The Dupont Summit 2011
Science, Technology & Environmental Policy:
Pressing Issues, Little Time

United States Space Exploration in the Next 20 Years
Prospects for Space Medicine Practice

Richard S. Williams, MD,
NASA Chief Health and Medical Officer
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The Space Environment

- 49,000,000 km
- 22 minute 1-way communication
- Biorhythms?
- Temperature extremes
- Vacuum
- Isolation & confinement

Water & food availability
New geo-ecosystem
Reduced gravity
Fuel & oxygen
Radiation
Spontaneous Events in Active Astronauts (Ground)

- V-tach, exercise induced
- Angina
- Atrial fibrillation
- Allergic reaction - severe
- Retinal detachment
- Appendicitis
- Diverticulitis
- Choledocholithiasis
- Pancreatitis
- Hemorrhagic cyst
- Lower GI bleeding
- Duodenal ulcer with GI bleeding
- Stroke

- Cervical disc herniation with impingement on spinal cord
- Ureteral calculus
- Clostridium difficile infection
- Gastroenteritis/colitis
- Inguinal hernia
- Olecranon bursitis r/o septic joint
- Hand bacterial tenosynovitis
- Pneumonia
- Corneal ulcer
- Severe epistaxis
- Right ovarian cyst
- Dysmenorrhea
- Sudden hearing loss
- Cancer

Adapted from: Johnston, et al, 2000
Analogue Environments
Health and Medical Standards

• Selection/Qualification Standards
  – Training
  – Short Duration Flight
  – Long Duration Flight
  – Exploration Class Missions

• Environmental Health Standards
  – Based on OSHA and industry standards, adjusted to 24/7

• Space Flight Specific Exposure Standards
  – Bone loss, muscle strength, cardiovascular deconditioning, nutrition, etc.

• Space Medicine Standards of Practice
• Spacecraft Requirements
CPR in Space

ISS004-E-00180 (11 March 2002) — Astronaut Carl R. Walz, Expedition Four flight engineer, performs cardiopulmonary resuscitation (CPR) on a jury-rigged "human chest" dummy in the Destiny laboratory on the International Space Station (ISS).

Bone Mineral Loss in Space

- 1% per month
- Primarily from gravity dependent areas 1 - 3
- Recovery post-flight as long as 3 to 4 times the length of exposure
- Bone deposition and removal in other areas continues
- Fracture risk
- Fracture healing

m. = month
Sprains, strains and bone fractures
  - In Space and on other Planetary Bodies
    - Stress fracture while in EVA suits or attempting to stop a mass with significant inertia
    - Crush injuries (fractures due to injury by being between two large masses)
  - On return to Earth
    - Normal exercise induced stress fractures
    - Increased falls & traumatic injuries due to accidents (balance disorders, etc.)
    - Osteoporosis fractures (fractures occurring with forces normally associated with sedentary daily activity) at an earlier retirement age
    - Intervertebral disc disease
    - Back pain, spinal nerve impingement

Renal stones
  - In Space and on other Planetary Bodies (<1G)
    - Increased urine calcium excretion with decreased normal urinary stone inhibitors
Possible Mission Consequences

Minor

• Crew member has limited duty for several days (stress fracture, intervertebral disc disease, renal stone)

Major

• Crew member can become incapacitated for several days to weeks, requiring significant medical resources and associated crew support
• Crush or traumatic fracture or a renal stone may become life threatening to crew member and could end the mission
Current Countermeasures to Prevent Musculoskeletal Deconditioning
Bone Mineral Loss in Space
• **Galactic Cosmic Rays (GCR):**
  - highly penetrating protons and heavy ions of extra-solar origin
  - large amounts of secondary radiation
  - largest doses occur during minimum solar activity in an 11-year solar cycle

• **Trapped Radiation in South Atlantic Anomaly:**
  - medium energy protons and electrons
  - effectively mitigated by shielding

• **Solar Particle Events (SPE):**
  - medium to high-energy protons
  - occur during maximum solar activity

