SPACE MEDICINE: A SHORT GUIDE FOR FUTURE PRACTIONERS

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NLM/NIH/HHS

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OUTLINE

- Space medicine defined
- The Environment of Exploration
- Effect of the Environment on Health
- Protecting Crews on Long duration Missions
- Search for Life
- Future of Space Medicine

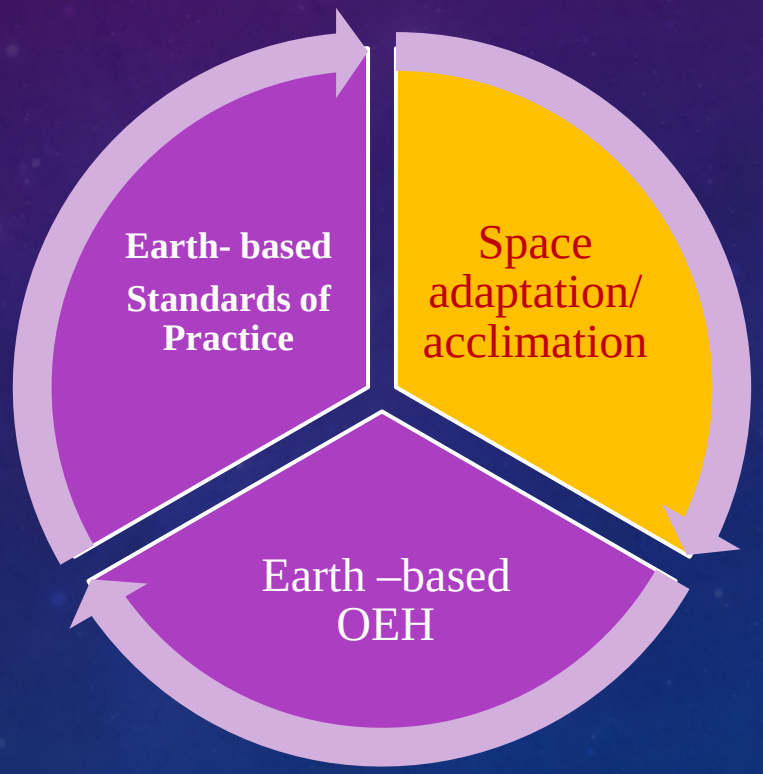
LEARNING OBJECTIVES

1. Recognize issues surrounding the safety, security and health of space travel
2. Identify policies, knowledge gaps and practices aimed at improving the operational safety and health of space crews

Bernardino Ramazzini (3 November 1633 – 5 November 1714), noted the futility of treating chronic disorders in sailors in long sea voyages

SPACE MEDICINE: WHAT IS IT?

[LIVING AT THE CUSP OF DISASTER: PREDICTING AND PROTECTING AGAINST THREATS]



Role of Technology

1. Enable
2. Protect
3. Creates health risks

SOCIO CULTURAL MOMENTS IN SPACE

Improving morale, providing psycho-social support, team work

INFLIGHT

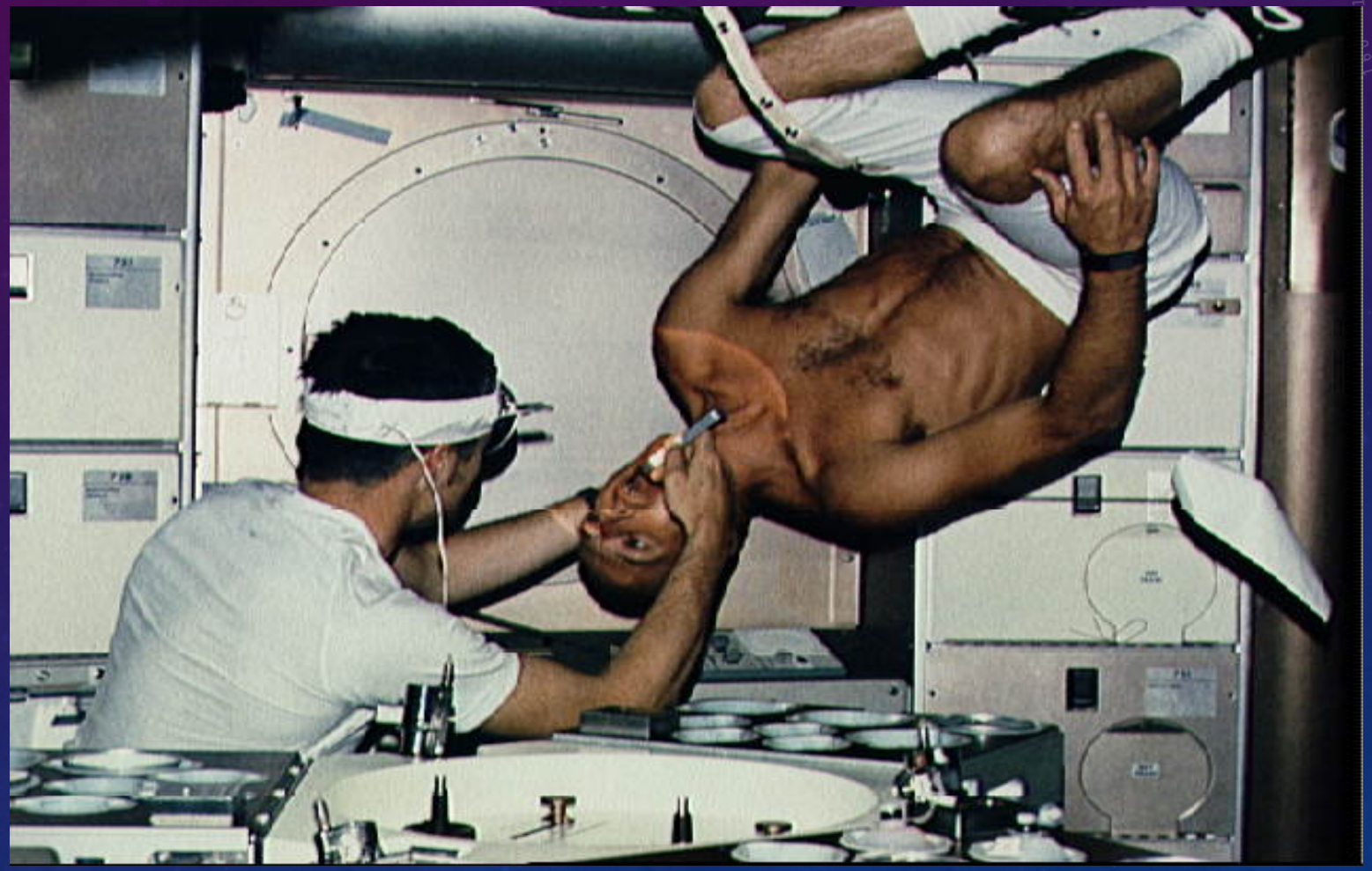
Preflight

Preflight

ASTRONAUT
SANDRA H.
MAGNUS, STS-112
MISSION SPECIALIST

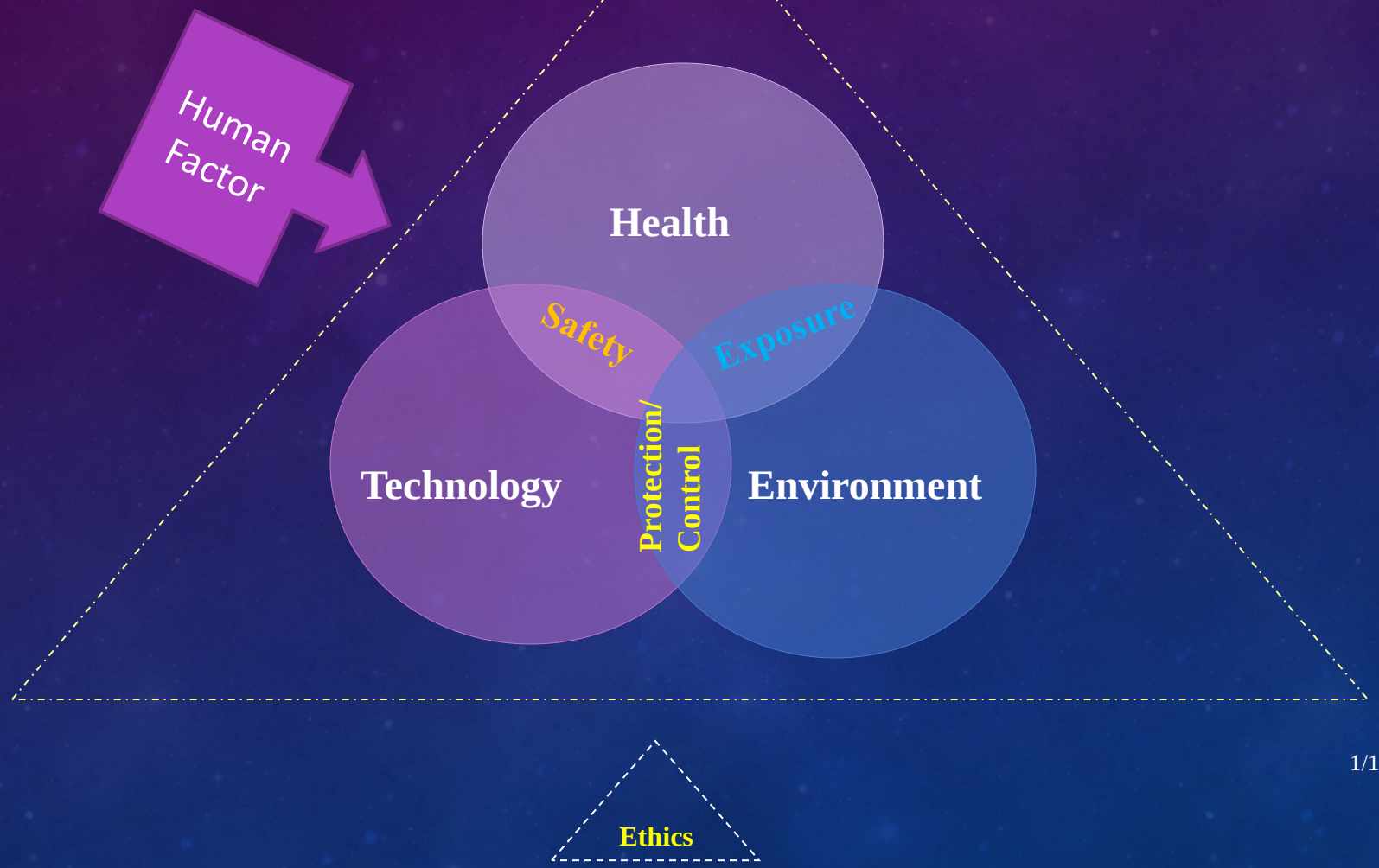
Inflight

SKYLAB DENTAL EXAMINATION



FOOT EXPERIMENT - ASTRONAUTS MICHAEL FOALE, EXPEDITION 8, AND KEN BOWERSOX, EXPEDITION 6, BOTH NASA ISS SCIENCE OFFICERS AND ATTIRED IN INSTRUMENTED BIKING TIGHTS, PARTICIPATE IN AN EXPERIMENT IN THE DESTINY LABORATORY. THE LOWER EXTREMITY MONITORING SUIT, THE CYCLING TIGHTS OUTFITTED WITH 20 SENSORS, MEASURE FORCES ON FEET AND JOINT AND MUSCLE ACTIVITY

