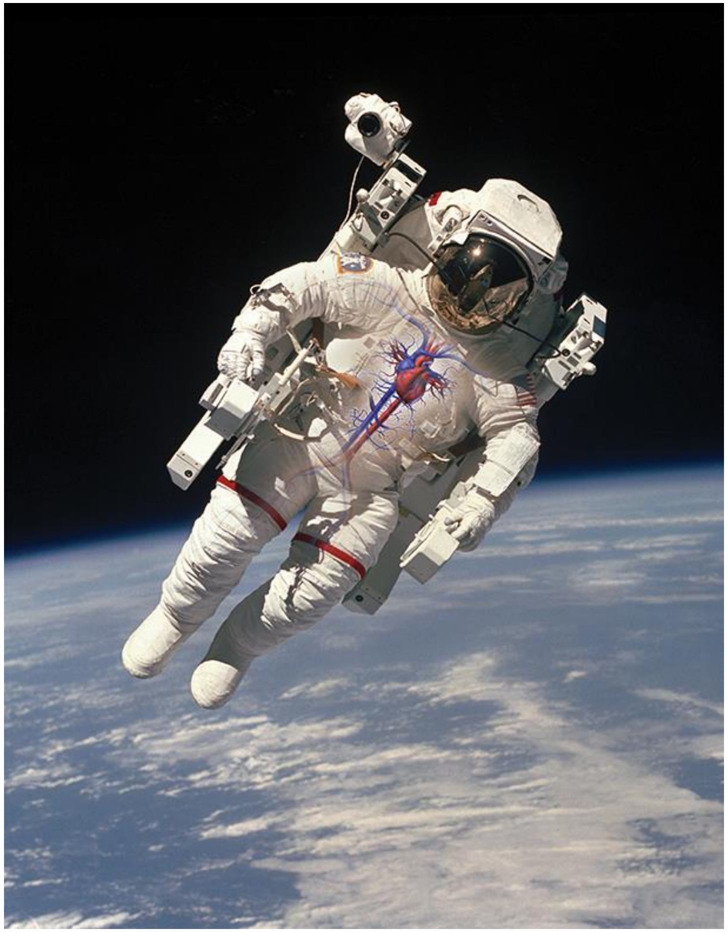


AEROSPACE MEDICINE

Vince Michaud, MD, MPH

Colonel, USAF (Retired)

TCU '84

Deputy, Chief Health and Medical Officer

Director, Health and Medical Systems

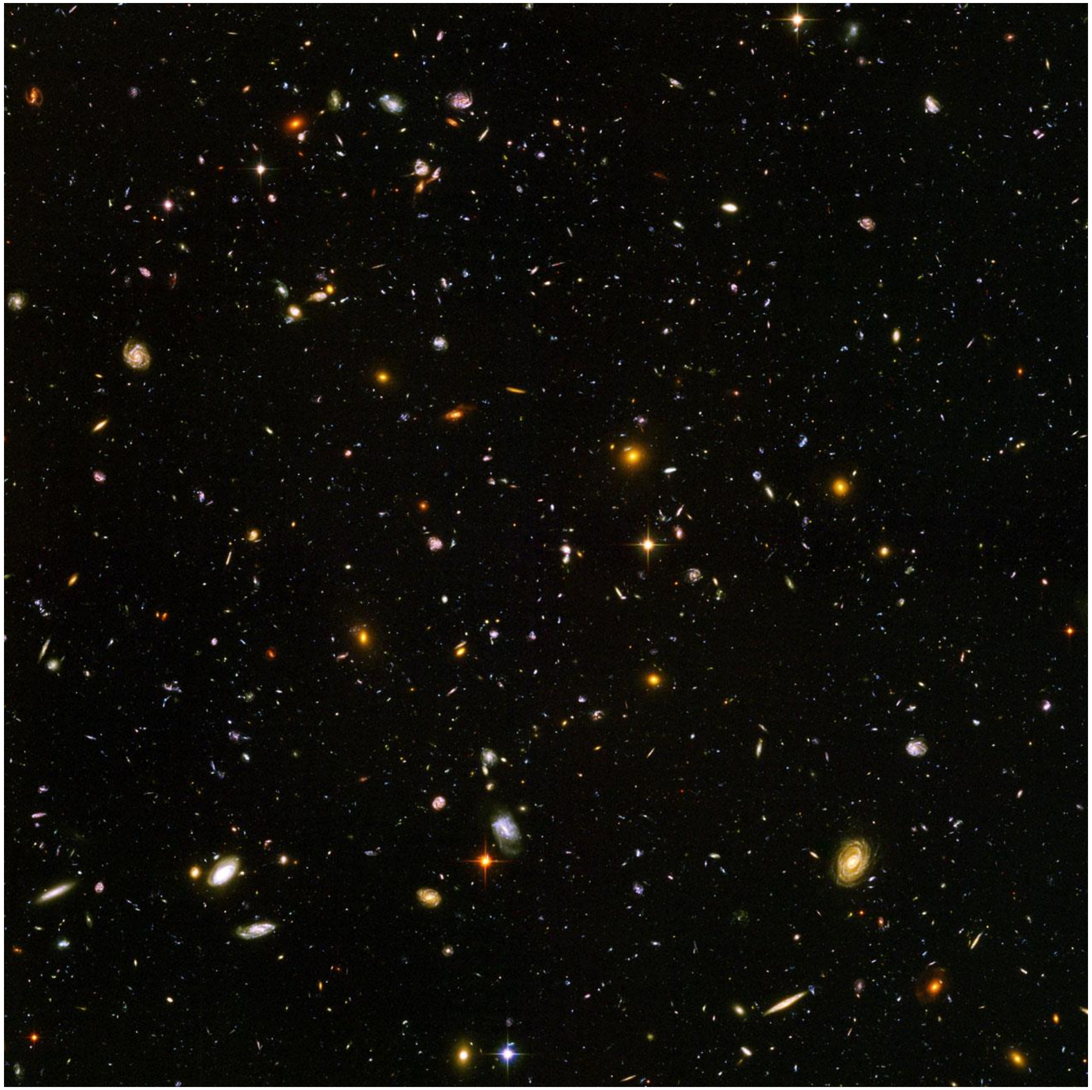
NASA Headquarters

Acknowledgement and Disclaimer

- **This presentation represents the views of the author and not necessarily of NASA**
- **No financial relationships to declare**

A Different Perspective

- **On medical specialty Aerospace Medicine**

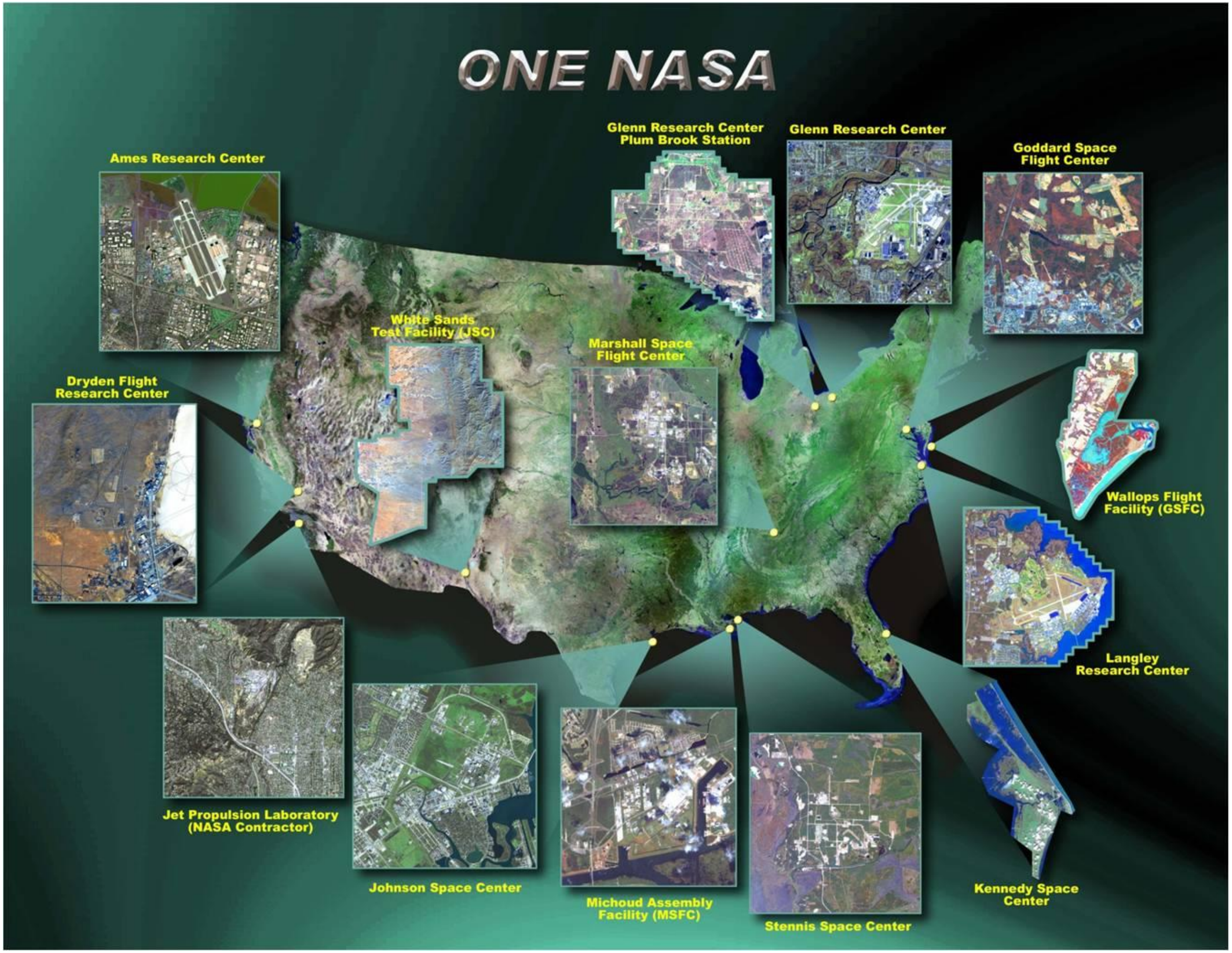


Where did 25 years go?

