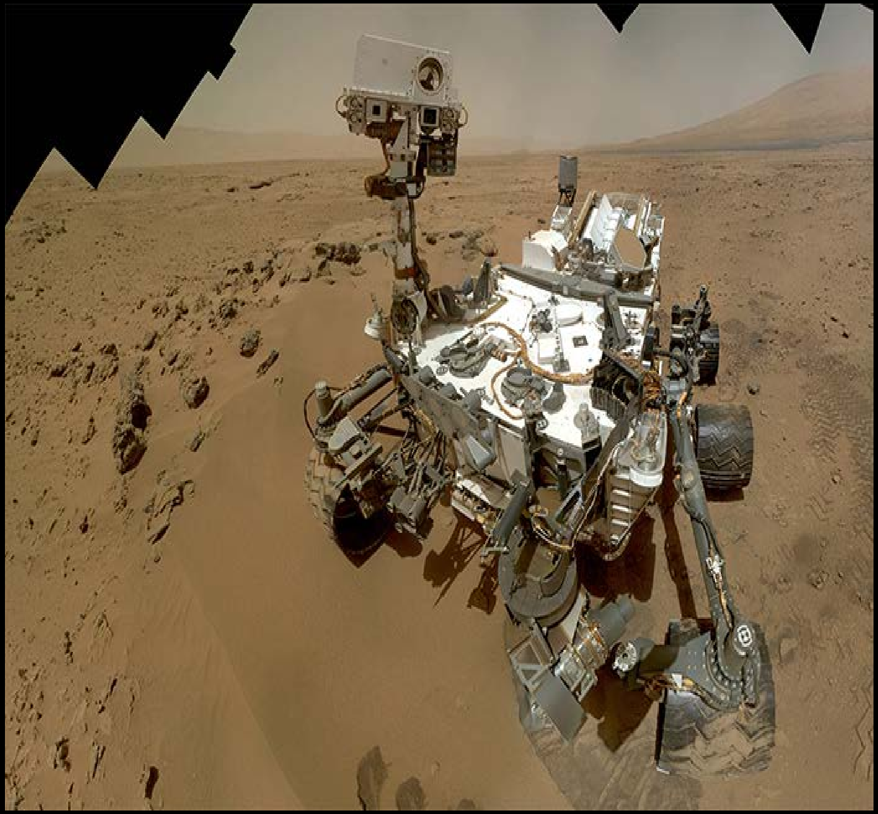
Loose Ends

Adequate Shielding on Mars - Moon

- The Mars rover Curiosity has allowed us to finally calculate an average dose over the 180-day journey. It is approximately 300 mSv, the equivalent of 24 CAT scans. In just getting to Mars, an explorer would be exposed to more than 15 times an annual radiation limit for a worker in a nuclear power plant.

- The Mars One habitat will be covered by a necessary layer of soil that provides shielding even against galactic cosmic rays. **Six feet (2 meters) of Martian soil provides the same protection as the Earth's atmosphere**. The Mars One habitat can support a soil layer 36 feet (11 m) thick. If the settlers spend, on average, **two hours per day outside the habitat, their individual exposure adds up to 22 mSv per year.**



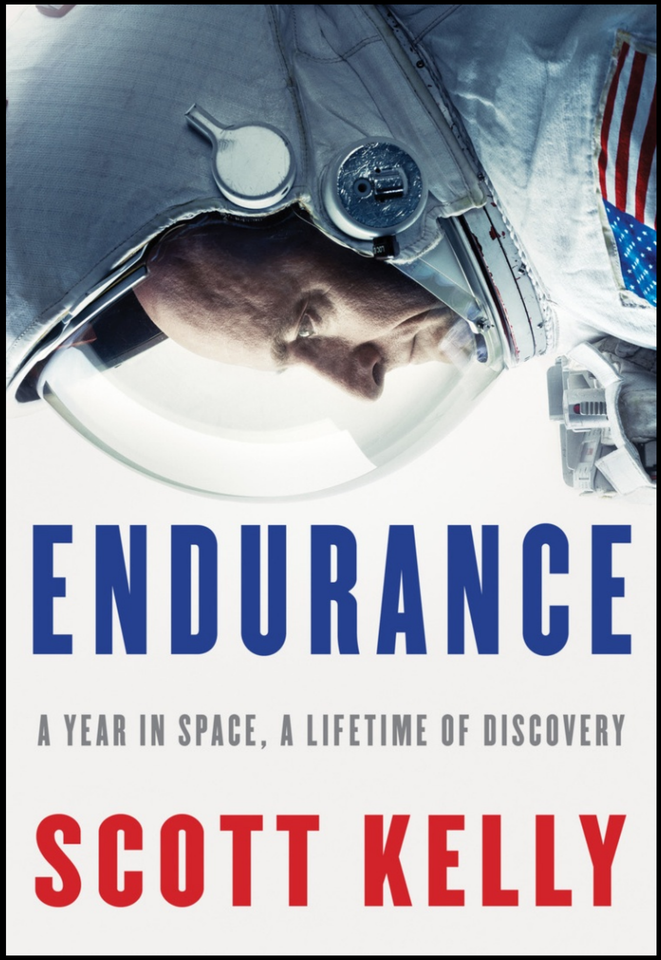
Falcon 9 Landing – December 2017

Falcon Heavy at the Pad – December 2016

Overcoming the Critical Path Single Point Failure in Human Space Exploration

DR. DENNIS CHAMBERLAND

NASA Astronaut Scott Kelly
342 days (11 months, 3 days) in space
Returned to Earth 2016