HEALTH RISKS AND HAZARDS STEM FROM LACK OF EVIDENCE BASED POLICIES, HUMAN ERRORS, TECHNOLOGY AND ENVIRONMENTAL EXPOSURES



AS OF JANUARY 2015

Space Travelers

- Total Space Flight Time: **128** crew-years
- Individuals in space 575

[Astronauts and Cosmonauts]

Men 512

Women 63

- Space Tourists 10

Mortality

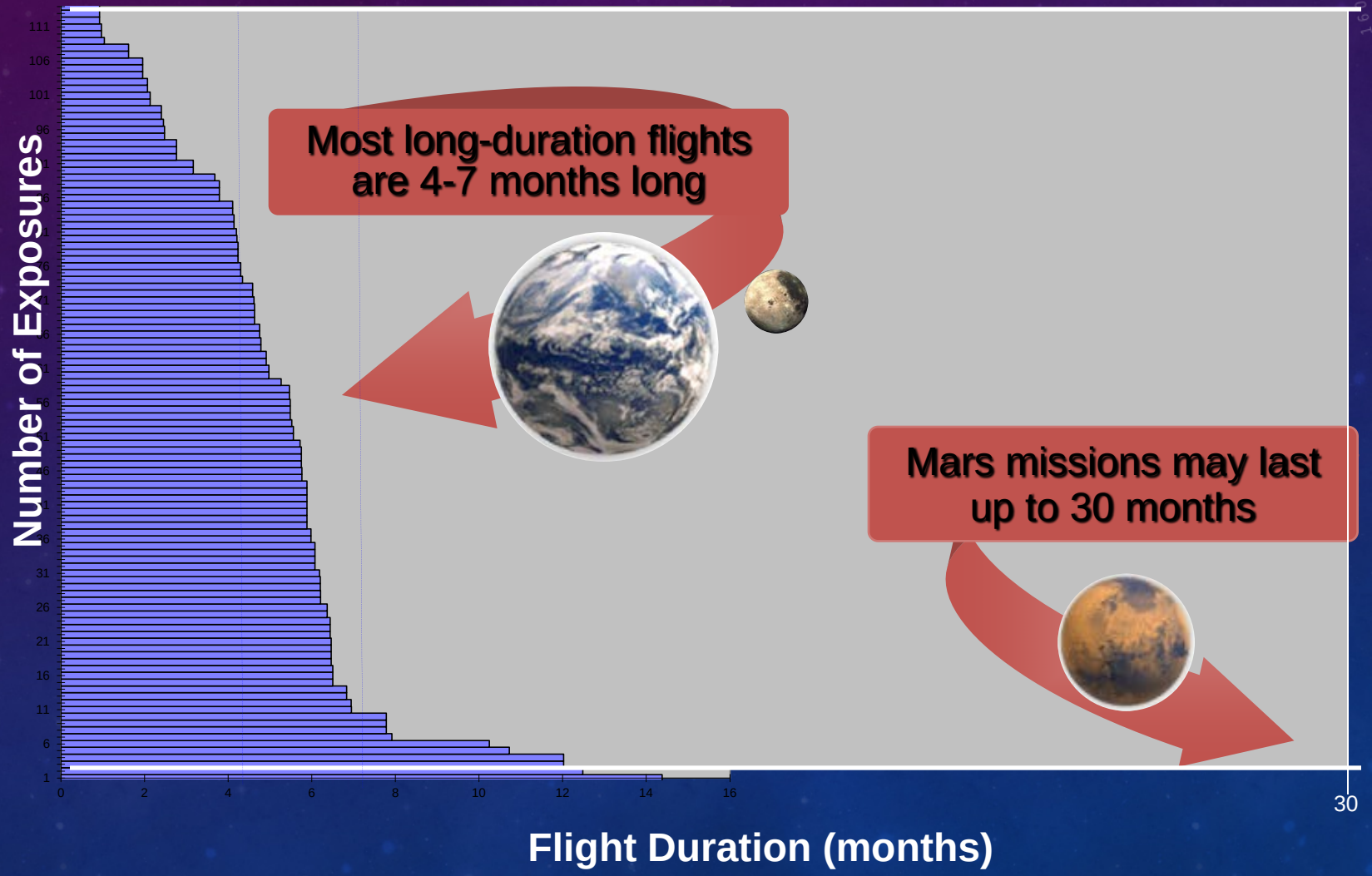
- Accidents
  - Non-Space 21
  - In- Space 15
- Medical Conditions 105 [not related to space flight]

CURRENT STATUS AS OF 2014

Astronaut Status	Number
Selected	339
Active	43
Retired	226
Management	34
Deceased	56
Flown	346

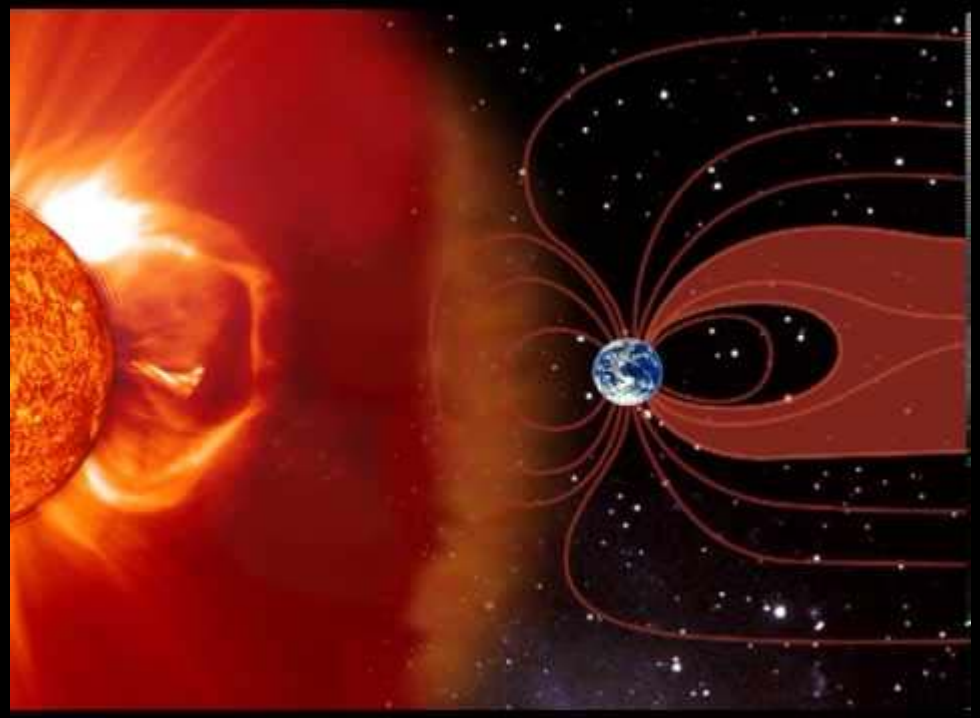
SPACE FLIGHT EXPERIENCE (CONTINUOUS)