- **Texas Christian University**
- **Southwestern Medical School, Dallas**
- **Internship in General Surgery with US Air Force**
- **Duty as Squadron Flight Surgeon in United Kingdom and Germany**
- **Residency in Aerospace Medicine and Occupational Medicine**
- **Other assignments in Florida, DC, Germany, and Korea**
- **Now at NASA as a civil servant**

UT SOUTHWESTERN
MEDICAL CENTER

NASA Centers



Major Center Functions

- **Ames Research Center-** IT, fundamental aeronautics, bio and space science technologies
- **Armstrong Flight Research Center-** Flight research
- **Glenn Research Center-** Aeropropulsion and communications technologies.
- **Goddard Space Flight Center-** Earth, the solar system, and Universe observations
- **Jet Propulsion Laboratory-** Robotic exploration of the Solar System
- **Johnson Space Center-** Human space exploration
- **Kennedy Space Center-** Prepare and launch missions around the Earth and beyond
- **Langley Research Center-** Aviation and space research
- **Marshall Space Flight Center-** Space transportation and propulsion technologies
- **Stennis Space Center-** Rocket propulsion testing and remote sensing technology

Occupational Health Program

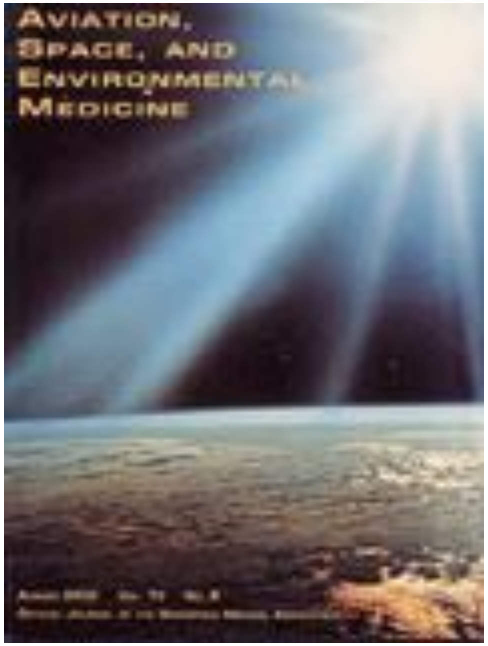
- **18,000 Civil Servants and 20-40,000 Contractors**
- **All Center OH clinics are contracted out**
- **Very few civil servant medical professionals**
- **Hazardous Environments**
  - **Explosive Chemicals like rocket fuel**
  - **Reactors**
  - **Largest indoor pool in the world**
  - **Confined Space: to include vacuum and microgravity**
- **Astronaut Health Care**
  - **Full spectrum while actively flying**

NIOSH Affiliate

- **Recently invited to be a NIOSH affiliate**
- **Recognized for several decades of strong occupational health and health promotion activities**

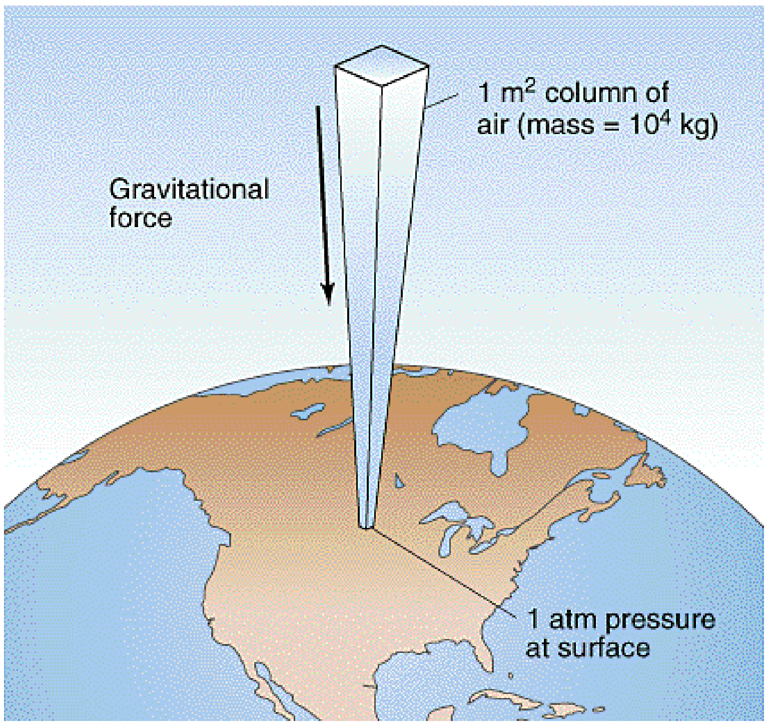
Aerospace Medicine

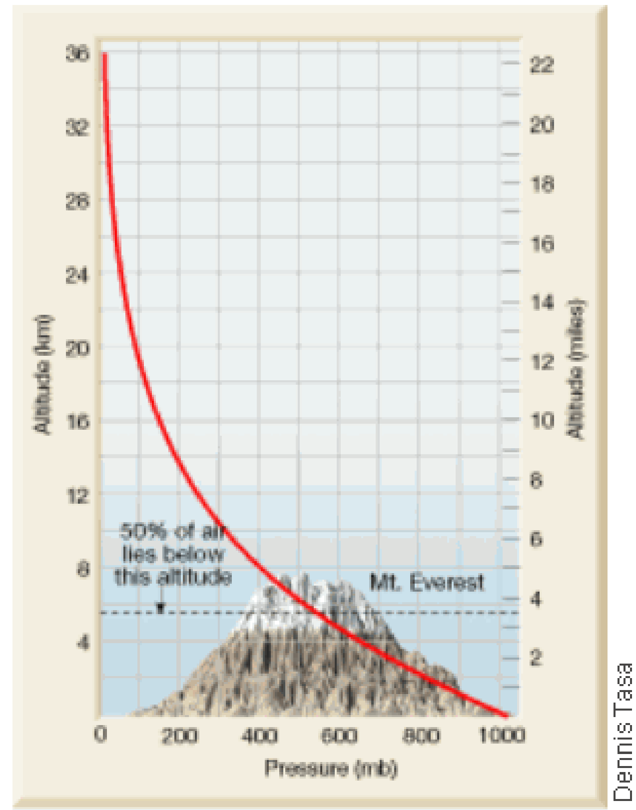
- **Aerospace Medicine is that specialty area of medicine concerned with the determination and maintenance of the health, safety, and performance of those who fly in the air or in space**



Why Aerospace Medicine

- **The physiologic environment changes the moment you leave the surface of the earth**





$$F_{\text{gravity}} \propto \frac{Mm}{d^2}$$

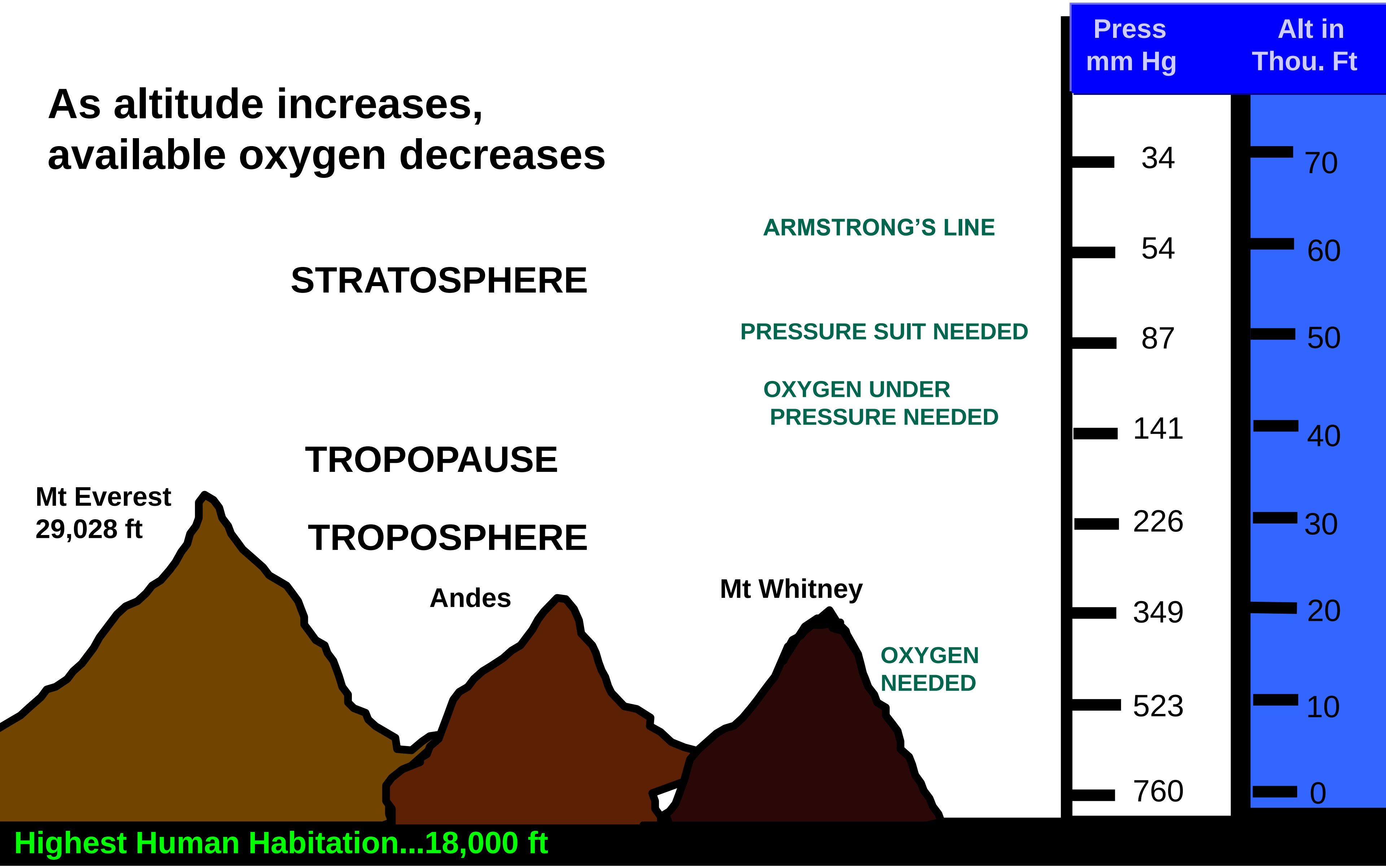
14.69 lbs/in^2 at Sea Level

Physiologic Effects of Air Travel

- **Hypoxia**
- **Decompression Sickness**
- **Trapped Gas**
- **Acceleration**
- **Spatial Disorientation**
- **Visual Illusions**
- **Somato-sensory Illusions**
- **Human Factors**

Environmental Requirements Oxygen

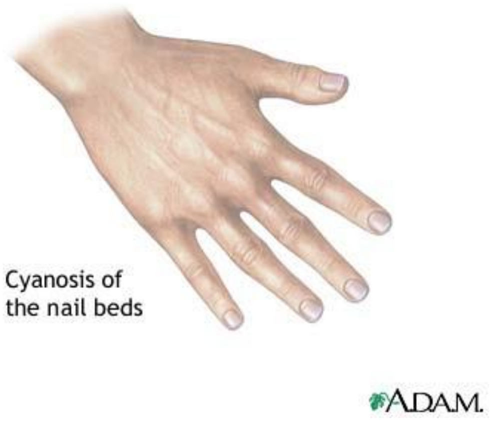
As altitude increases, available oxygen decreases



Aerospace Medical Association

Hypoxia

- **Subjective symptoms**
  - **Breathlessness, apprehension, headache, dizziness, fatigue, nausea, blurred vision, tunnel vision, numbness, tingling**
- **Objective signs**
  - **Increased respiratory depth and rate, cyanosis, confusion, poor judgment, behavioral changes, loss of coordination, somnolence, unconsciousness**
- **Effective Performance Time**
  - **18000 ft – 20 to 30 minutes**
  - **25000 ft – 3 to 5 minutes**
  - **30000 ft – 1 to 2 minutes**
  - **35000 ft – 0.5 to 1 minute**
  - **40000 ft – 15 to 20 seconds**
  - **43000 ft – 9 to 12 seconds**