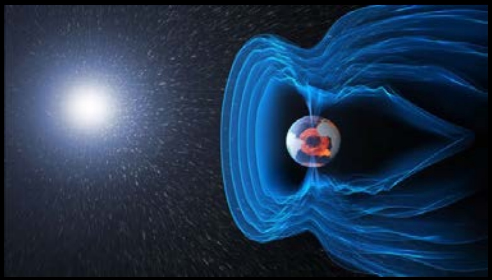


Q: What is THE Problem in Human Space Exploration?

A: It is a problem of philosophy. It is the Expectation of Human Adaptation to the Space Environment

Three Potential Critical Path Failures in Human Space Exploration

<u>1. Cosmic Radiation</u>
Effective Countermeasures?



<u>2. Advanced Life Support</u>
Effective Countermeasures?

<u>3. Effects of Microgravity</u>
Effective Countermeasures?

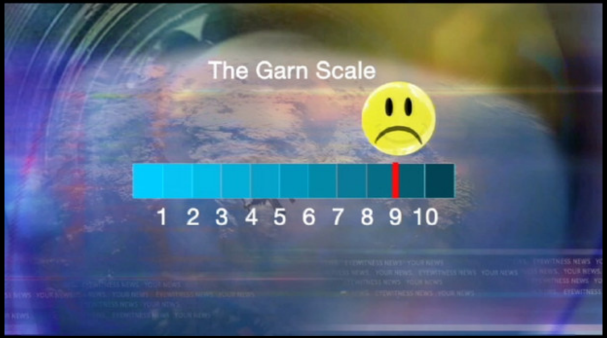
Adaptation to Microgravity (Zero-G) is the most serious immediate problem threatening to halt all long term space voyages.

It is the Most Critical Path Single Point Failure in Human Space Exploration

Space Adaptation Sickness

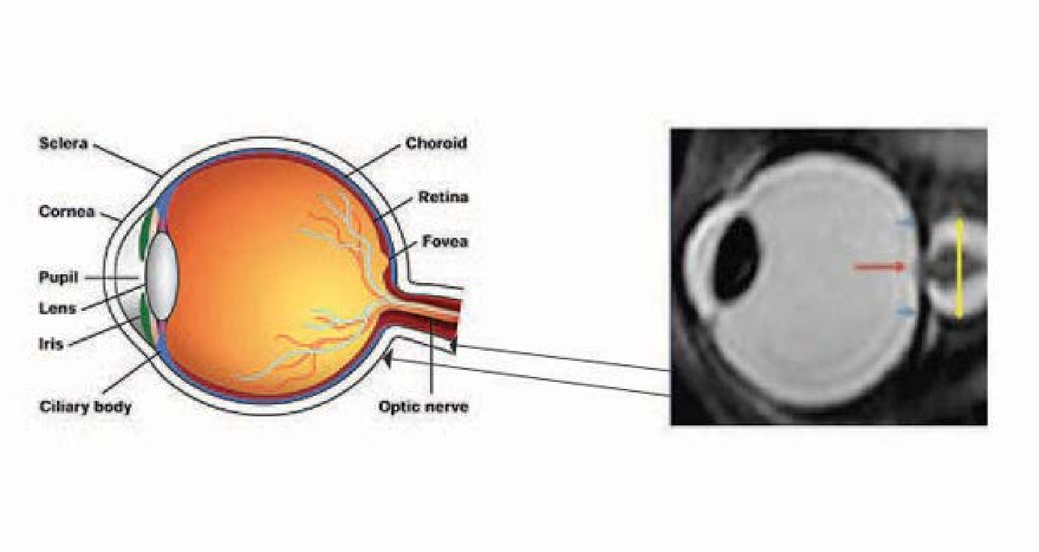
Space sickness is much like motion sickness and has the same root cause – temporary vestibular disorientation.

Except for the misery index for several days, it generally passes for most astronauts. Measured in “Garn Units” after US Senator Jake Garn.



It is a non-issue – but… tossing cookies in a space suit is highly discouraged!