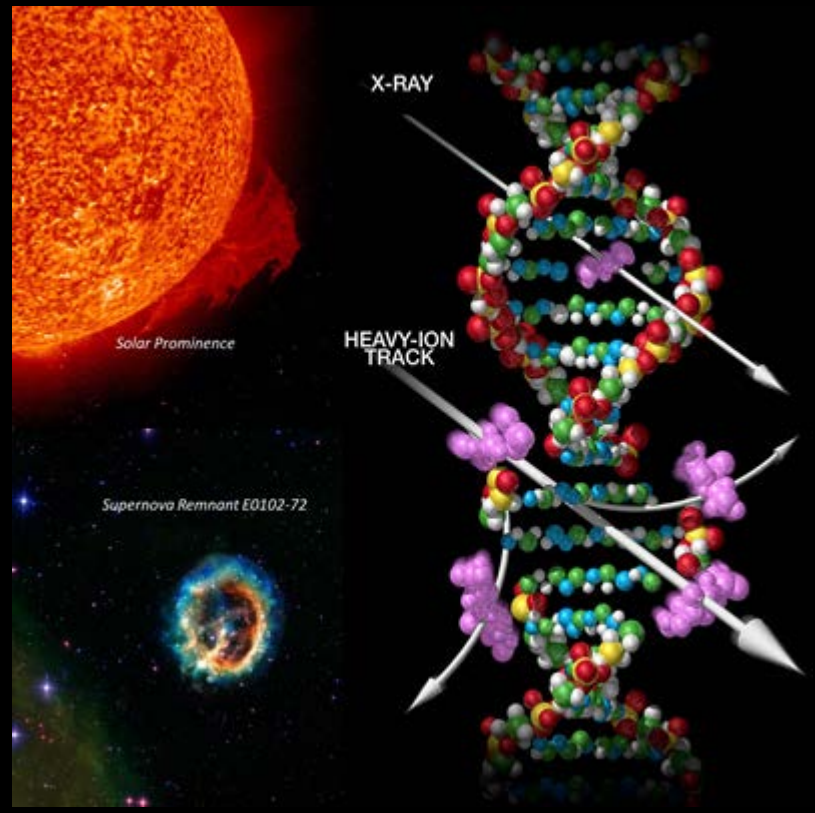
Flights longer than 28 days



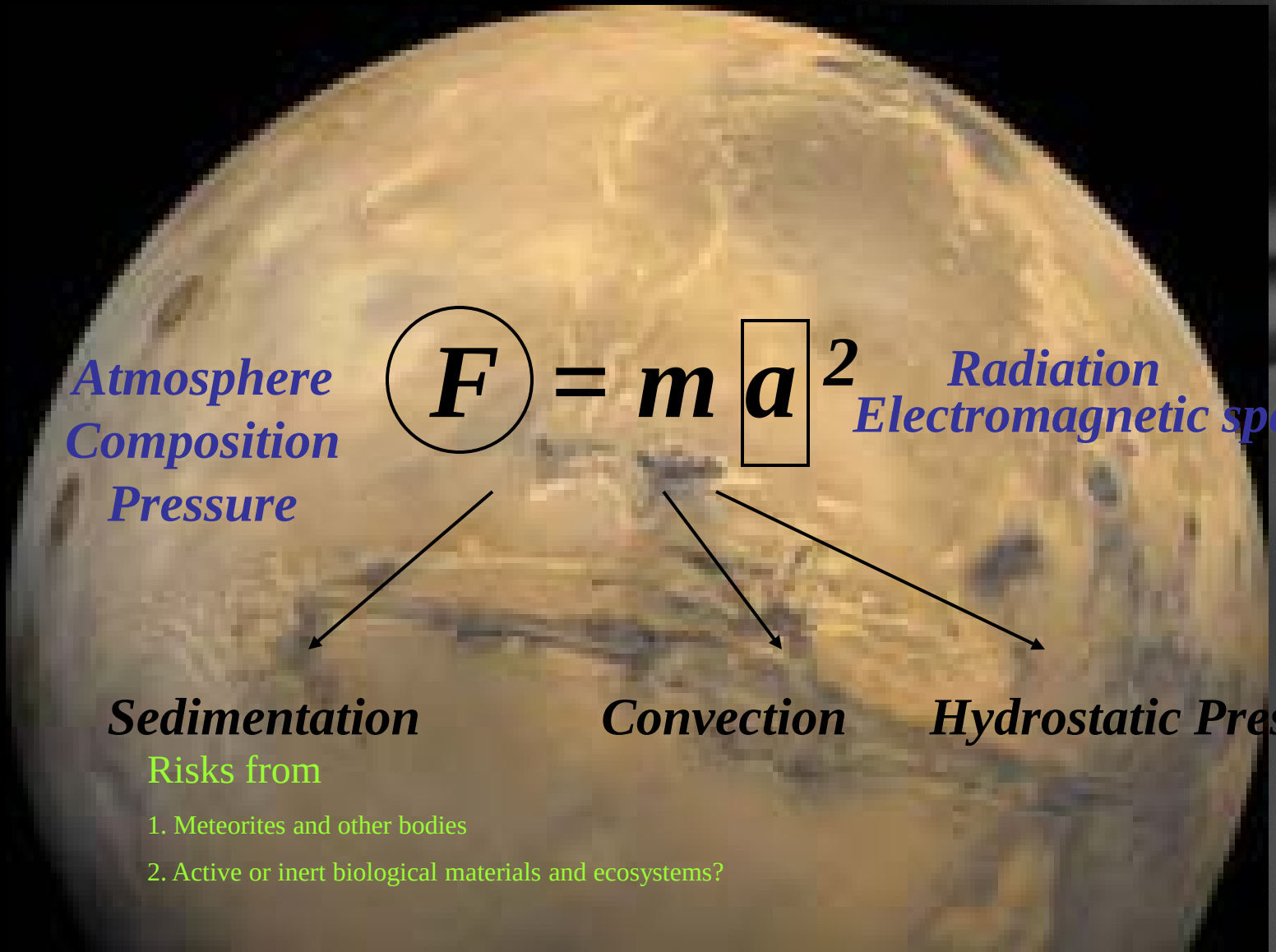
Calling Earth
Mercury
5-12 min.
57 million km
Venus
2-15 min.
26 million km
Jupiter
34-52 min.
391 million km
Saturn
71-88 min.
795 million km
Uranus
151-168 min.
1693 million km
Neptune
241-259 min.
2706 million km
Pluto
320-337 min.
3573 million km
Mars
4-22 min.
49 million km
* Mean distances from Earth

Radiation Environment





The Physical Environments of Space



Atmosphere
Composition
Pressure

$$F = m a^2$$

Radiation
Electromagnetic spectrum

Sedimentation ***Convection*** ***Hydrostatic Pressure***

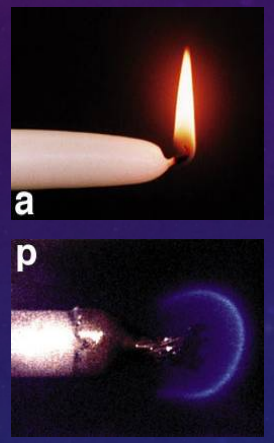
Risks from

1. Meteorites and other bodies
2. Active or inert biological materials and ecosystems?

ATTRIBUTES OF SPACE

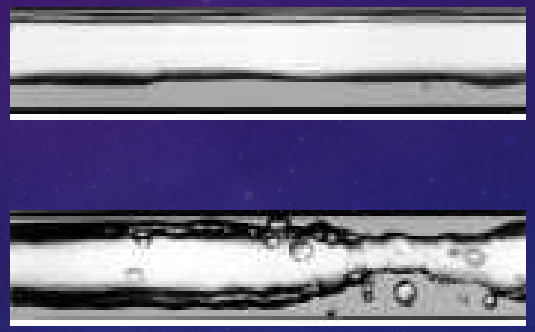
In microgravity, there is no…..

Convection



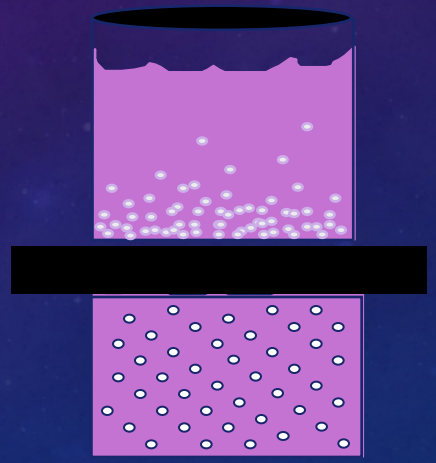
A candle burns on Earth (top) & in microgravity (bottom).

Buoyancy



Fluid flows through a pipe in Earth's gravity (top) and in microgravity (bottom).

Sedimentation



On Earth, particulates settle out of a liquid (top), but in space, particulates are suspended evenly (bottom).

Removal of the Gravity Gradient

ACUTE RESPONSE

- Fluid Redistribution and loss
- Neurosensory
- Tissue deformation

ADAPTIVE RESPONSE

- Cardiopulmonary
- Hematological
- Neurosensory

CHRONIC RESPONSE

- Musculoskeletal
- Endocrine
- Immune
- Cellular damage

SYMPTOMS

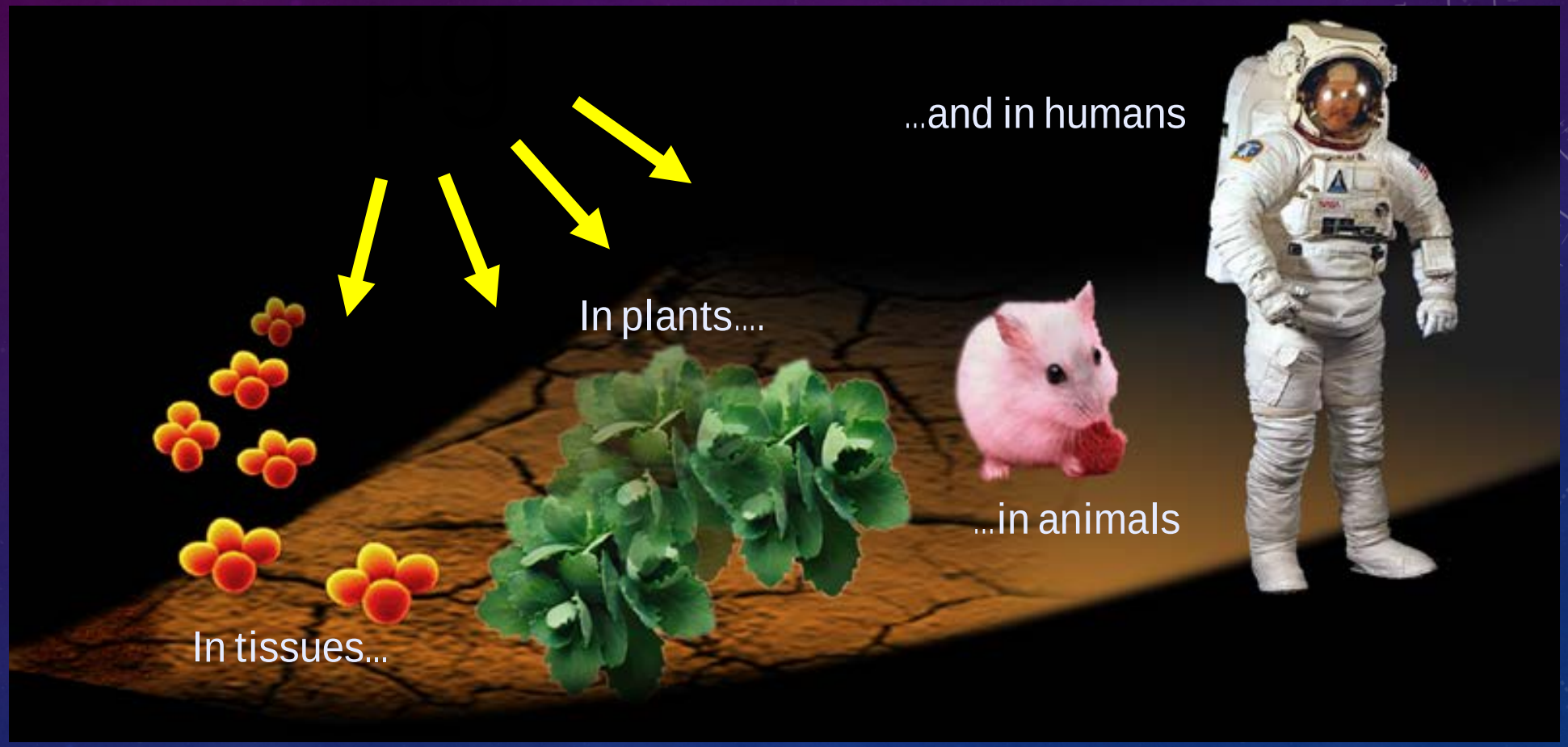
1. Space Motion Sickness
2. Upper body tissue swelling and congestion
3. Visual problems
4. Headaches and lumbar pain
5. Post flight dehydration, orthostatic intolerance & ataxia