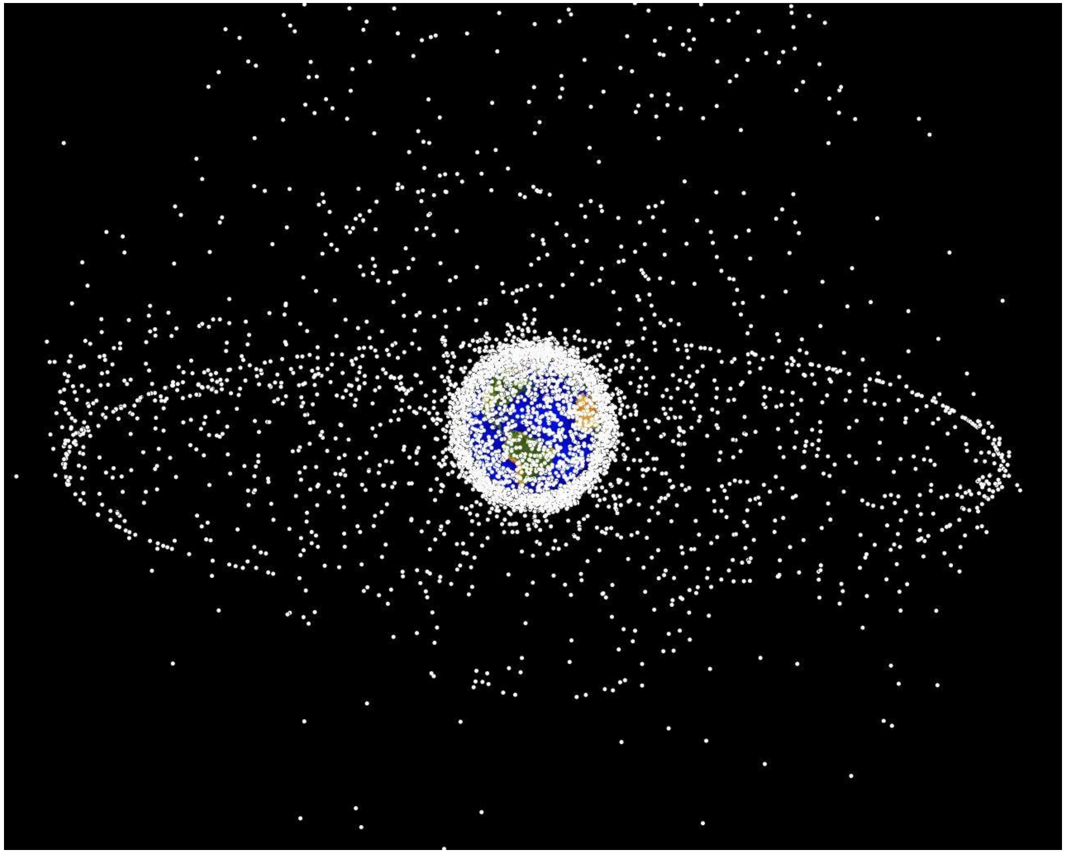


What's the big deal

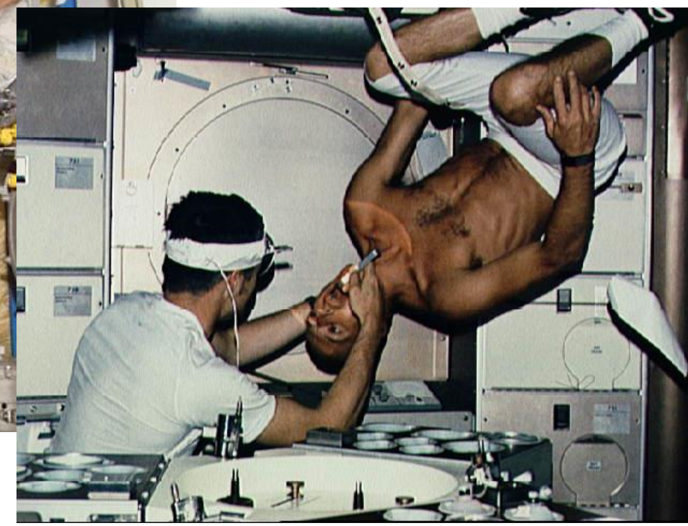
- **Huge consequences, in flight**
- **There isn't always a curb to pull over too**

Challenges to Humans of Space Travel

- No Air
- Different Gravity
- Really High Speeds
- Really Long Distances
- Too much Radiation
- Isolation



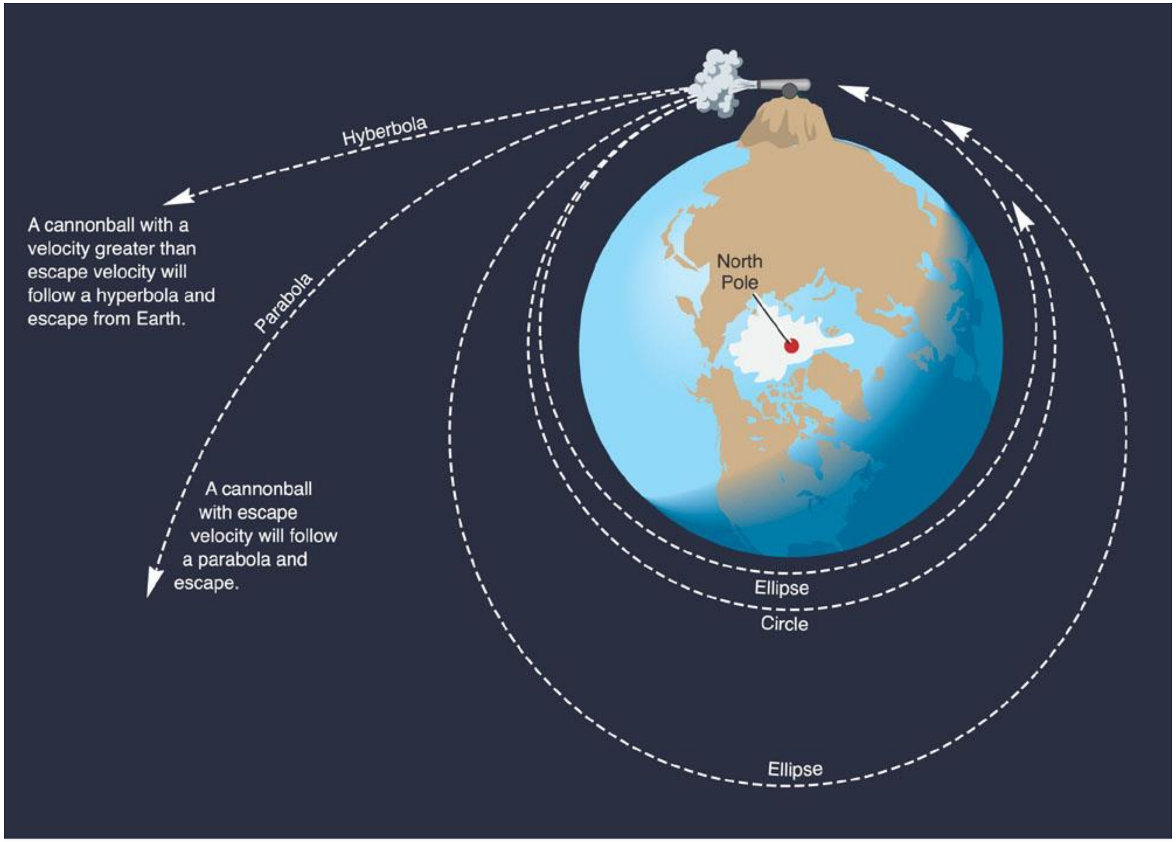
Weightlessness



High Speeds

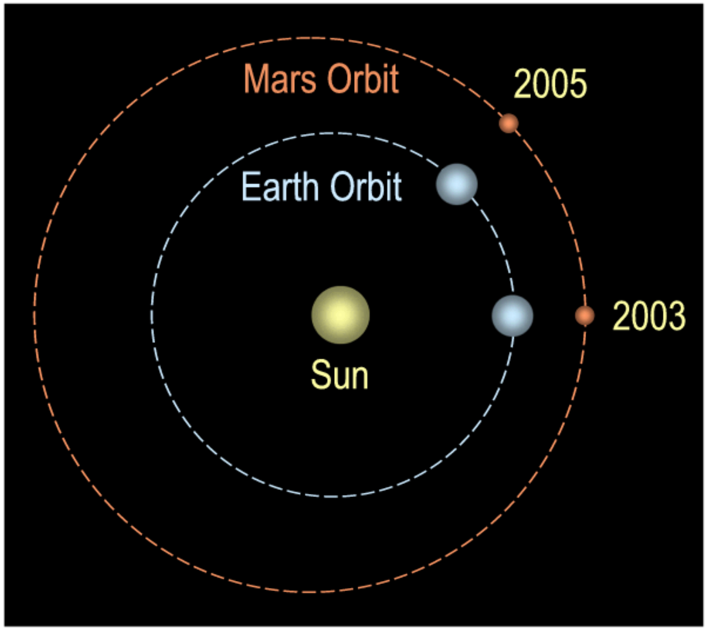
- Orbital velocity is 17,000 miles per hour
- Escape velocity is 25,000 miles per hour