Courtesy Dr. Jeff Jones
Primary human skin cells irradiated with 2 Gray $\gamma$-rays (left) or Titanium ions (right) at NSRL. DNA damage is clearly visible at sites marked by new fluorescent technology. DNA damage is diffuse for $\gamma$-rays and localized along the Ti ion tracks through the cells. This pattern of energy deposition accounts for most of the increased risk of space radiation. (Cucinotta et al. 2004)
NASA Space Radiation Lab (NSRL) at DOE’s Brookhaven National Laboratory

MEDICAL Dept.
- Long-Term Laboratories
- Logistic and Administrative Support
- Animal Care Facility
- Liaison Scientist
- X-Ray Source

BIOLOGY Dept.
- Management
- Logistic Support
- Gamma Source

CAD-AGS-NSRL
- Beam Line
- Target Area
- Dosimetry
- Staging Area
- Liaison Scientist

NSRL
The Space Radiation Problem: What is Needed

Knowledge to manage risk
- Space Radiation Environment
  - Solar Particle Events
  - Galactic Cosmic Radiation
- Health Effects of Space Radiation
  - Acute Effects
  - Chronic Effects
- Advanced Radiation Shielding
  - Materials and Structures
  - Other Concepts
- Countermeasures to
  - Minimize Deleterious Health Effects

Technologies for
- Shielding
- Monitoring
- Warning and Forecasting
- Analysis

Policy Recommendations for
- Acute and Chronic Dose Limits
- Shielding Requirements
- Monitoring Requirements
- Flight Rules
Calling Earth

Mercury
5-12 min.
57 million km

Venus
2-15 min.
26 million km

Earth
4-22 min.
49 million km

Mars
4-22 min.
49 million km

Jupiter
34-52 min.
391 million km

Saturn
71-88 min.
795 million km

Uranus
151-168 min.
1693 million km

Neptune
241-259 min.
2706 million km

Pluto
320-337 min.
3573 million km

* Mean distances from Earth
What is it like being a long way from Earth?

Seeing Earth through a telescope from Mars Orbit

Earth and Jupiter from the Martian surface
Ultrasonography for Autonomous Medical Care in Limited Resource Environments
Morbidity in Space
US and Russian

• Evacuation occurred
  – Cardiac arrhythmia - SVT
  – Prostatitis » sepsis
  – Suspected toxic exposure

• Evacuation pending
  – Toxic inhalation
  – Urinary tract infection: prostatitis/pyelonephritis » sepsis

• Near misses
  – 3 cardiac ischemic events just prior to, or within 2 years after flight
  – Adverse reactions to intravenous injections x 2
  – Brain tumor
  – Physical fatigue: assistance required to ingress station during EVA
  – Inhalation injury post-fire
  – Second degree burns
  – Anxiety reaction on boarding station
  – Rapid cabin depression secondary to breach of hull

• High Operational Impact
  – Toxins - Pyrolysis
    • Carbon monoxide release
  – Toxins - Spills
    • Ethylene glycol spills
  – Toxins - Metabolic
    • CO2 toxicity
  – 2 episodes of cardiac ischemia (suspected)
  – 2 eye injuries
  – 4 cases of urinary retention
  – Dental abscess
  – Suspected appendicitis (ureteral stone)
  – Dermatologic infection/contact dermatitis
  – Depressive reactions
  – Fatigue: Contributor to Mir/Progress collision

• Performance Impact
  – Misuse of on-orbit medications
  – Unexpected reaction to on-orbit medications
  – Suspected clavicle fracture
  – Skin infection
  – Severe nerve pain / numbness
  – Probable DCS (reported after mission)
    – Collins, Carrying the Fire: An Astronaut’s Journey, Cooper Square Press, 1974

After Clark; Marshburn; Bacal
Critical Areas of Consideration

• Bone Loss
• Muscle Alteration and Atrophy
• Cardio-vascular Alteration
• Immunology, Infection and Hematology
• Neurosensory and Motor Alteration
• Nutrition
• Psychological Challenges
• Radiation Challenges
• Space Motion Sickness
• Vision Changes