RISKS

- Muscle, Bone, and Joint injury or damage
- Renal stones
- Infections
- Metabolic Syndrome
- Stochastic and/or deterministic carcinogenesis
- Optic disc edema

Physical Effects of Reduced Gravity * (< g = 9.81 m/s^2 = 32.2 ft/s^2)	Physiological/Biological Consequences	Clinical Significance (*reported and observed*)
Acceleration Forces **(a=[1/m]F or F=ma)** **Loss of** 1. *Buoyancy and* 2. *Hydrostatic pressure-gradient*	1. Cephalad fluid shifts 2. Fluid extravasation into tissues 3. Changes in the circulatory patterns affect lower extremities vascular compliance 4. Possible increased intra-cranial and ocular pressures 5. Altered neuro-sensory threshold (<0.01g) perception 6. Increased neuro-vestibular synapses in rodents 7. Tissue deformation, and 8. Cellular shape and function (cytoskeleton and extra-cellular matrix) changes	1. Headaches 2. Nasal congestion 3. Altered sense of taste 4. Impaired intestinal absorption (bolus contact with cell villi) 5. Hormone secretion and receptor function 6. "Space anemia" due to reduced production of Rbcs and decrease iron uptake by erythroblasts 7. "Space motion sickness", post flight orthostatic intolerance and postural control/balance (ataxia) 8. Changes in baroreceptor control of heart rate and blood pressure 9. Increased physical/contact injuries 10. Loss of muscle slow-twitch fibers 11. Loss of bone mass/matrix
Sedimentation	1. Change in food and medication absorption, distribution and elimination (aerosols and solutions) 2. Changes in taste	1 Diagnostic tests such as ESR 7 lipid layers not possible 2 Reduced medication efficacy
Convection	1. Heat dissipation 2. Sweat evaporation 3. Perception of temperature in lower extremities	1. Impaired thermal regulation 2. Decreased physical exercise/endurance 3. Combustion localized, life support will affect fire spread, safety and respiration

COMMON PROCESSES



subcellular, cellular ... complex biological structures, processes, and development