VIIP – Visual Impairment Intracranial Pressure Syndrome

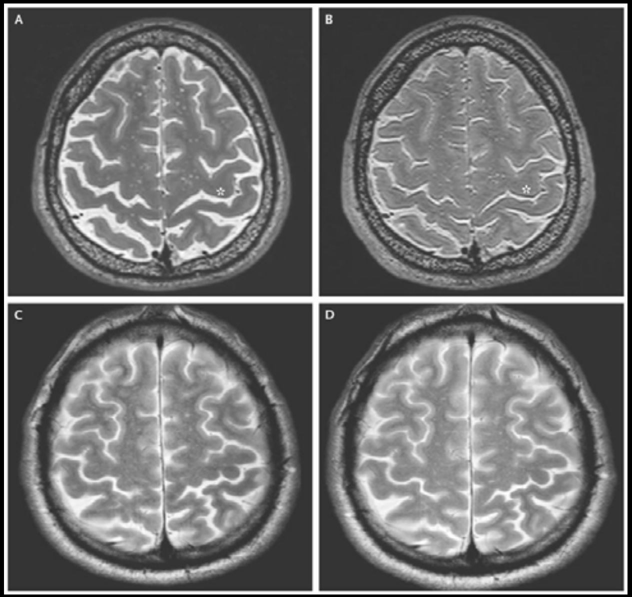


Characterized as visual impairment/intracranial pressure, the changes include papilledema (swelling of the optic nerve), globe flattening, choroidal folds, "cotton wool" spots, thickening of the optic nerve, and decreased visual acuity.

<u>In-flight prognosis</u>: Potential blindness over many months exposure. Astronaut John Phillips' eyesight changed from 20/20 to 20/100 in six months on orbit.

<u>Post flight recovery</u>: condition persists for years. Ultimate prognosis is unknown. "…may never return to baseline." (NASA)

Brain Squeezing and CNS Tissue Reconfiguration

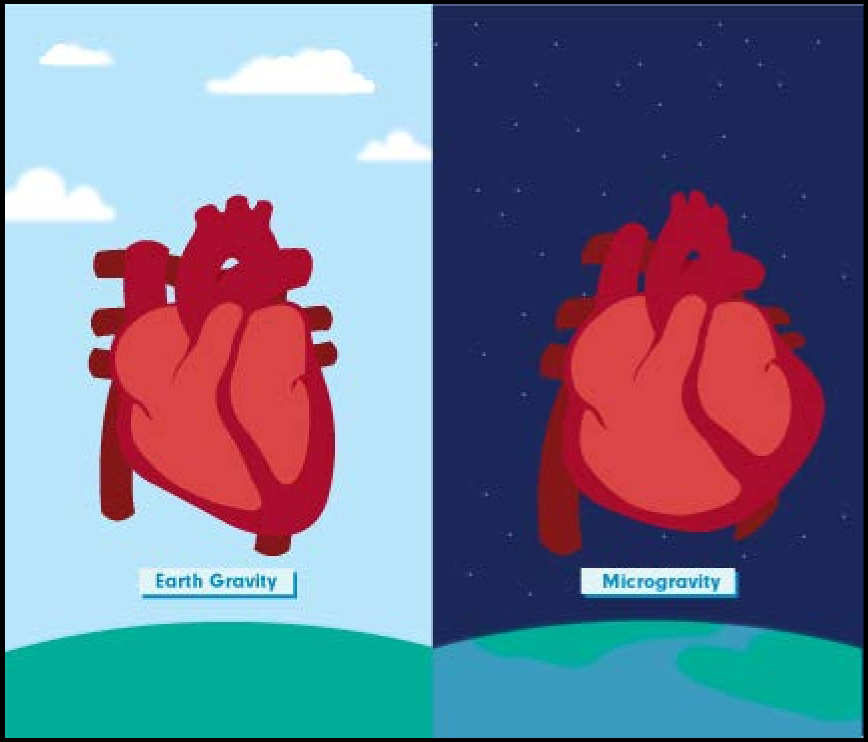


Morphological - structural changes to the brain result from absence of gravity. The brain and its structure collects fluid over time and swells. Cause of VIIP. Results in feelings of head pressure during flight.

In-flight prognosis: potential blindness; unknown brain function changes over longer periods; increasing discomfort.

Post flight recovery: condition may totally reverse in gravity. Ultimate prognosis is unknown.

Cardiac Muscle Atrophy

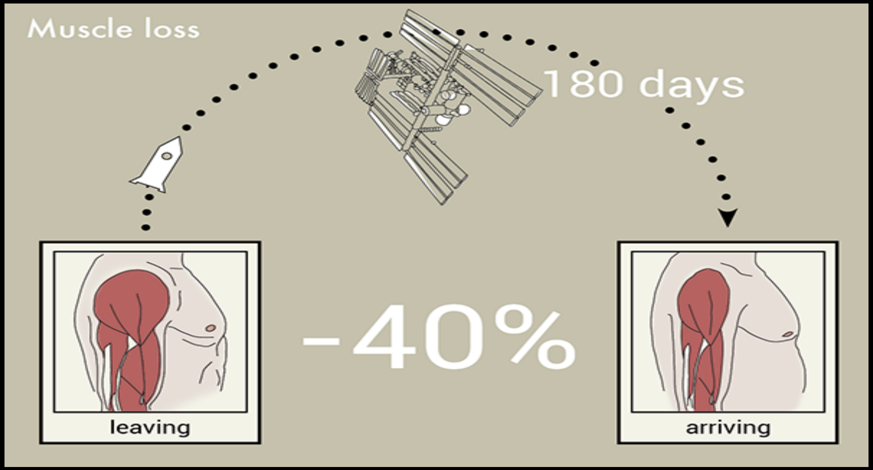


Spaceflight is known to cause a variety of cardiac effects. Upon return to Earth, astronauts commonly become lightheaded or pass out in a condition known as orthostatic hypotension, in which the body experiences a sudden drop in blood pressure when standing up. Arrhythmias have also been observed during space travel. The heart works a lot less and that leads to less muscle mass, even over a relatively short duration.