*****Airliners fly at about 600 miles per hour*****

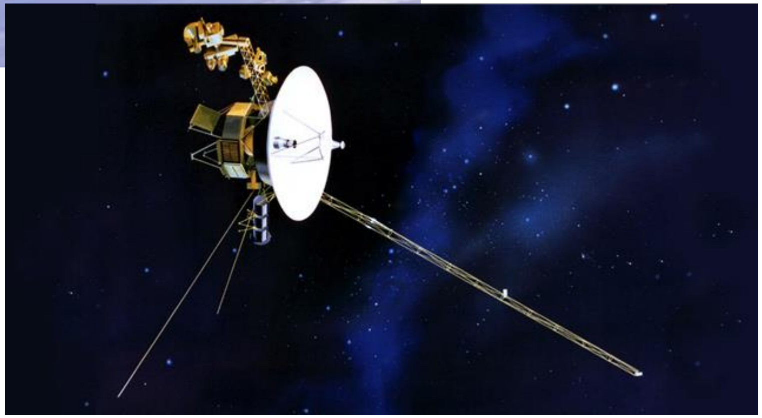


Long Distances

The average distance from the Earth to the Moon is 238,854 miles

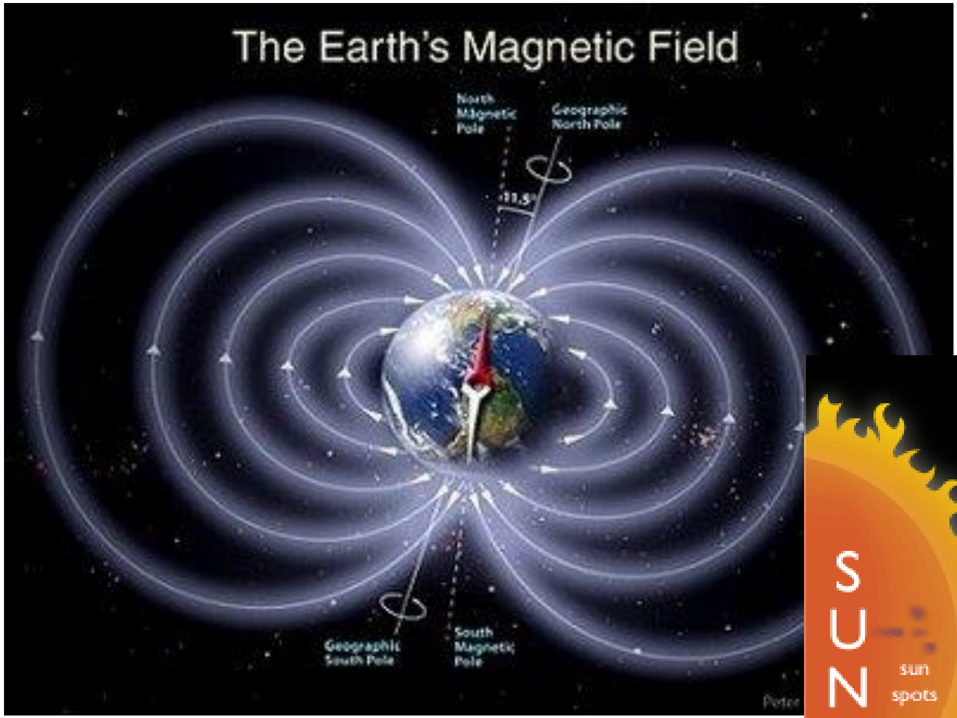


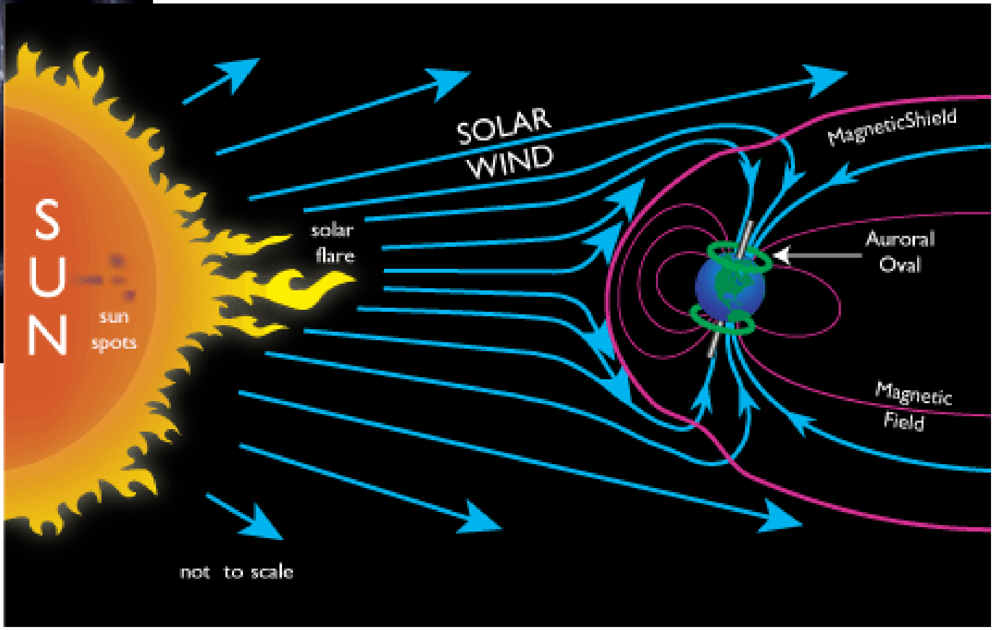
The average distance from Mars to the Earth is about 142 million miles, with a range of 56 to 401 million miles



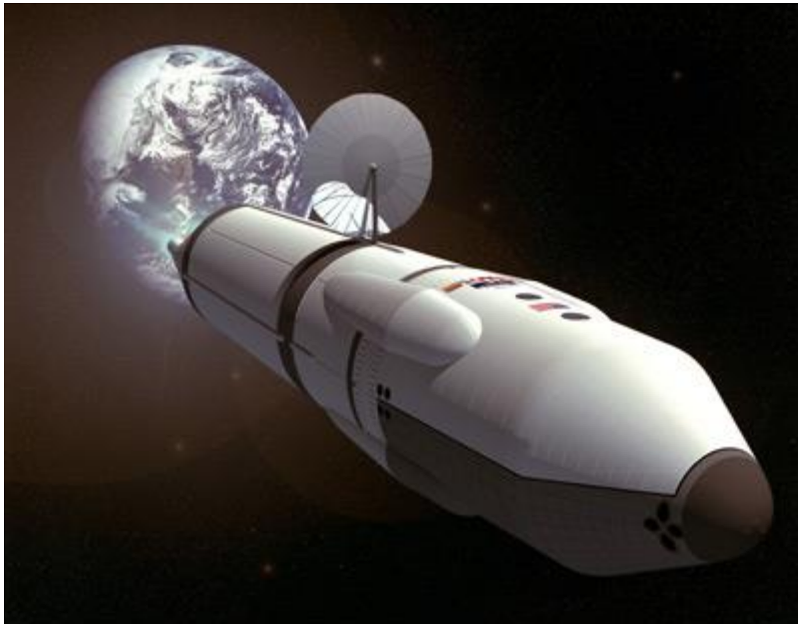
Voyager 1, 1977
119 AU

Radiation Protection





Isolation



Eating and Drinking in Space

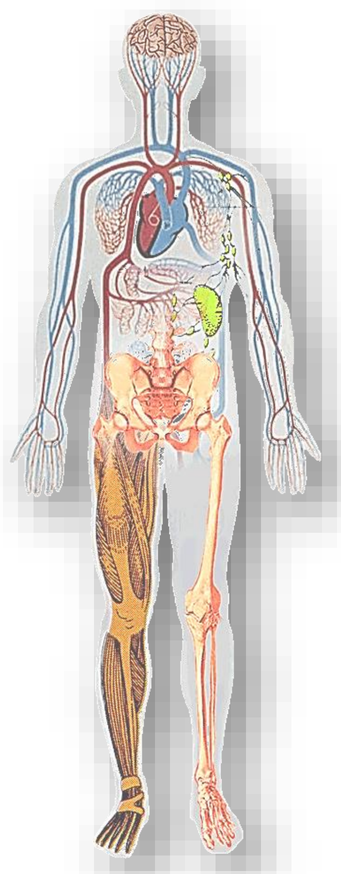
Human Spaceflight Risks Derive from Hazards

Altered Gravity - Physiological Changes

Balance Disorders
Fluid Shifts
Visual Alterations
Cardiovascular Deconditioning
Decreased Immune Function
Muscle Atrophy
Bone Loss

Distance from Earth

Drives the need for additional "autonomous" medical care capacity – cannot come home for treatment



Space Radiation

Acute In-flight effects
Long-term Cancer Risks
CNS & Cardiovascular Risks

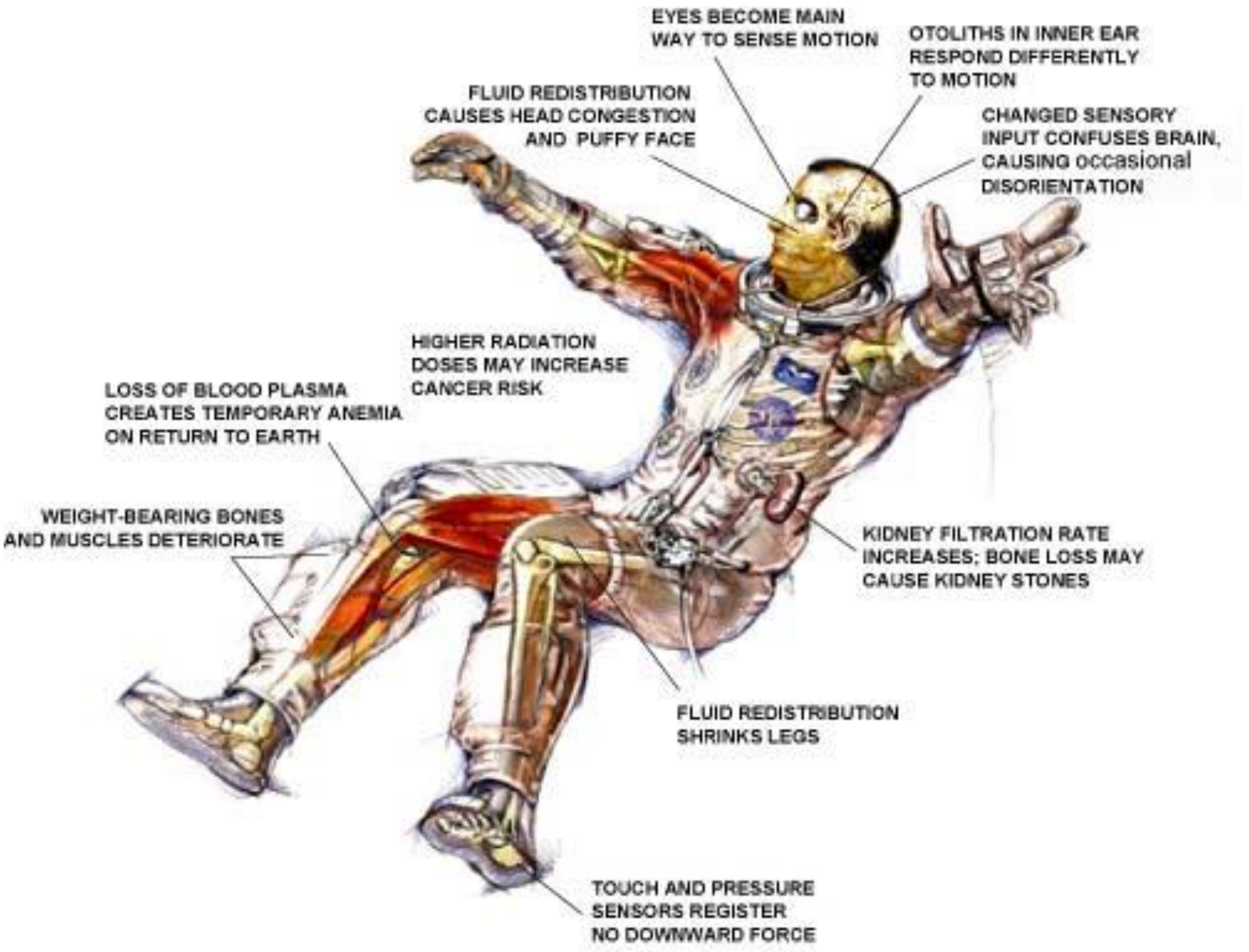
Hostile/ Closed Environment

Vehicle Design
Environmental – CO_2 Levels, Toxic Exposures, Water, Food

Isolation & Confinement

Behavioral Aspect of Isolation
Sleep Disorders

Space Physiology



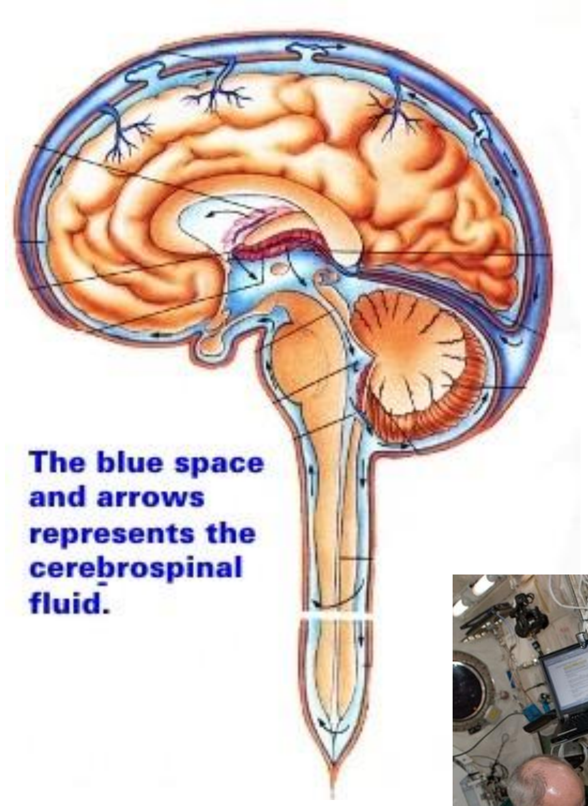
Top 3 Human Health Risks

- Visual Impairment and Increased Intracranial Pressure (VIIP)
- Bone Loss
- Radiation Exposure