ADAPTATION/ACCLIMATION

Adaptive

Pathological

Neurosensory & Neuromotor

Cardiovascular/
Pulmonary

Endocrine

Musculoskeletal

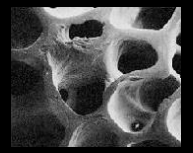
Radiation

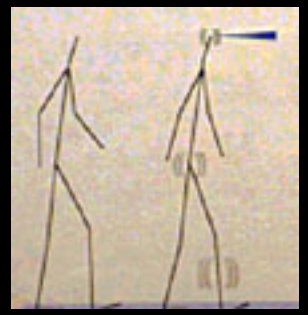
Confinement

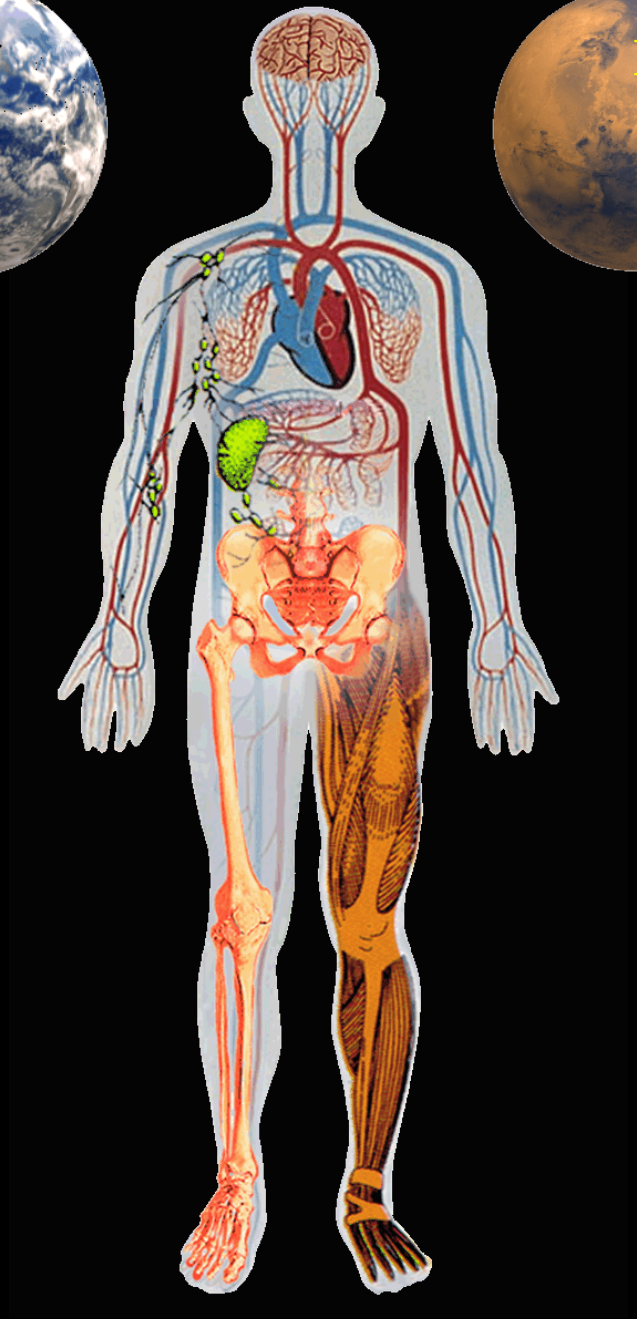
parallels with aging…

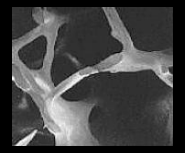
Earth Physical Conditioning

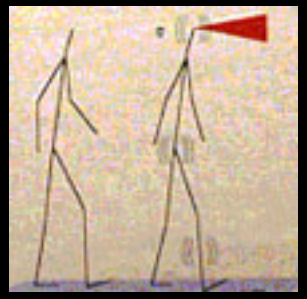
Lost on the Trip to Mars

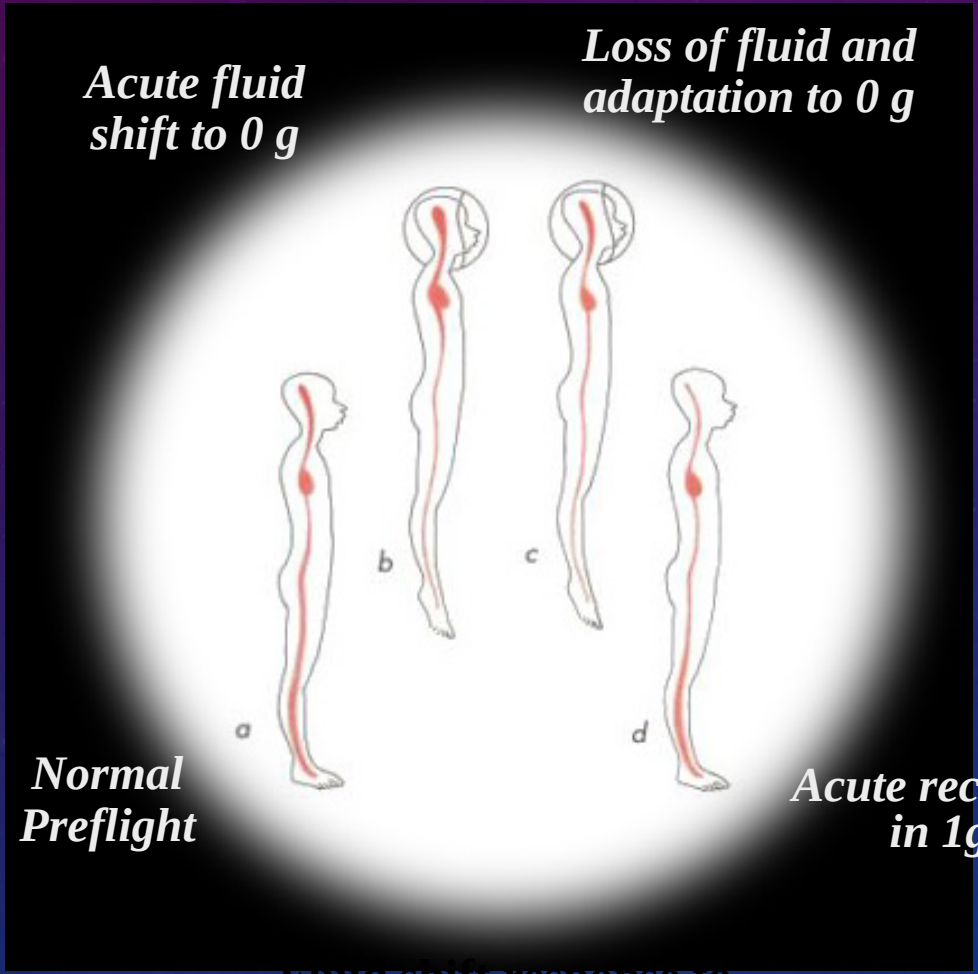




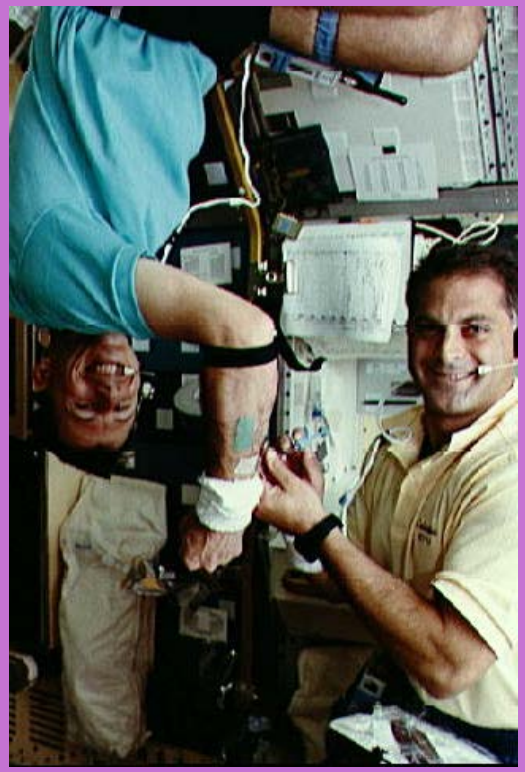






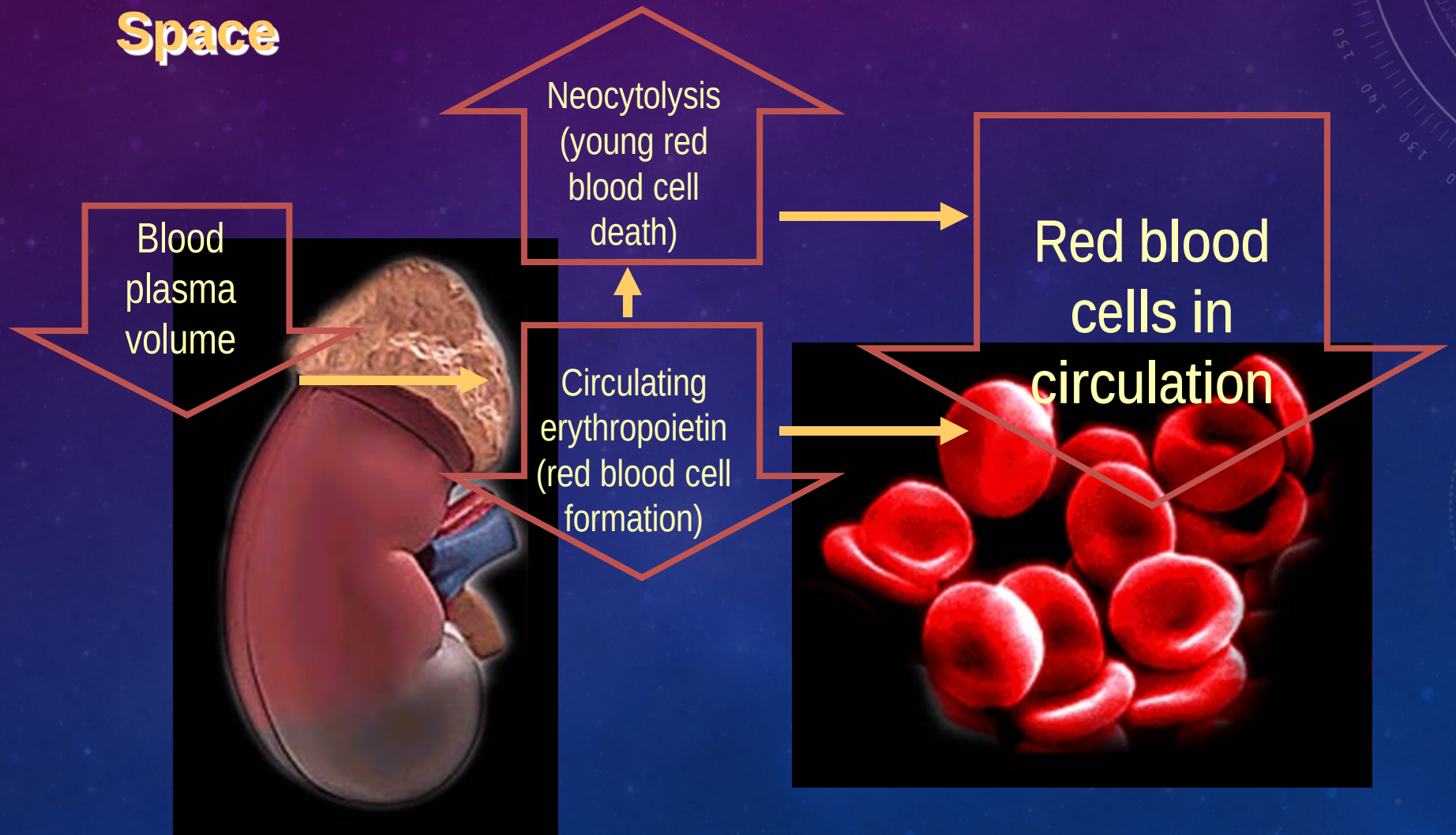


Fluid shift response to microgravity exposure