In-flight prognosis: Structural morphology changes to spherical; heart muscle slows; heart muscle atrophies; arrhythmias observed; chronic drop in blood pressure; cardiac output steadily declines over long periods.

Post flight recovery: Cardiac tissue may never fully rebuild and recover. Ultimate prognosis is unknown.

Musculature Atrophy

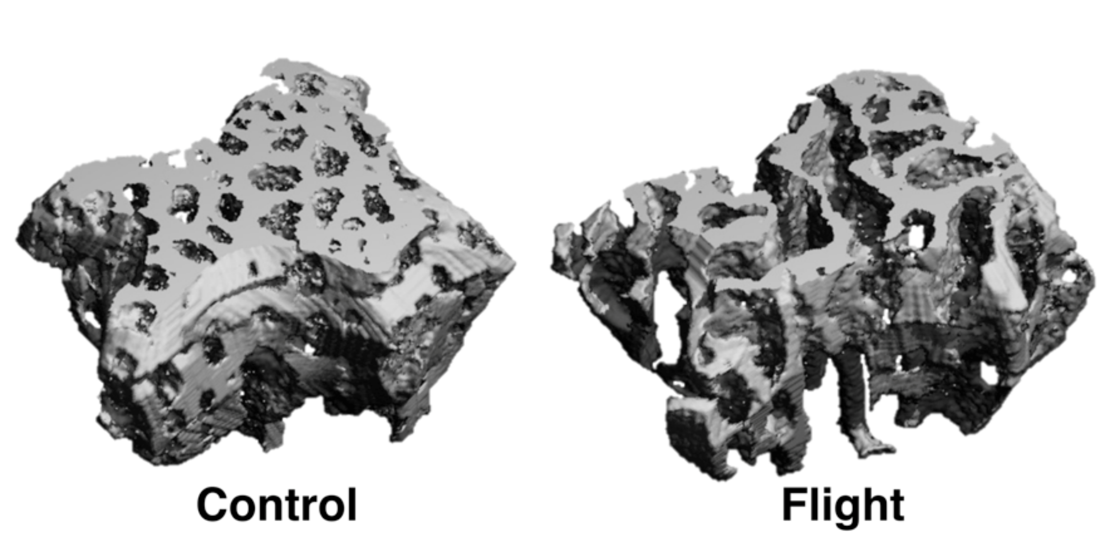


Prolonged exposure to weightlessness could cause astronauts to lose more than 40 percent of their muscle strength <u>even with regular exercise</u>, researchers said. On a long voyage, a healthy 30- to 50-year-old astronaut could end up with the strength of an 80-year-old. A 10-month trip to Mars would cause such extreme muscle deterioration that astronauts would find it difficult to perform even routine tasks and may not be able to perform on the surface of Mars.

<u>In-flight prognosis</u>: On a long voyage, a healthy 30- to 50-year-old astronaut could end up with the strength of an 80-year-old.

<u>Post flight recovery</u>: On return there is a danger of several kinds of injuries in performance of everyday tasks. Return of full musculature is unlikely.

Permanent Bone Loss

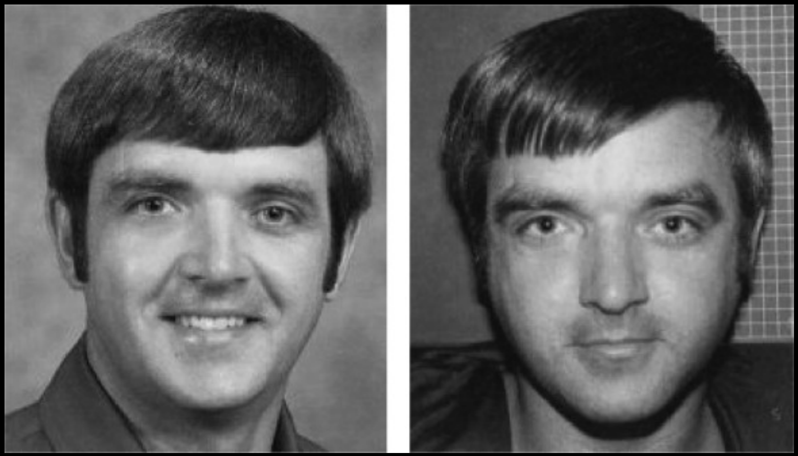


The legs and spine are especially affected by the lack of weight-bearing in space. They leach calcium and become brittle and weak in a process called "disuse osteoporosis." Studies have shown that astronauts lose about 1 to 2 percent of their bone mass each month they are in space.
(Mice bone sections shown – after 30 days in flight)