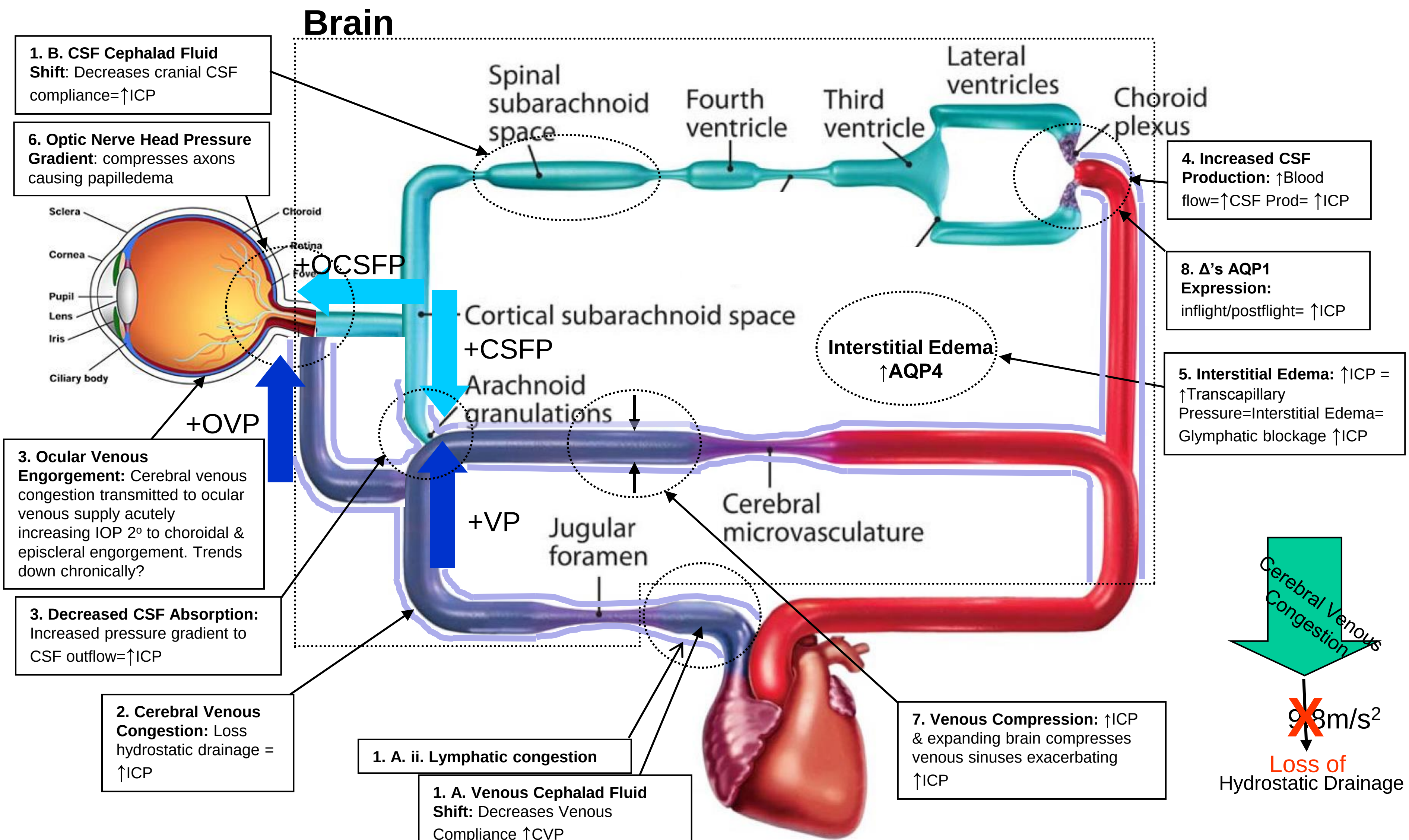
Risk vs Cost of Mitigation

Intracranial Pressure (ICP)

- This risk was "recently" found
  - First case noted in 2008
- Visual degradation and increased cerebral spinal fluid pressure found after "long duration" space flight
- Symptoms include visual disturbances after long duration space flight
- Postulated causes: microgravity fluid shift or physiologic response to increased CO_2 levels
- New assessments and research initiated



VIIP Pathophysiological Hypotheses: Vascular, CNS & Ocular



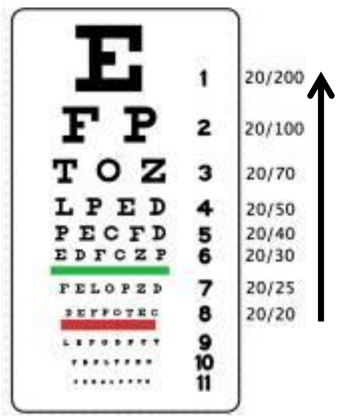
C. Otto, M.D., Lead Scientist, NASA VIIP Risk.
Image adapted from Rekate *Cerebrospinal Fluid Research* 2008 5:2

Clinical Findings

After long-duration spaceflight astronauts had findings consisting of:

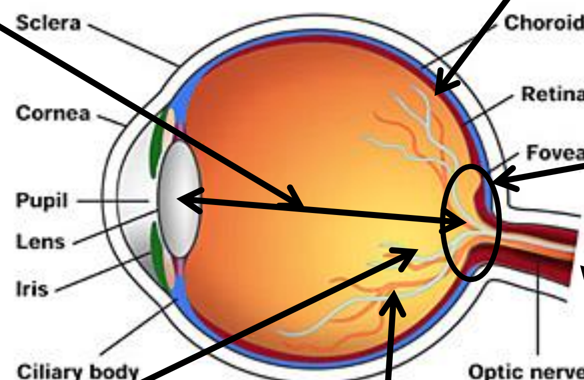
•Hyperopic Shifts

-Up to +1.75 diopters



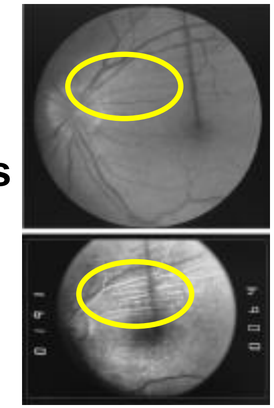
•High Intracranial Pressure

-Up to 28.5 mmHg



•Choroidal Folds

- parallel grooves in the posterior pole

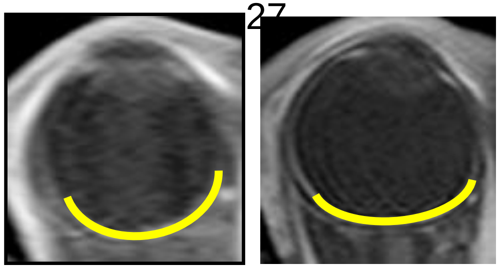


•Optic Disc Edema (swelling)

ICP

•Globe Flattening

27



Normal Globe Flatten Globe

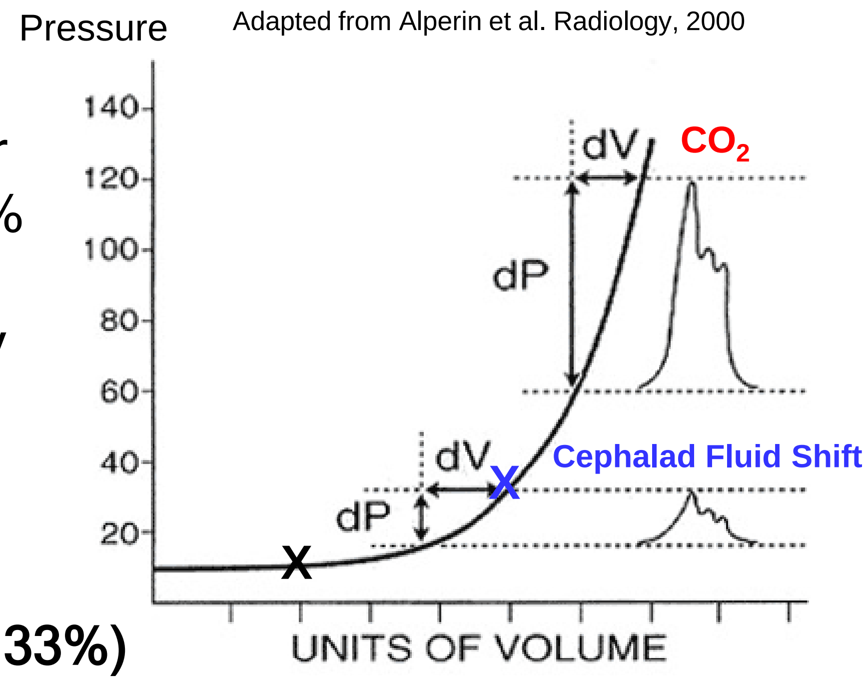
MRI Orbital Image showing globe flattening

•Altered Blood flow

•“cotton wool” spots

•Increased Optic Nerve Sheath Diameter

CO_2 Levels on ISS



- CO_2 is an extremely potent vasodilator
  - Every 1mmHg increase $PaCO_2$=4% increase in dilation
  - Cerebral blood vessels are already congested

- CO_2 mission average=3.56mmHg **(0.33%)**
  - 10x normal sea level atmospheric: **0.0314%**
  - Average Peak CO_2=8.32mmHg **(0.7%)** (20x)

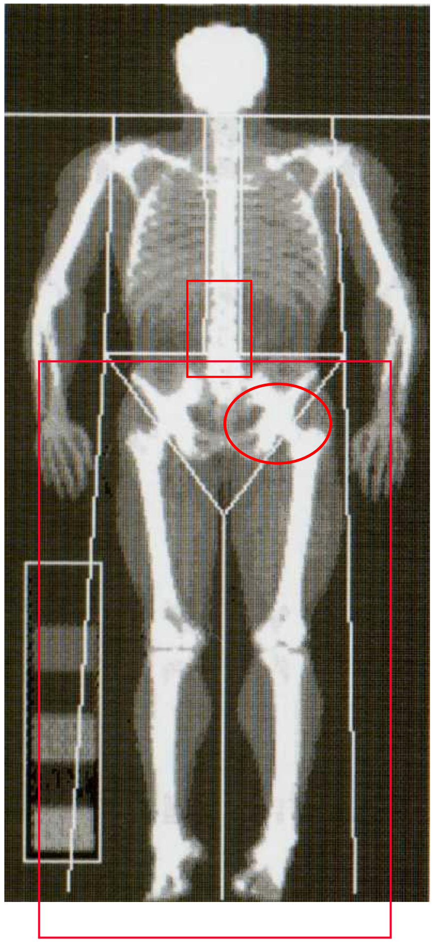
- *CO_2 also causes increased CSF production*