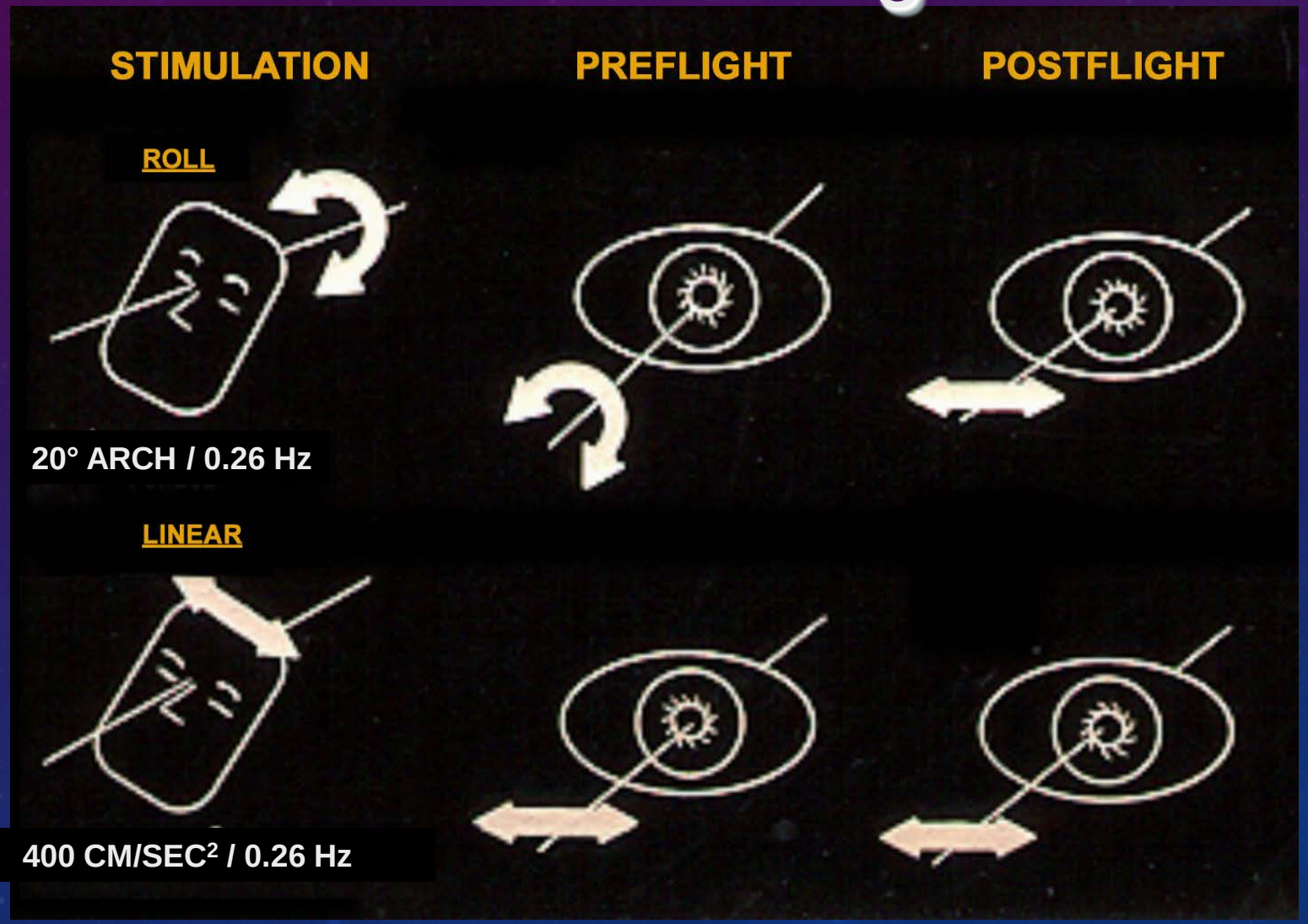


Samples were collected to study fluid volume regulation mechanisms

Red Blood Cell Response

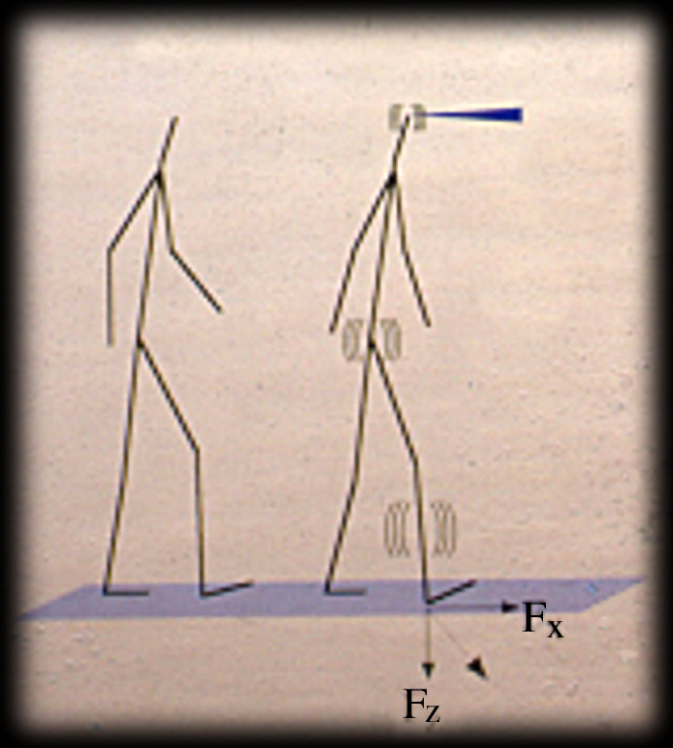


CNS Motion Perception
Parallel Swing

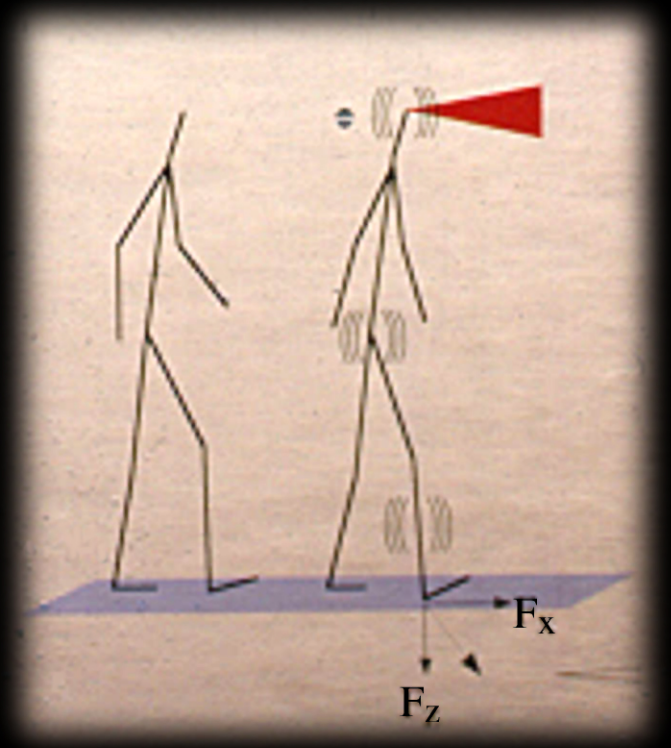


Locomotion and Head/Gaze Control

Preflight

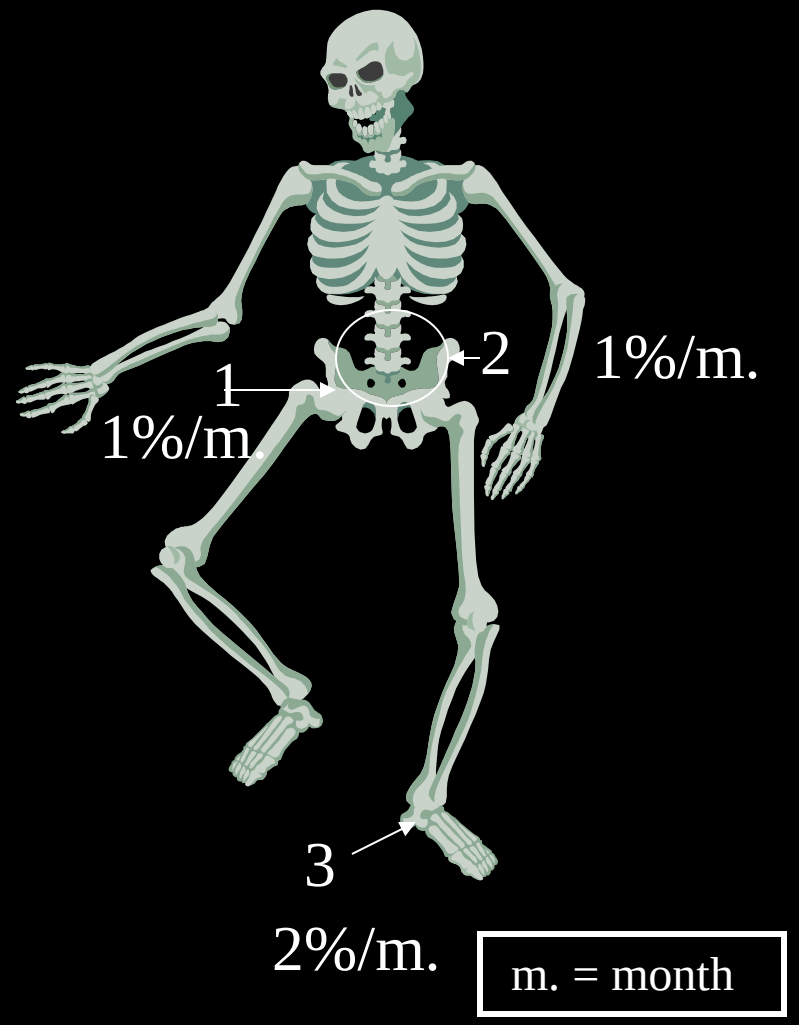


Postflight



Bone Mineral Loss in Space

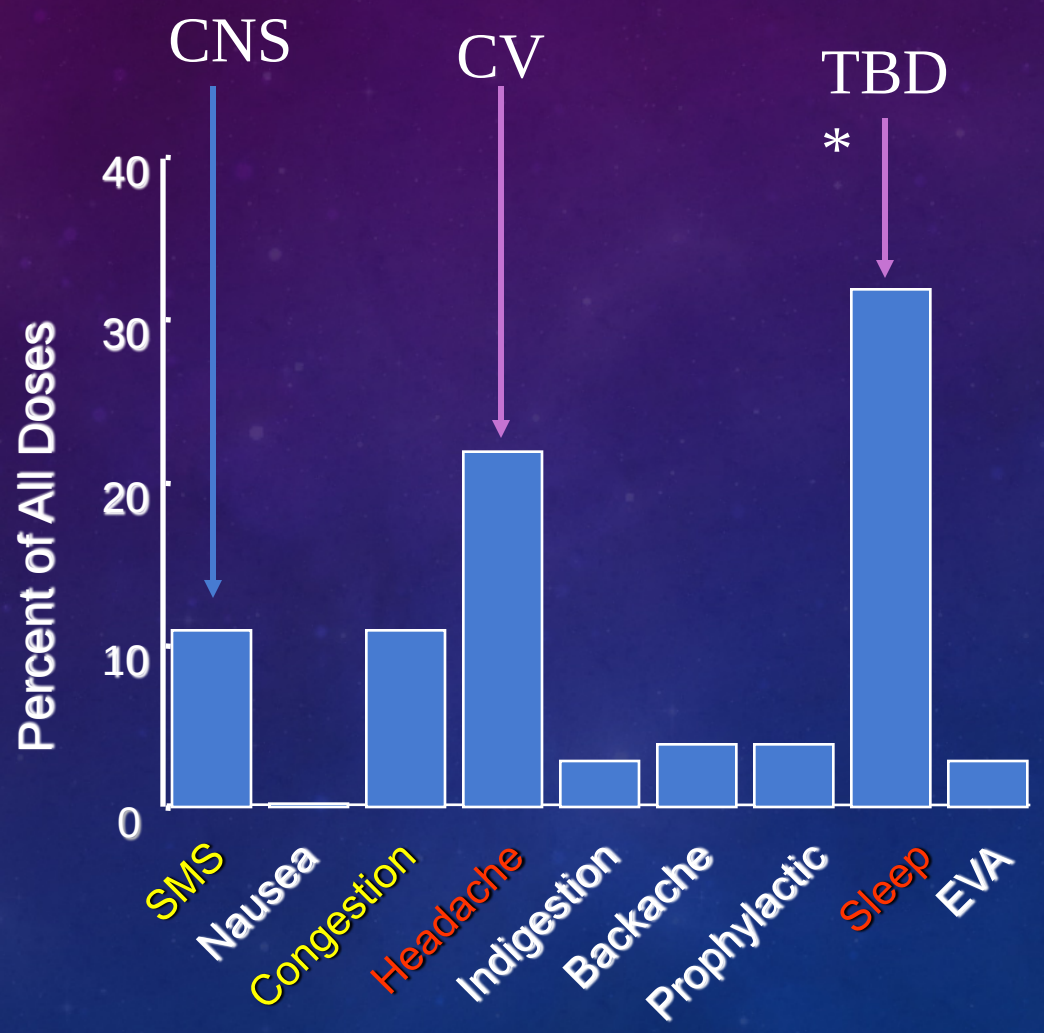
- 1% per month
- Primarily from gravity dependent areas
- Recovery post-flight as long as 3 to 4 times the length of exposure
- Bone deposition and removal in other areas continues