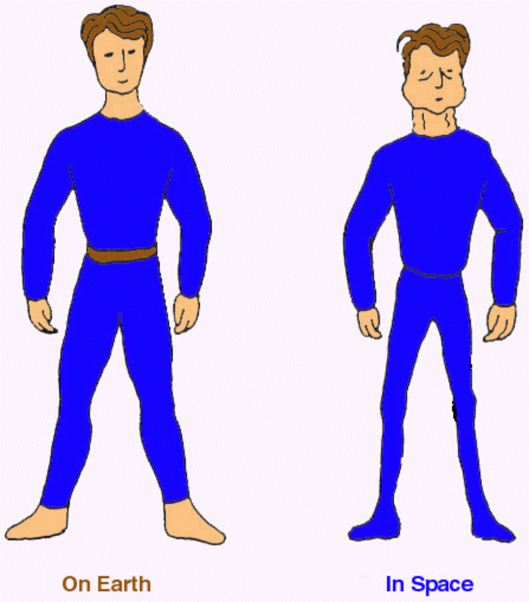
In-flight prognosis: Increasing loss of bone density may result in fractures during routine tasks. Decalcification of bones leads to kidney stones.

Post flight recovery: On return there is a danger of several kinds of injuries in performance of everyday tasks. Most loss of full bone density is permanent.

Body Fluid Shifts



NASA Astronaut "Puffy Face Syndrome"



In microgravity, body fluids are redistributed to the upper body, resulting in bulging neck veins, puffy face, and sinus and nasal congestion – resembling a constant cold. This results in a decrease in plasma volume of around 22% of original blood volume.

In-flight prognosis: Dangerous cranial and optic pressure builds; constant discomfort; decreasing orthostatic tolerance.

Post flight recovery: Return to Earth produces a marked problem with "orthostatic tolerance", or the body's ability to send enough oxygen to the brain without the astronaut's fainting or becoming dizzy. Condition resolves over time.

Surface Tension Effects

😬

NASA's $20 million Russian Toilet on ISS

In microgravity, fluids are not influenced by gravity but by surface tension. ALL fluids 'crawl' along all available surfaces. EXAMPLES: urine and skin; ingested fluids; spilled fluids; any fluid touched by hands.

<u>In-flight prognosis</u>: A human factors nightmare; an engineering challenge requiring <u>many</u> countermeasures; failure of the sanitary system in space is 'problematic'.

Note the different toilet non-gravity engineering countermeasures – not for the timid…

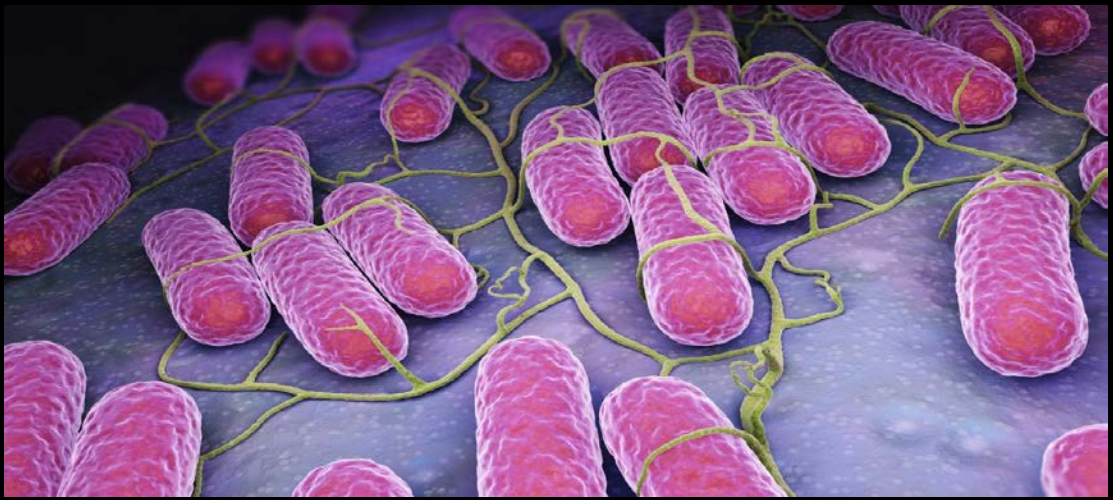
Immune System Dysfunction

In prolonged exposure to microgravity in exploration class space missions, there is evidence of immune system dysregulation.

<u>In-flight prognosis</u>: Increased incidences of infections; allergic and hypersensitivity reactions occur with increasing frequency; viral reactivation occurs; impaired tumor surveillance resulting in increased incidence of malignancies and impaired wound healing.

<u>Post flight recovery</u>: Recovery of the immune system has not been well documented, but one study showed at least partial recovery beginning 3 days post flight.