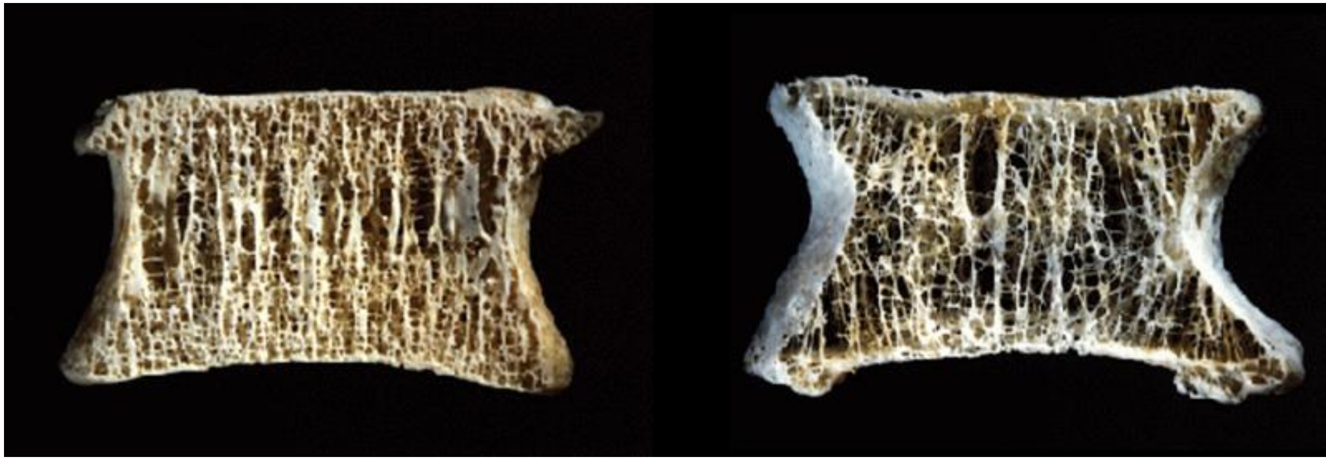
Bone Loss

- Given some parameters of skeletal adaptation may not be reversible after return to earth, there is the possibility that an early onset of osteoporosis may occur.

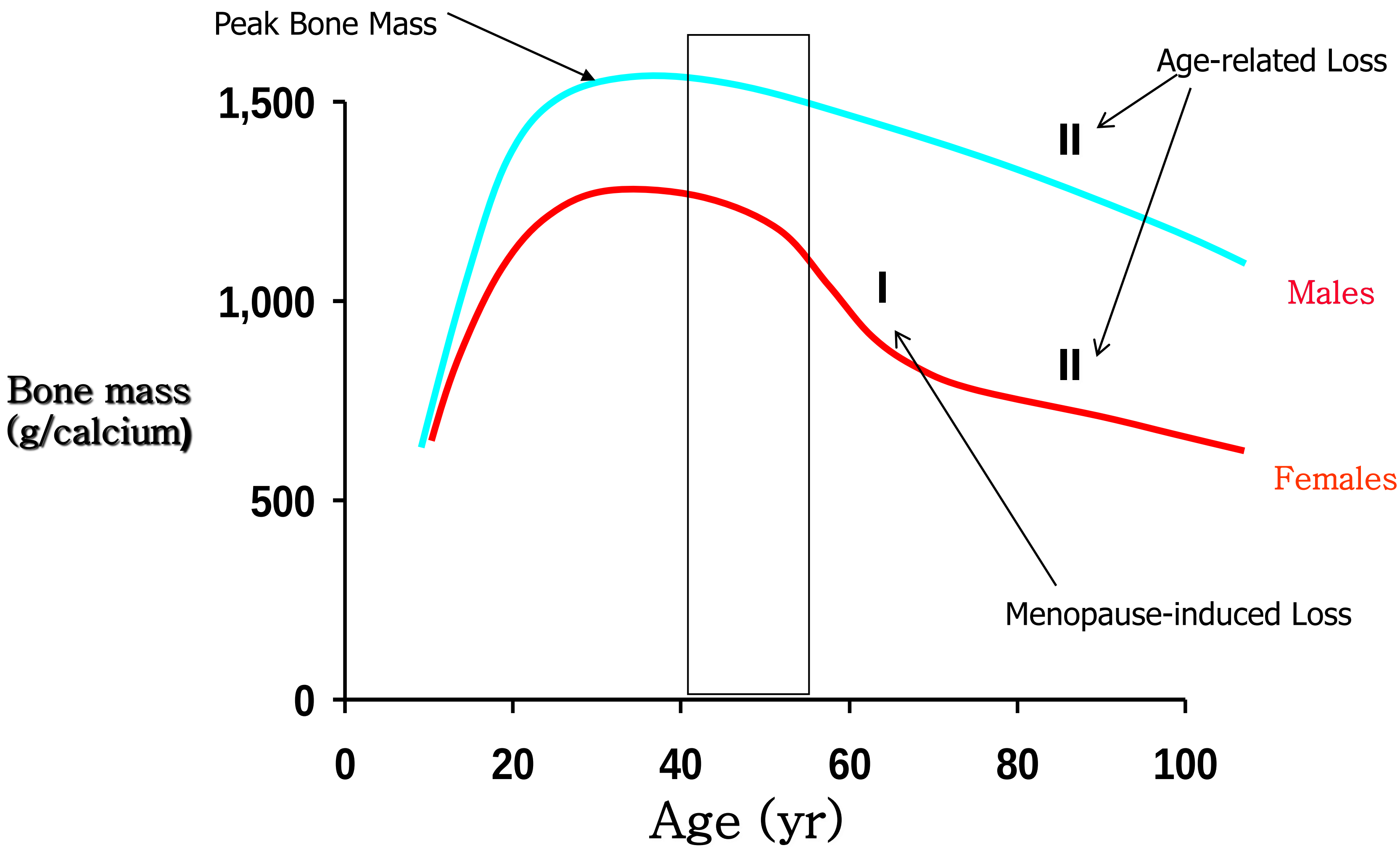
Bone Loss

- Loss of horizontal trabecular struts



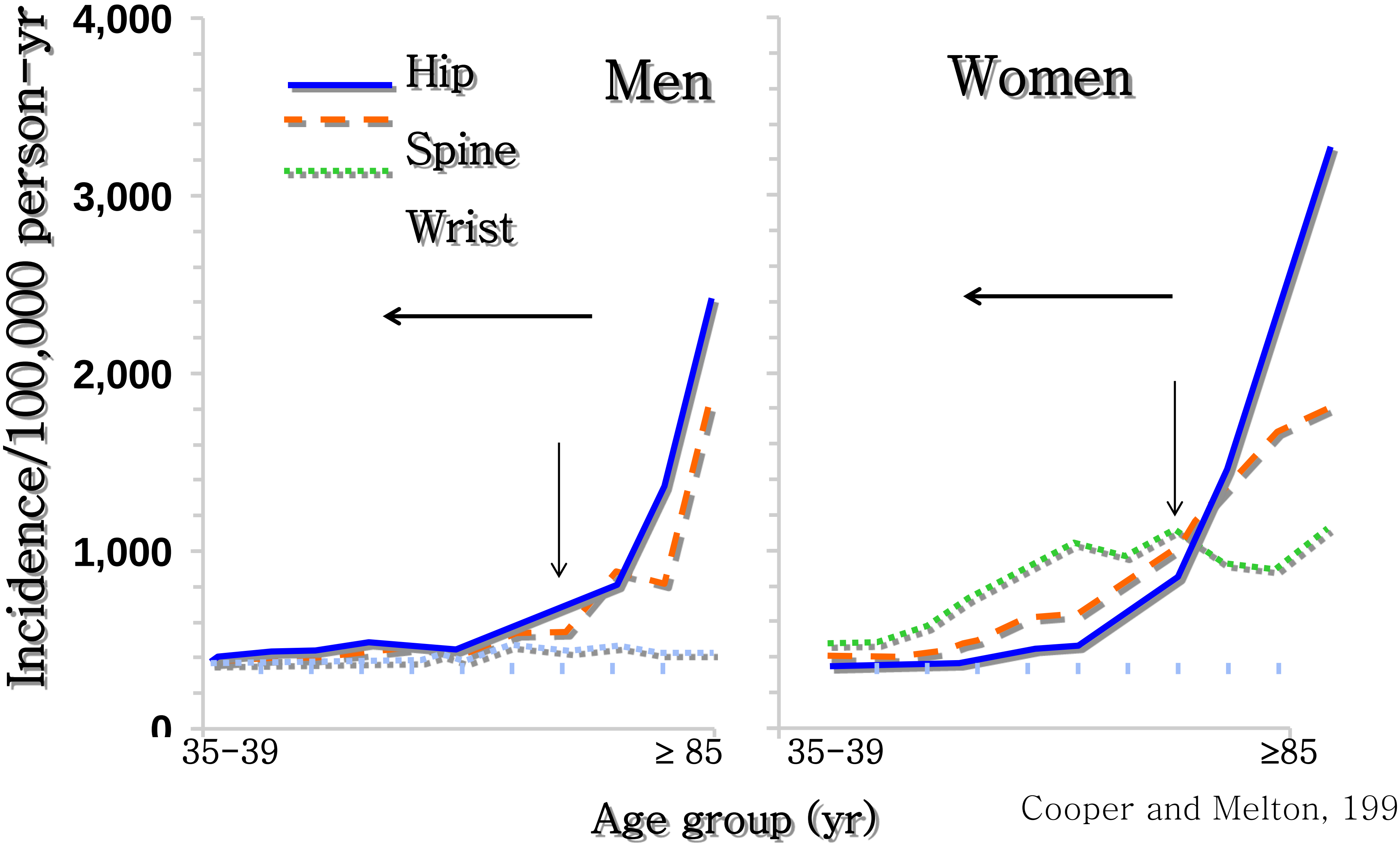


Risk/Concern Description



Riggs BL, Melton LJ: Adapted from
Involutional osteoporosis
Oxford Textbook of Geriatric Medicine
SLIDE COURTESY OF Dr. S. AMIN, Mayo Clinic