ILLNESS IN FLIGHT AS OF 2014

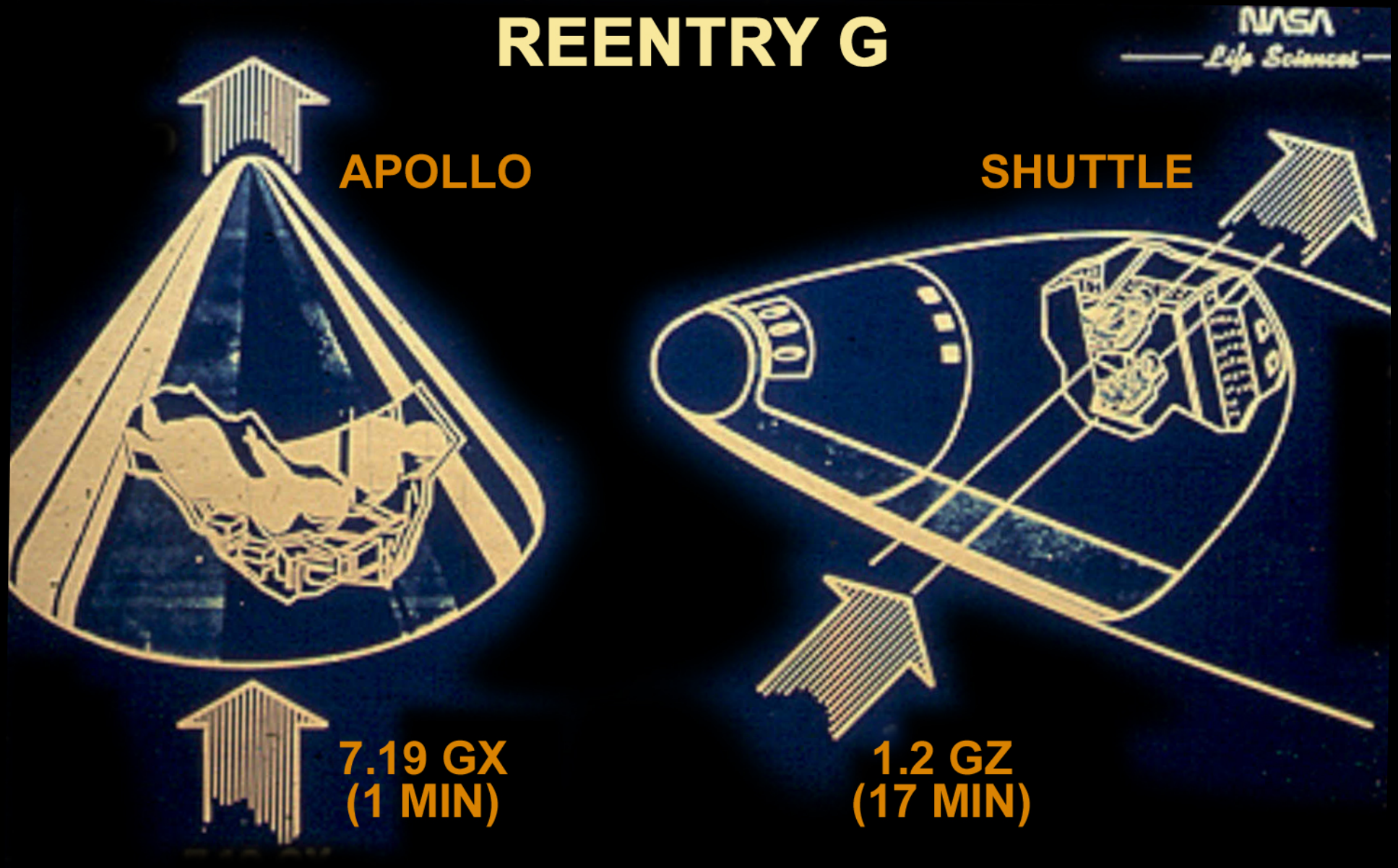
- **Single occurrence**
  - Renal Stone (*evacuated*)
  - UTI+ pyelonephritis (potential septicemia) (*evacuated*)
  - Idiopathic cardiac arrhythmia (*evacuated*)
  - Bilateral knee arthritis (treated on orbit)
  - Suspected risk for CAD (flight continued with monitoring)
  - Injury to the forehead from bungee cords
- **Multiple occurrences (all treated on orbit: mission objectives completed)**
  - SMS
  - Colds
  - Bladder retention
  - Psychosocial adjustments
  - Superficial burns
  - Abrasions
  - Foreign body in the eye
  - Contusions and bruises during the first several days in flight
  - Iatrogenic effect from dye injection during research (treated on orbit)

Pharmacologic Countermeasures used in Space



* Æthiology to be determined

REENTRY G



Task Complexity

Increased number of displays

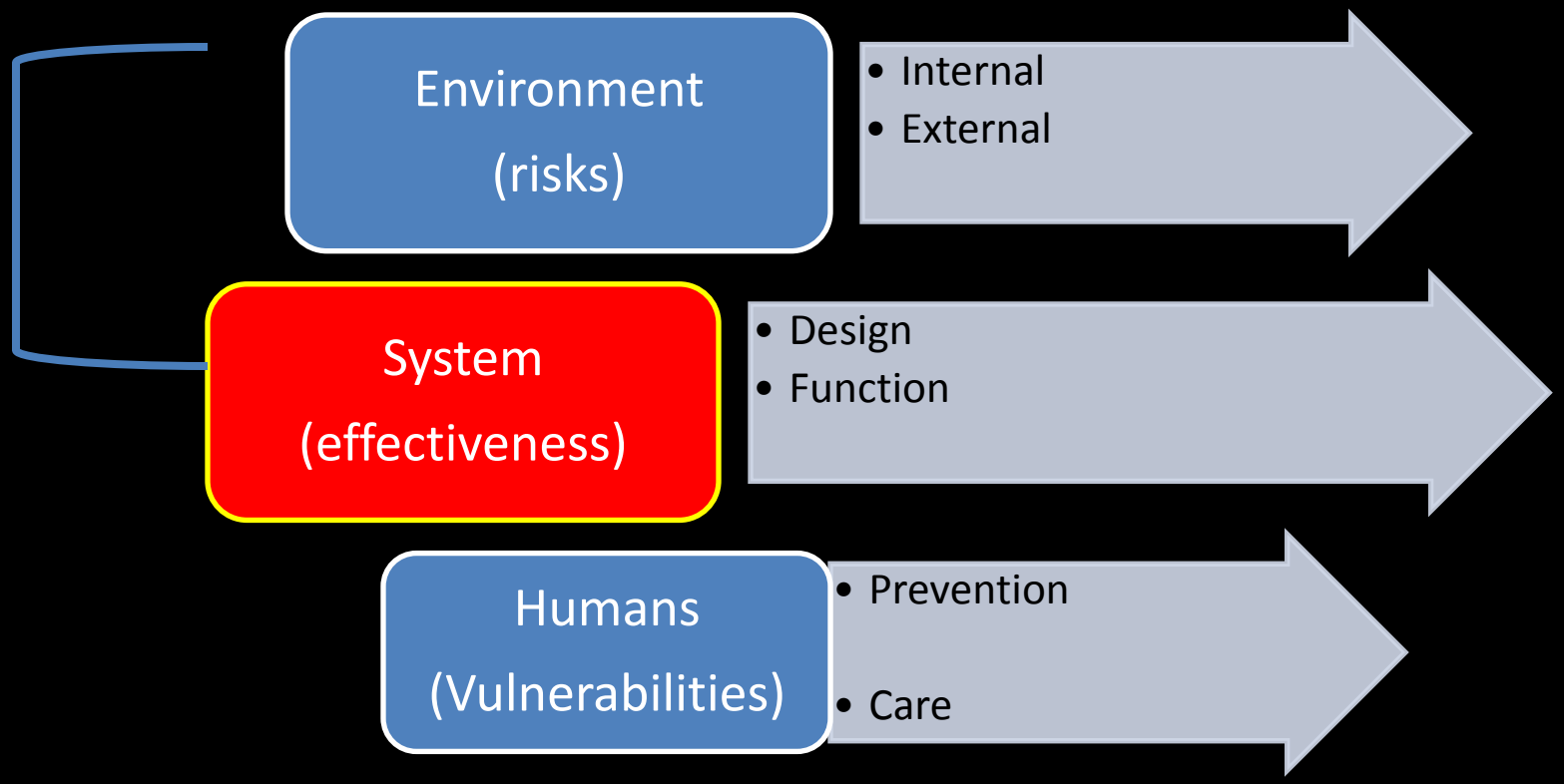
- Mercury 100 parameters – crew monitors 53
- Apollo 948 parameters – crew monitors 494
- Space Shuttle 7800 displays
- ISS >10000

Increasing requirements for maintenance

Increased burden on ground control

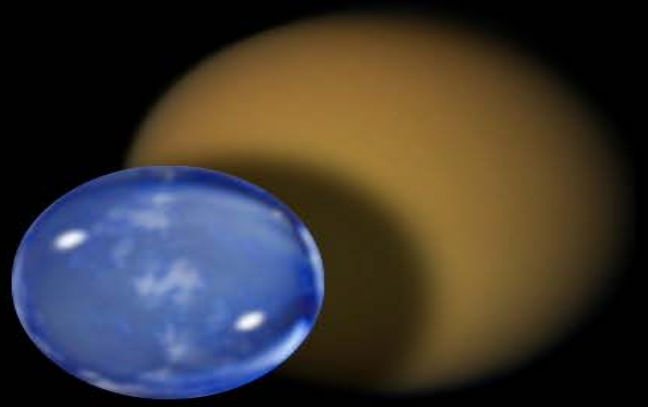
Significant time allocated to training

Priority Setting for Operator and Passenger Health In Space [Ethical Considerations]