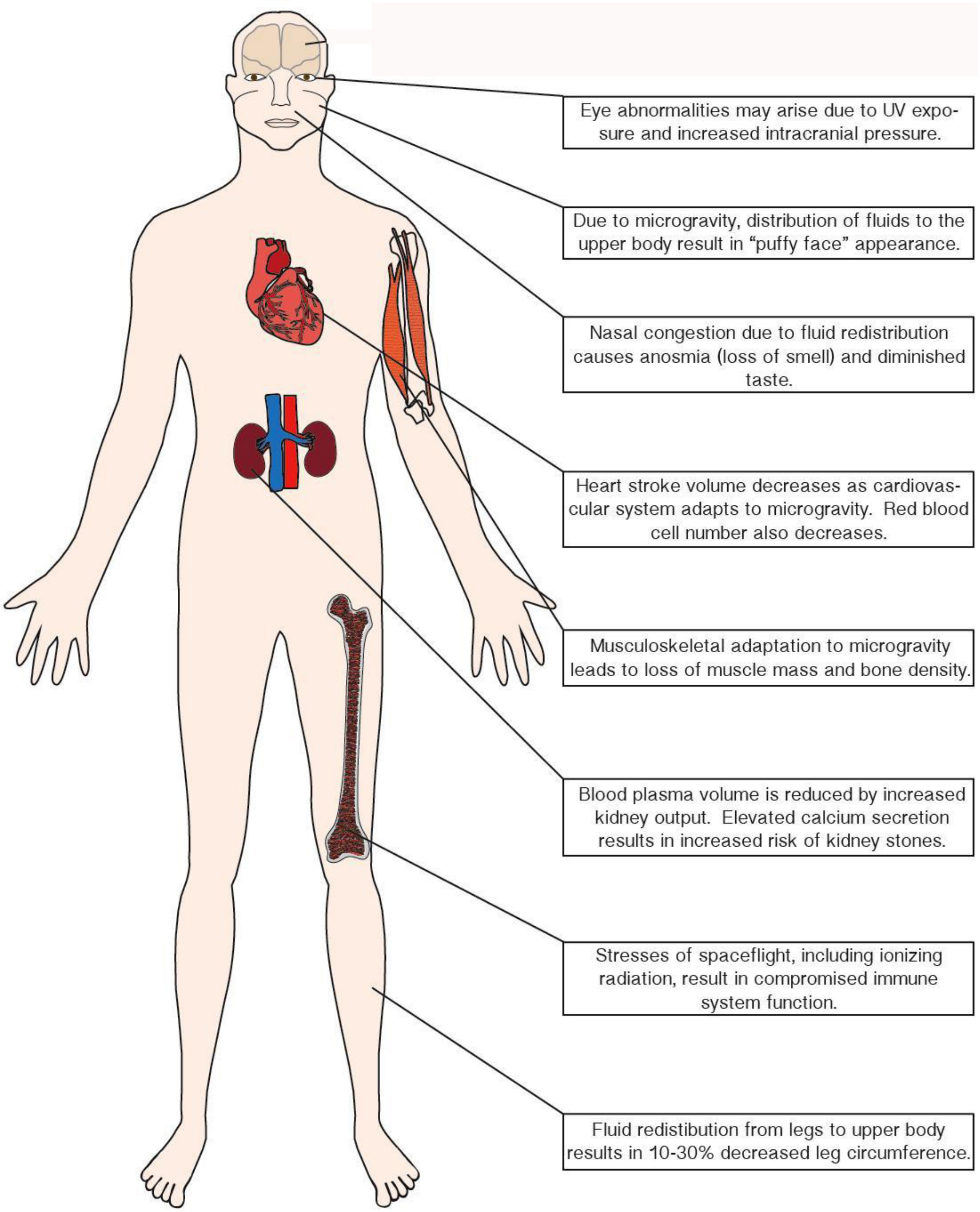
Bacterial Virulence



A 2006 Space Shuttle experiment found that *Salmonella typhimurium*, a bacterium that can cause food poisoning, became more virulent when cultivated in space. On April 29, 2013, scientists at Rensselaer Polytechnic Institute reported that, during spaceflight on the International Space Station, microbes seem to adapt to the space environment in ways "not observed on Earth" and in ways that "can lead to increases in growth and virulence“.

In-flight prognosis: Common microorganisms may become more infective. Not enough research has been conducted on this question.

Post flight recovery: N/A



The Big Picture

NASA’s Ala Carte ‘Countermeasures’ Approach

Endless Countermeasures – one for every problem.

Countermeasures for the eyes, the body fluids, bacterial virulence, bones, muscles, cardiac output, surface tension, etc.

Countermeasures for each of the hundreds of individual engineering problems in microgravity, including toilets and showers.

There is even a countermeasure for crying in space:

Canadian Astronaut
Chris Hadfield
cries for science
on orbit

So Now What?

"This is why we volunteered for this mission, after all: to discover how the human body is affected by long-term spaceflight."

"Our space agencies won't be able to push out farther into space, to a destination like Mars, until we can learn more about how to strengthen the weakest links in the chain that makes spaceflight possible: the human body and mind."   - Scott Kelly

With all due respect – Astronaut Kelly is <u>wrong</u>.

