and environmental monitoring

Diagnose: in-flight diagnostic capabilities

Treat: in-flight therapeutic capabilities

Stabilize: prepare patient for stresses of transport and medical capabilities of vehicle

Transport: rapid deorbit capability (Shuttle, Soyuz, modified Soyuz)

Stabilize/Transport/Hospital: return to earth with location and extraction by ground forces, preparation for and transport to Hospital, terminating in arrival at care location

# Countermeasures- Exercise



*Due to measured de-conditioning in even short duration space missions, an exercise device is felt to be needed by the ECP to protect/facilitate:*

Cardiovascular fitness – to maintain overall fitness level, aid in ambulation during G-transitions, and to minimize fatigue

Muscle strength and endurance – to complete both nominal and contingency mission tasks (e.g., lunar rover failure requiring “walk back” of distances up to 10km; post landing egress)

Muscle recovery – from strenuous tasks or confined postures

Other possible system benefits – psycho/social, postural stability

**A multifunctional exercise device to protect the maximum number of physiological systems?**



# 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 Pressurized 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
- ◆ Emergency Surgical Capability



# Medical Capabilities Envisioned to Support Exploratory Class Space Flight Implications for the Future



## ◆ “ALL”

- Autonomous
- Light (modular)
- Lean



# Medical Kit Size Comparison



## 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

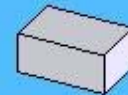
## CEV to Lunar Orbit



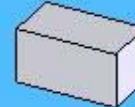
Contingency Cleanup Kit  
7 x 7 x 5 in



Environmental Health  
7 x 7 x 7 in



Medical Kit  
14.5 x 7 x 9.5 in

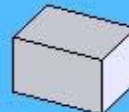


Exercise  
9.75 x 16.75 x 9.25 in

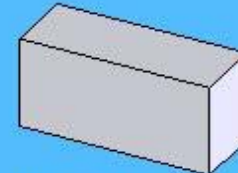
## LSAM



Medical Interface Kit  
7 x 5 x 5 in

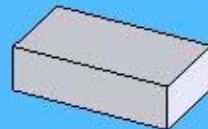


Airlock EVA Contingency Response  
10 x 11 x 15 in



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



# Analog Exploration Environments



- ◆ **Backyard/Nearby**
  - Rockpile
  - Desert RATS
- ◆ **Remote/Extreme Environments**
  - Devon Island, Haughton-Mars Crater
  - NEEMO
  - Antarctica- Coastal and Polar Stations
- ◆ **Flight**
  - Zero-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



# NEEMO

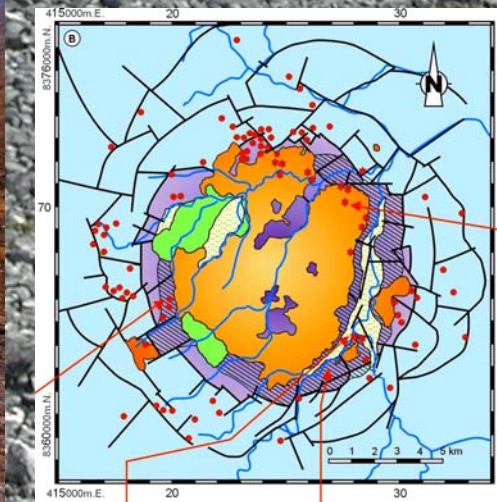
- ◆ Remote location, not easily accessible
- ◆ Transient Buoyancy- gravity offset, but hyperbaric
- ◆ Operationally focused- multiple “EVA’s”/day & several days/week



Remote guidance utilized heavily

# ***Houghton Crater, Devon Island***

“The closest thing to being on Mars without leaving Earth”



# HMP as a Moon/Mars Analog



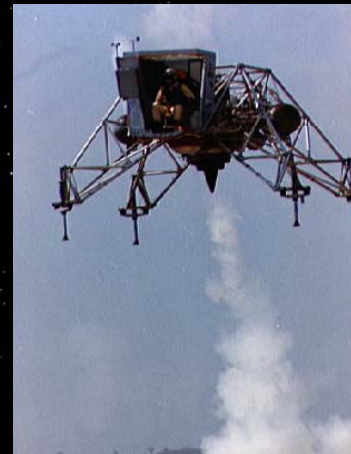
## ◆ Lunar Surface Operations

- 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 Med Ops Project



*Apollo 16 Geological field training in New Mexico*

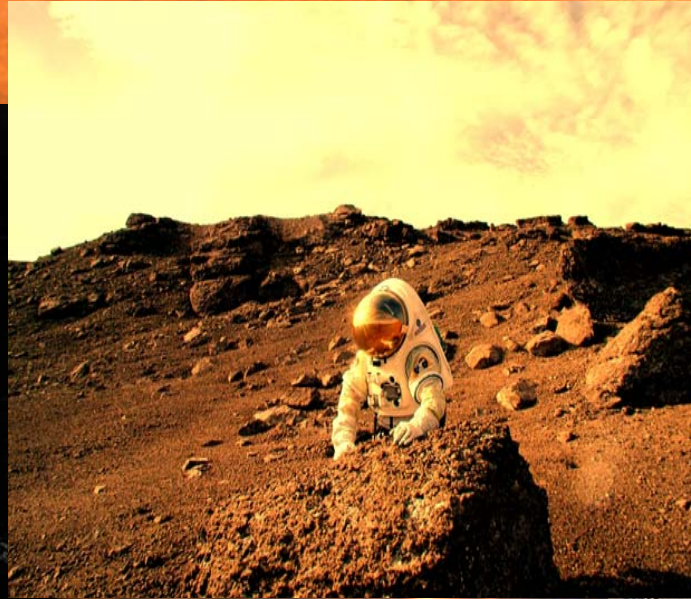


*Apollo 12 Lunar Lander Training Vehicle (LLTV) Ellington Field*



*Apollo 17 Lunar Surface Activity training at KSC*

# Suit Mobility/Functionality Tests



Field Evaluations of Hamilton Sundstrand's Concept Spacesuit for Advanced Planetary Exploration



“This cause of  
exploration and discovery  
is not an option we choose;  
it is a desire written  
in the human heart.”

~George W. Bush