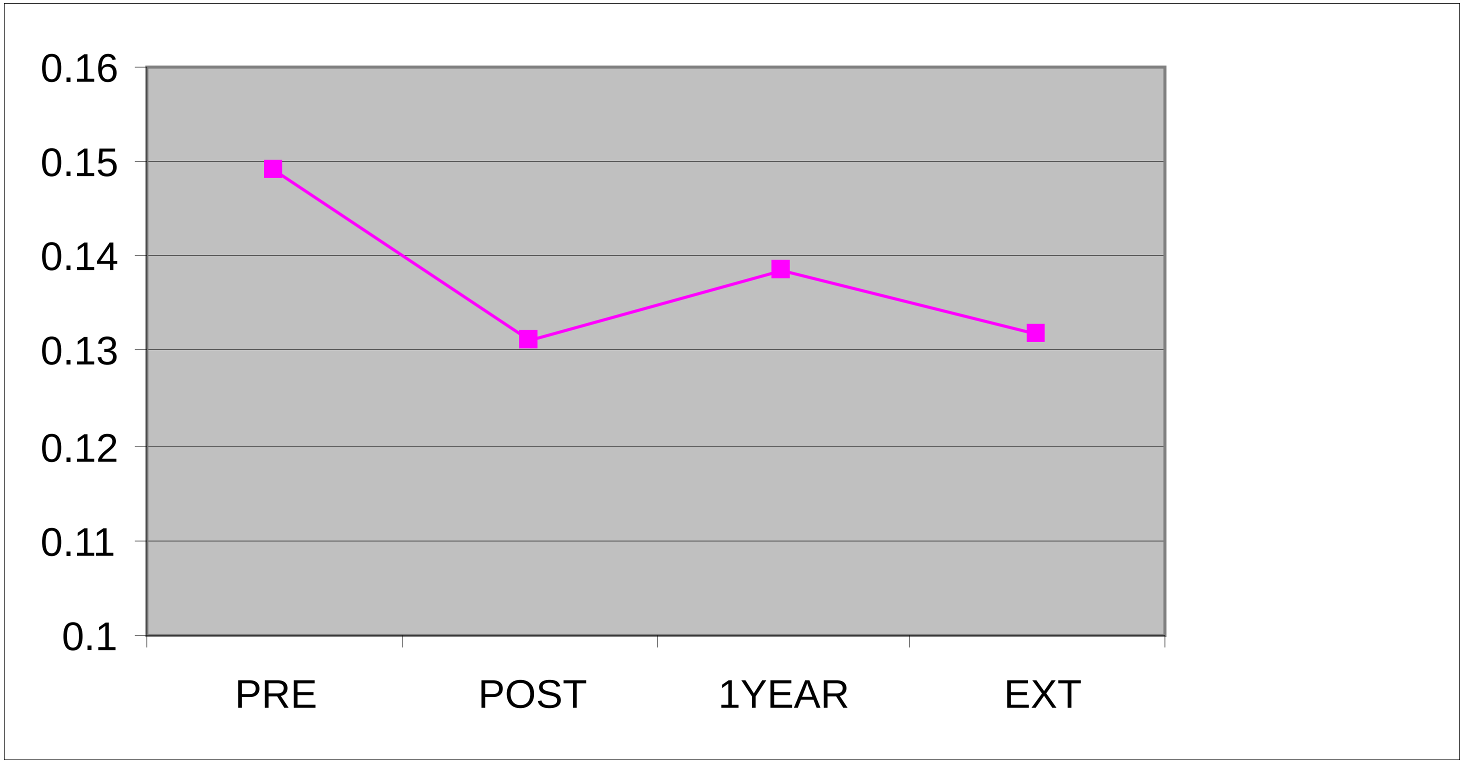
Age-Related Fractures



Cooper and Melton, 1992

SLIDE COURTESY OF Dr. S. AMIN, Mayo Clinic

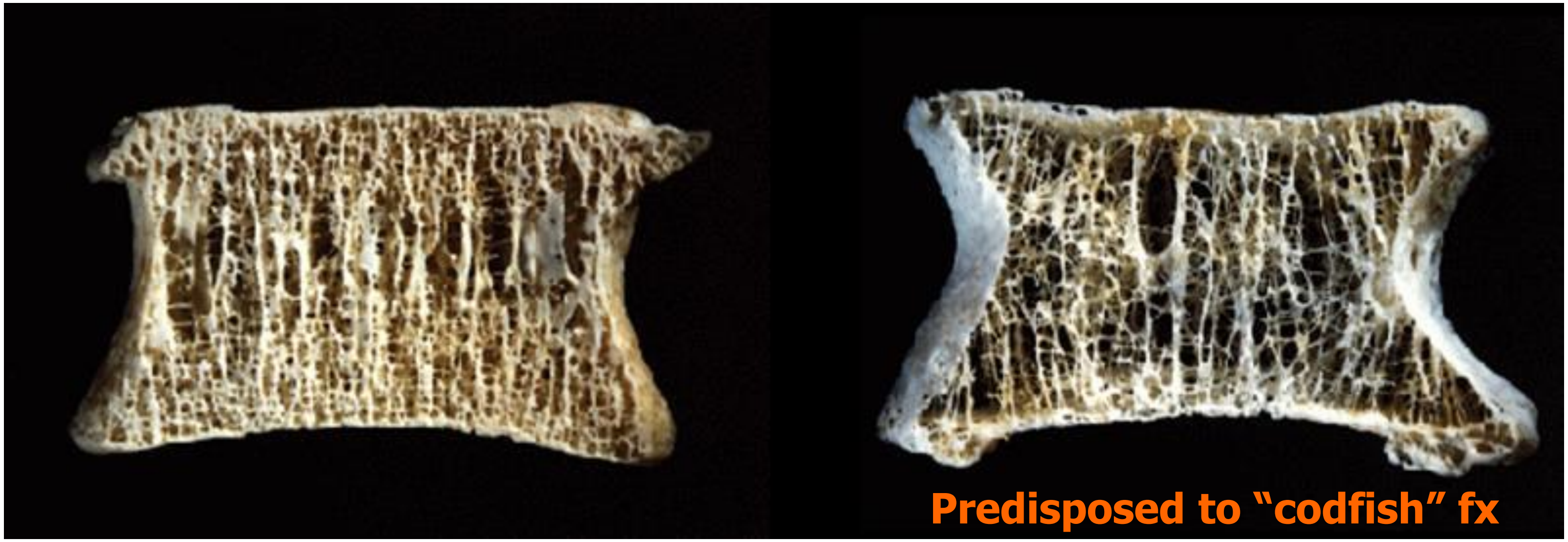
QCT: Trabecular BMD at hip does not appear to show a recovery 2-4 years postflight.



PRE: n= 16 POST: n= 16 1 YEAR: n=16 EXT: n=8

QCT Extension Study (n=8) Postflight Trabecular BMD in hip. Carpenter, D et al. Acta Astronautica, 2010.

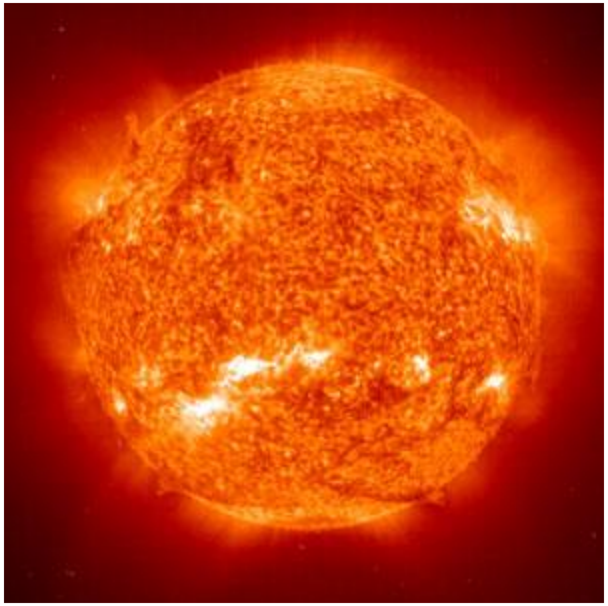
What is the impact of Trabecular Bone Loss on whole hip bone strength?



- Impact on hip, on its microarchitecture UNKNOWN*
- Knowledge base: Vertebral trabecular bone loss with menopause.
- Loss of horizontal trabecular struts and directionality , perforation of trabeculae*, reduction in mechanical strength, and increase in fracture risk (Mosekilde, 2000; Seeman, 2002, Silva 1997; Kleerekoper 1985)

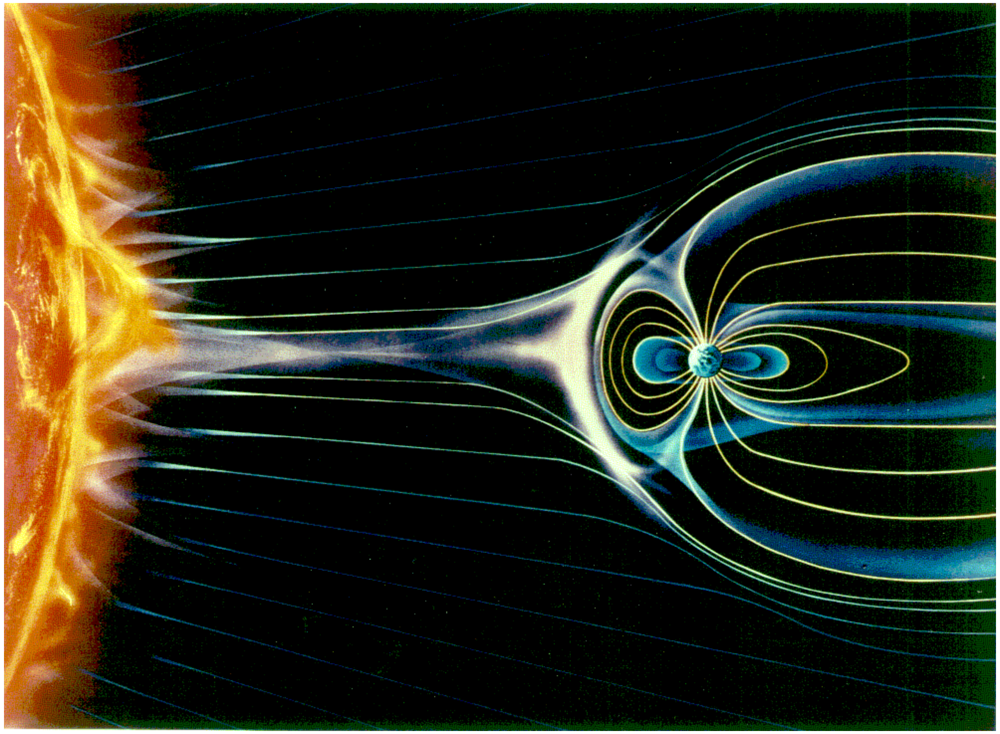
Radiation Risk

- **Risk Statement**
  - **Given that crewmembers are exposed to radiation from the space environment, there is a possibility for increased cancer morbidity or mortality**



Radiation

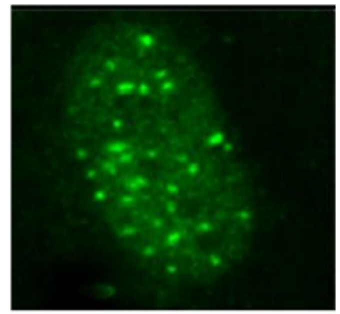
- **Space radiation is a major challenge to exploration:**
  - **Risks are high…potentially limiting mission length or crew selection**
  - **Large mission cost and uncertainties to protect against risks**
  - **New findings may change current assumptions**