Once again – the focus is on somehow forcing the human to adapt, as he stated, "to strengthen the weakest links…" …add even MORE countermeasures!

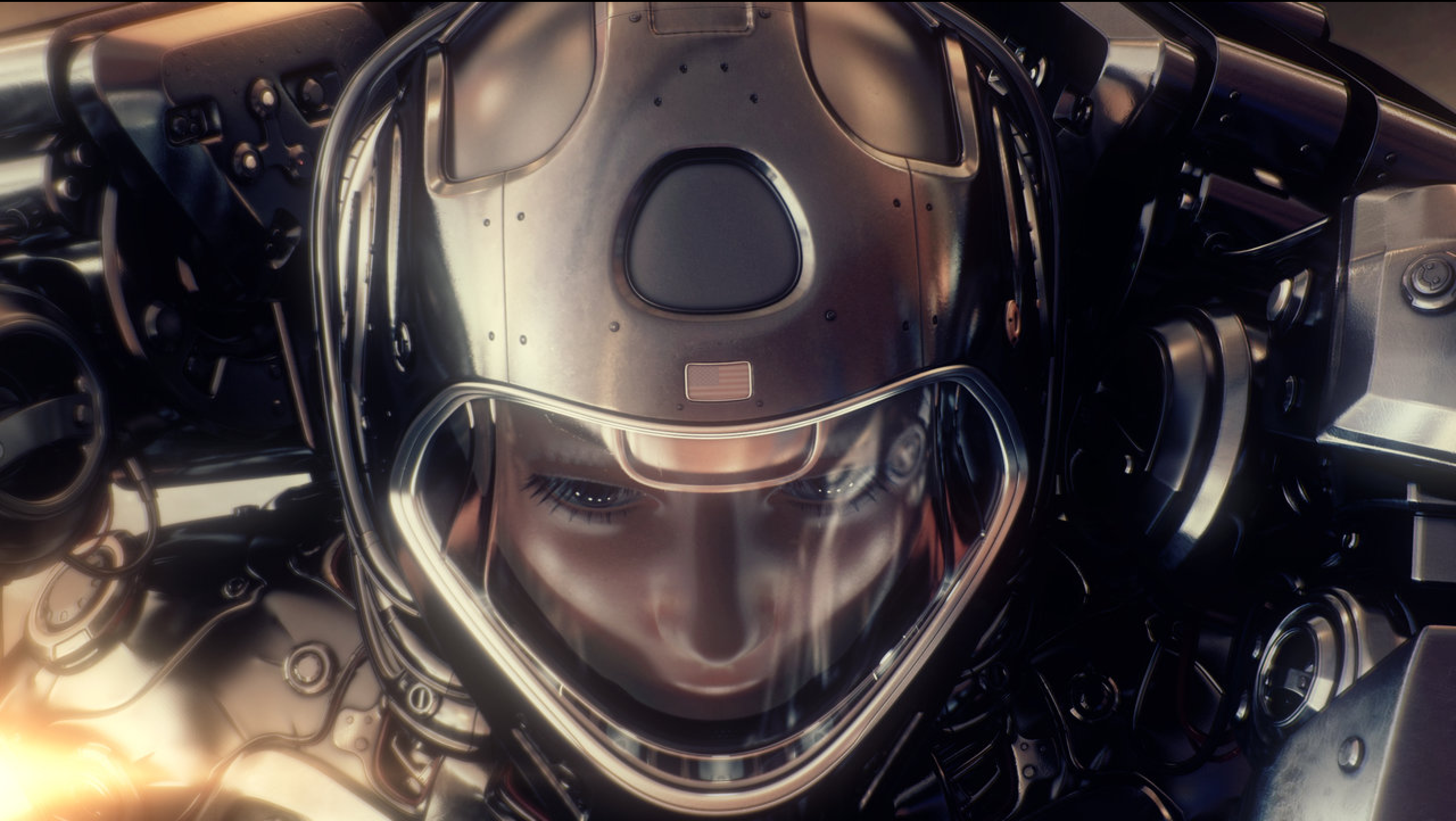
The ultimate solution is <u>not</u> to fix the human, <u>but to fix the philosophy</u>.

First Principle of Human Exploration

"In every exploration system, we must require the systems we build to adapt to the human standard rather than expect the human to adapt to the machine or the environment – and in every design activity we will protect the human as a primary objective."

Dennis Chamberland – 2007
Undersea Colonies

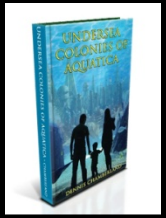
Change the Engineering
<u>Leave the Humans Alone</u>



<u>What is the ‘human standard’?</u>

<u>Borrowing a well known term from thermodynamics:</u>

“The condition of ‘One Earth Normal’, in human exploration is Standard Temperature, Pressure, Gravity and Background Radiation found at sea level on the surface of the Earth.”