Liquid Water in the Solar System

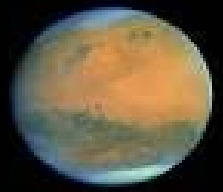
EUROPA



TITAN

EARTH

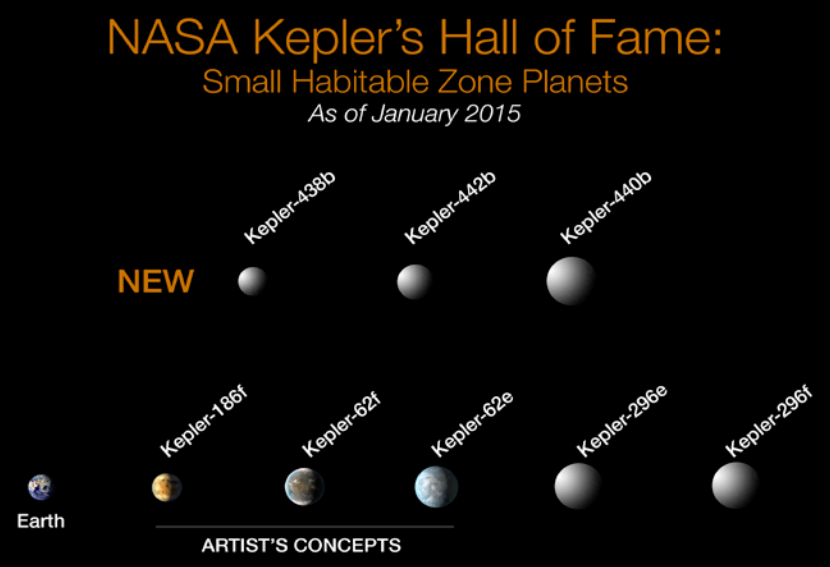
Enceladus



Mars

CREDIT: PHL @ UPR Arecibo, NASA

Search for Life in the Universe

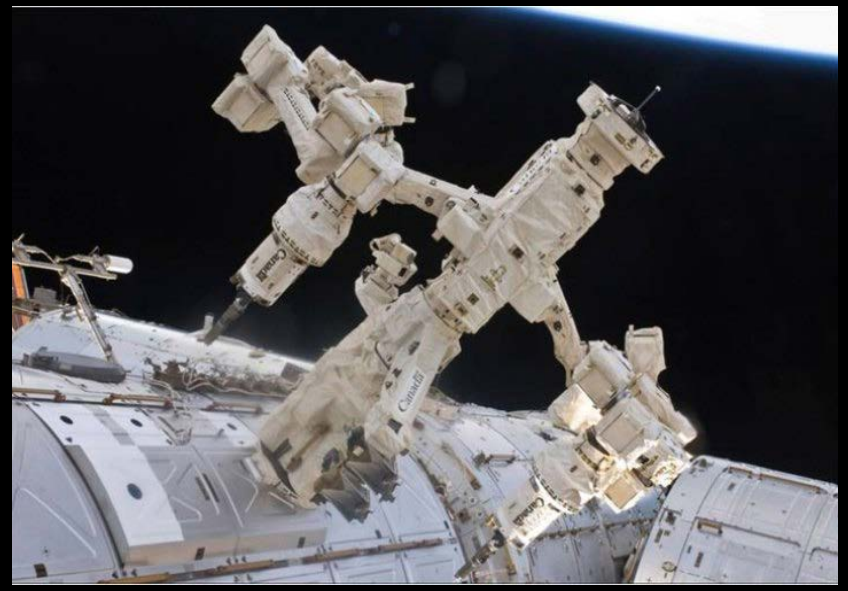


1,000 verified

1. Mars Lake bed Gillespie
2. Methane spikes on the planet could be produced by bacteria

The Future

MADE IN SPACE
MADE IN SPACE
MADE IN SPACE



TOM
MOBILE LIBRARY
CARTOONSTOCK .com
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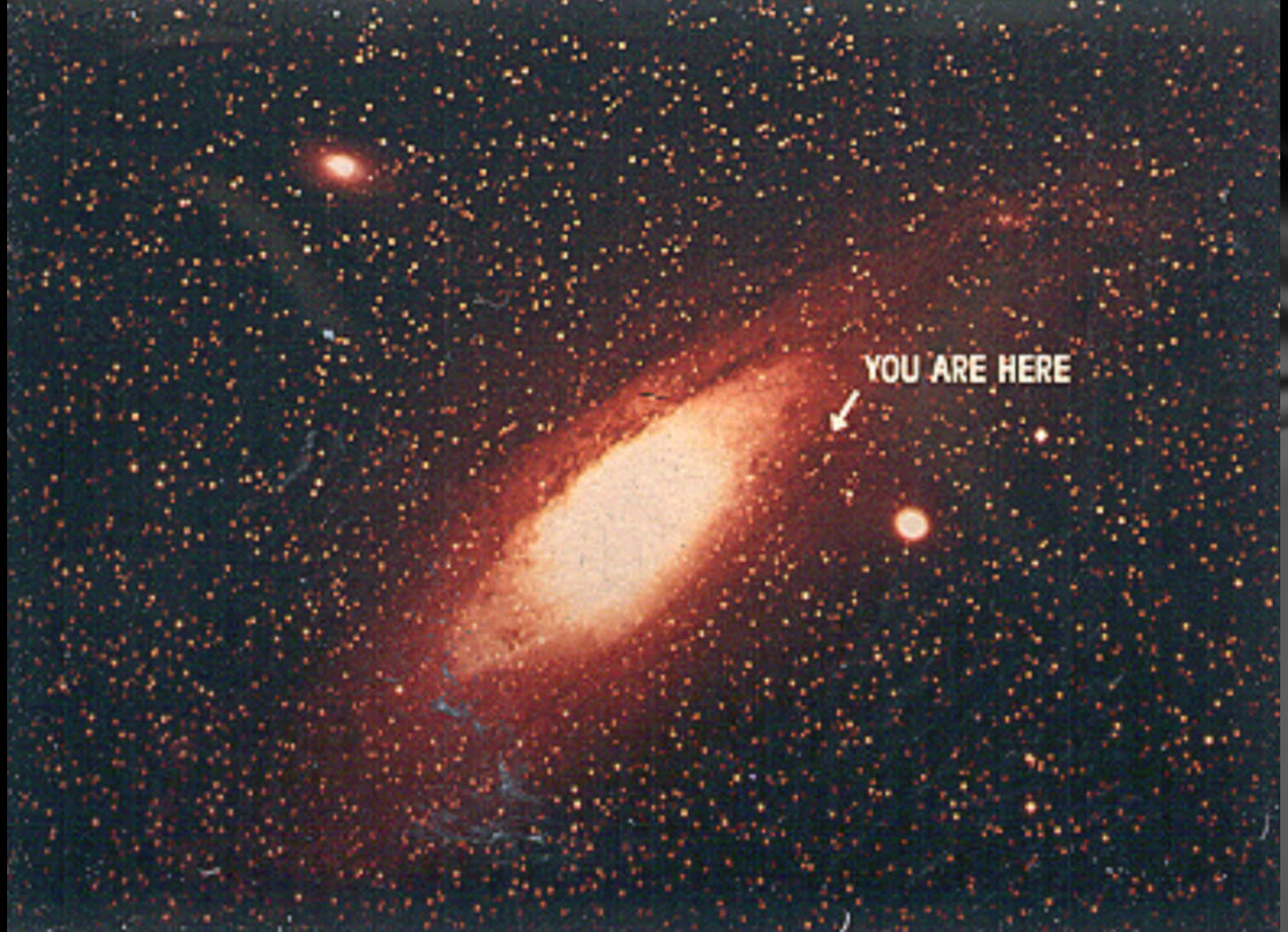
"Anything on suspended animation?"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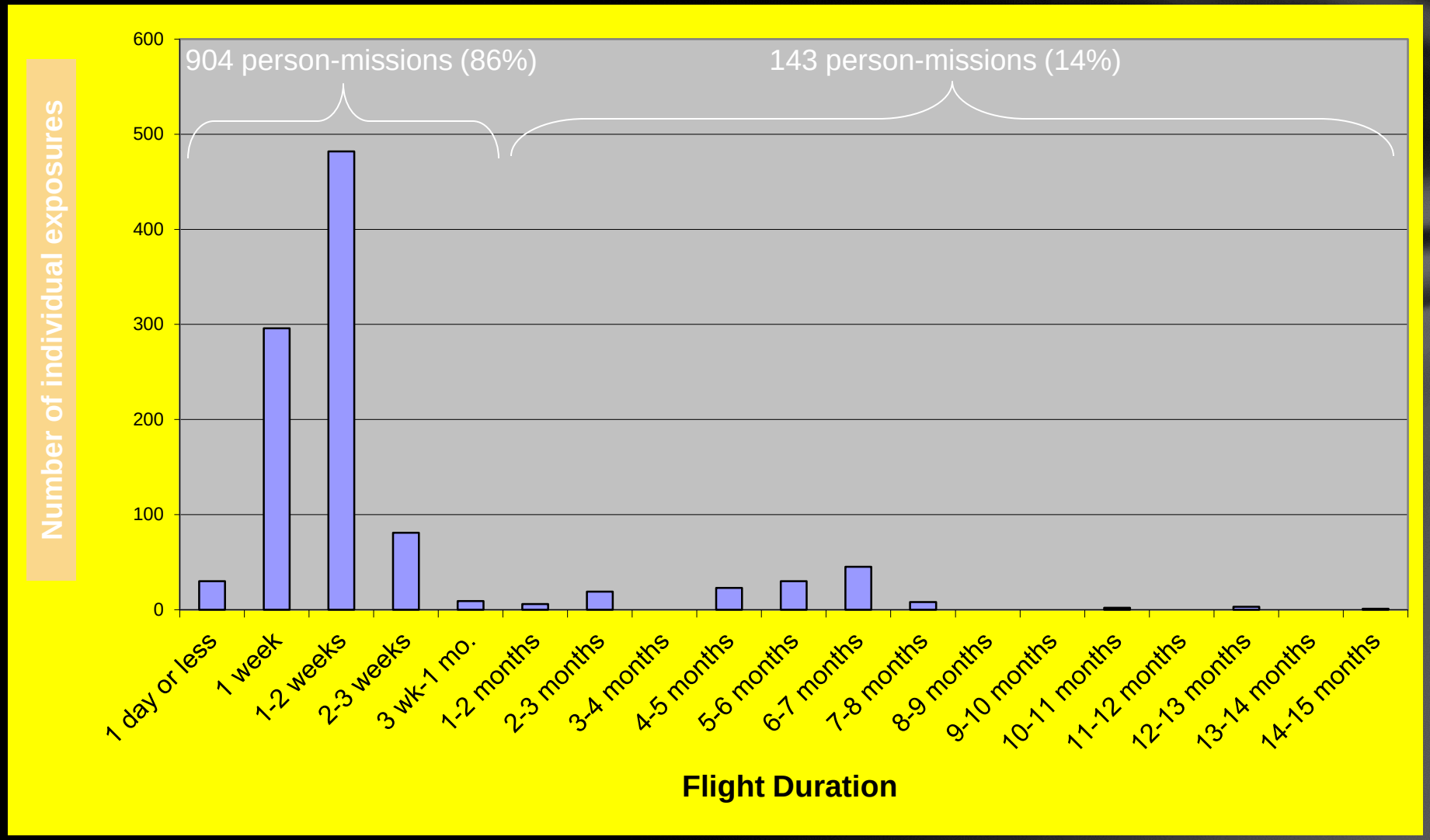
Human Space Flight Experience