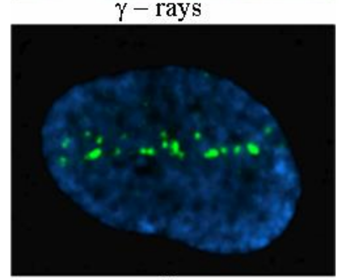


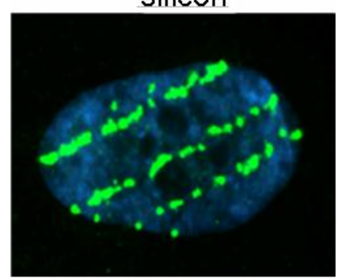
Categories of Radiation Risk

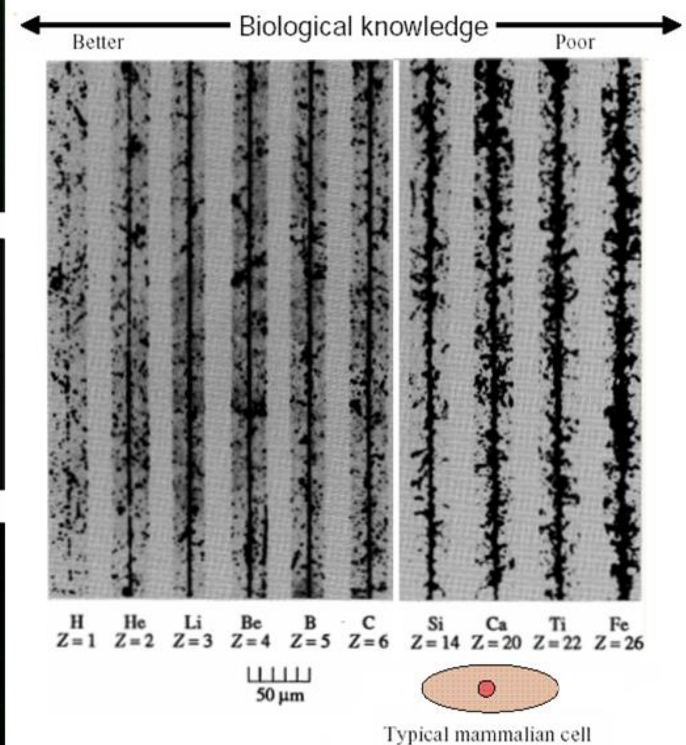
- ***Cancer***
- ***Acute and Late Central Nervous System (CNS) risks***
  - ✓ **Immediate or late functional changes**
- ***Chronic & Degenerative Tissue Risks***
  - ✓ **Cataracts, heart-disease, etc.**
- ***Acute Radiation Sickness***
  - ✓ **Prodromal risks**

Differences in biological damage of heavy nuclei in space with x-rays, limits Earth-based data on health effects of heavy ions


γ – rays

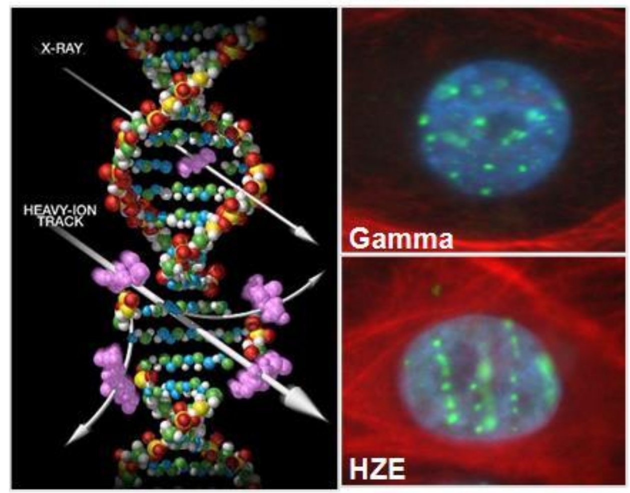

silicon


iron



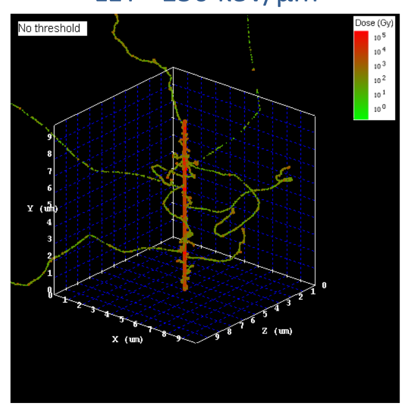
The Space Radiation Problem

- **Interplanetary crews will be exposed to a high LET radiation environment comprised of high-energy protons and heavy ions (HZE's) as well as secondary protons, neutrons, and fragments produced in shielding and tissue**
- **Heavy ions are qualitatively different from X-rays or Gamma-rays: High LET vs. low LET**
  - **Densely ionizing along particle track**
  - **Cause unique damage to biomolecules, cells, and tissues**
  - **Distinct patterns of DNA damage (mutation spectra, chromosome aberrations) and distinct profiles of oxidative damage**
- **No human data exist to estimate risk from heavy ions found in space**
  - **Animal and cellular models with simulated space radiation must be applied or developed**
- **Synergistic modifiers of risk from other spaceflight factors**



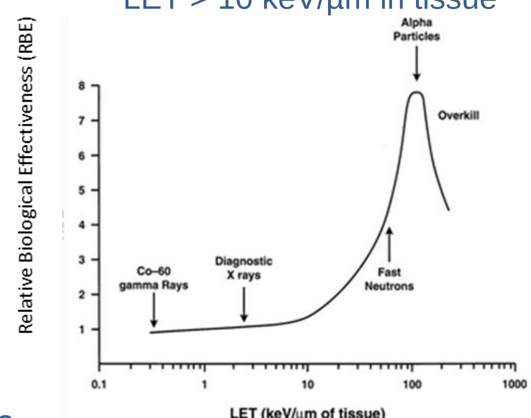
DNA Damage
γH2AX foci in EPC2-hTERT cells.
(Patel and Huff)

1 GeV/u ^{56}Fe nucleus
LET~150 keV/µm



Qualitative differences due to track "core" and correlated tissue damage along a particle path. (Plante, 2011)

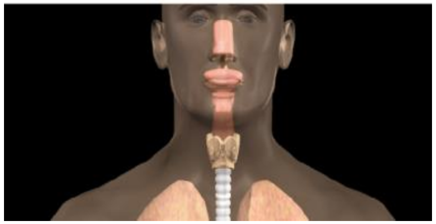
High LET defined as
LET > 10 keV/µm in tissue



Space Radiation Risks

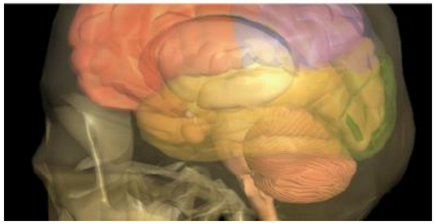
Risk of Radiation Carcinogenesis

- **Morbidity and mortality risks**



Risk of Acute (in flight) & Late Central Nervous System Effects

- **Possible in-flight risks: altered cognitive function including short-term memory, reduced motor function, and behavioral changes which may affect performance and human health**
- **Possible late (post-mission) risks: neurological disorders such as Alzheimer's disease (AD), dementia, cerebrovascular disease or premature aging**

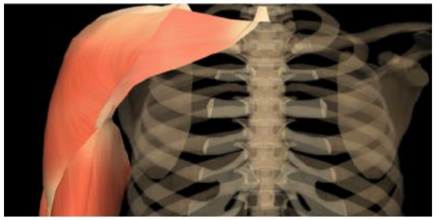


Risk of Cardiovascular Disease and other Degenerative Tissue Effects

- **Degenerative changes in the heart, vasculature, and lens**
- **Diseases related to aging, including digestive, respiratory disease, premature senescence, endocrine, and immune system dysfunction**

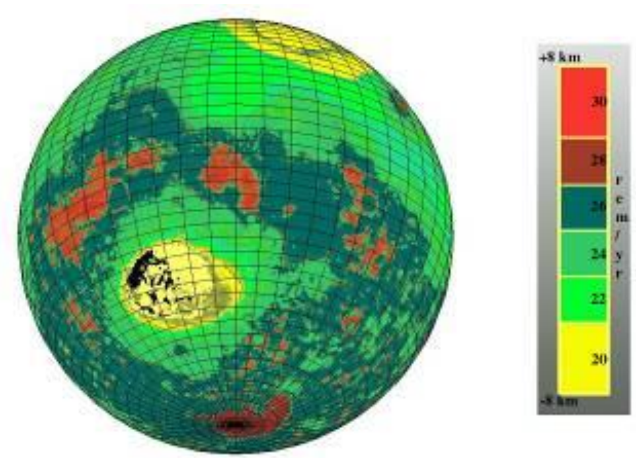
Risk of Acute Radiation Syndromes due to Solar Particle Events

- **Prodromal effects (nausea, vomiting, anorexia, and fatigue), skin injury, and depletion of the blood-forming organs**



Why space radiation research?

- **Astronauts on the International Space Station approach limits for acceptable radiation risks after 1 to 3 missions**
- **Acceptable levels of risk can be approached or exceeded for Lunar habitat missions after 4-7 months**
- **Acceptable levels of radiation risk are exceeded for all current Mars Mission Designs**



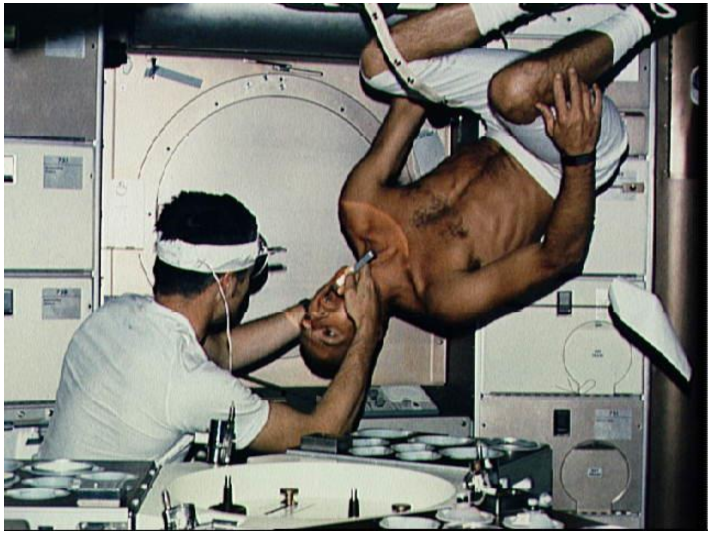
GCR doses on Mars

Doctors versus Engineers

- **Are humans the reason for the space program, or an inconvenience to the program?**

Human Systems Integration: The Health Care Professional's Perspective

- **Language Gap**
- **The importance of Human Systems Integration is a lesson that gets relearned over and over again**
- **Health professionals and engineers speak different technical languages**
- **Consistent HSI success occurs when health professionals understand and correctly communicate with engineers using "requirements"**



Human Factors

- **Results:**
  - **Tough lessons relearned**
    - **Frequently noted in mishap reports**
  - **Human factors being considered after the hardware was developed**
    - **Past aircraft and today's spacecraft have similar HSI short comings**

Conclusion

- **HSI is prevention**
- **Early HSI consideration saves**
- **Human health risks may be mission limiting, given current technology**

- **Solutions for the risks of long duration space flight**
- **We just need to solve the “big three”**
  - **Non-chemical based propulsion**
  - **Control gravity**
  - **Active Shielding for radiation**

Space Technologies

- **Wireless Devices**
  - **Hospital Telemetry Systems**
- **Infrared Thermometers**
- **Cordless Tools**
- **Dehydrated food…and ice cream too.**

- **Space program has inspired thousands students to go into Math and Engineering**

Questions