“*Any* chronic deviation from <u>One Earth Normal</u>
is potentially injurious to the human physiology.”
Dennis Chamberland – 2010

Adapt Other Industry Standards in Space Exploration

ALARA

As Low As Reasonably Achievable: make every reasonable effort to maintain exposures to ionizing radiation as far below the dose limits as practical.

ALARA In Human Space Exploration

ALARA means making every reasonable effort to insure exposure to any condition reflects One Earth Normal as much as is practical to prevent *any* injury or illness as a result of that exposure – As Low As Reasonably Achievable.

Philosophy – An Antidote for Human Stupidity Enabling the Short-Circuiting of Blind Alleys in Human Exploration

Examples

The Philosophical Failure – Forcing Humans to Adapt to Deep Pressure:
"The ultimate colonization of the oceans is impractical." Jacques Cousteau
"Undersea military bases are not safe or practical." US Navy

The Philosophical Resolution Is Resolved Completely by an Engineering Solution:
"Totally eliminate pressure differences at any depth with airlocks like astronauts in space stations or submarine crews." Dennis Chamberland

The Philosophical Failure – Space Hardware Cannot be Reused because of the Difficulty and Expense:
"…normal people cannot, or should not want to, develop large launch vehicles." NASA Administrator

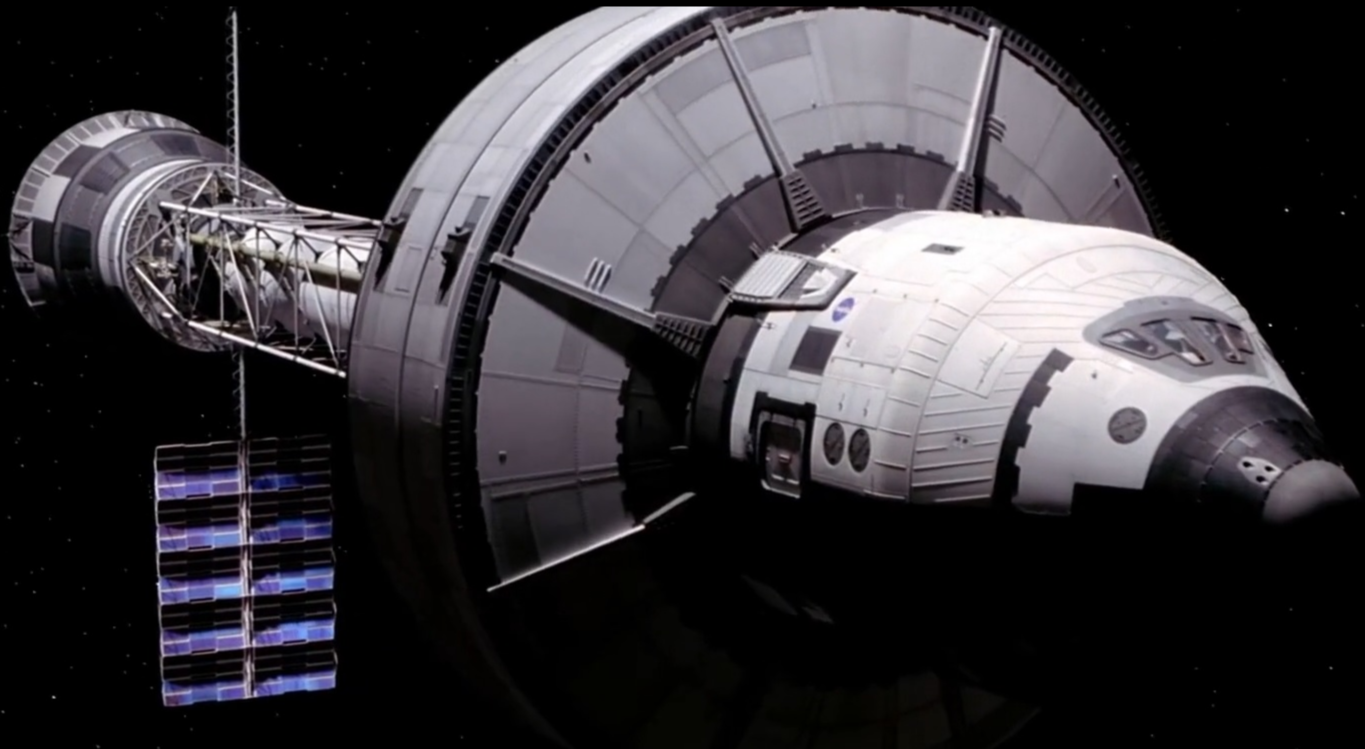
The Philosophical Resolution Is Resolved Completely by an Engineering Solution:
Engineering re-use from the ground up and not reusing old exploration engineering paradigms.

The Philosophical Failure – Expecting and Forcing Humans to Adapt to Microgravity:
"Our space agencies won't be able to push out farther into space, to a destination like Mars, until we can learn more about how to strengthen the weakest links in the chain." Scott Kelly

The Philosophical Resolution Is Resolved Completely by a SINGLE Engineering Solution:

Instead of HUNDREDS of Countermeasures
For Microgravity - We Only Need

ONE

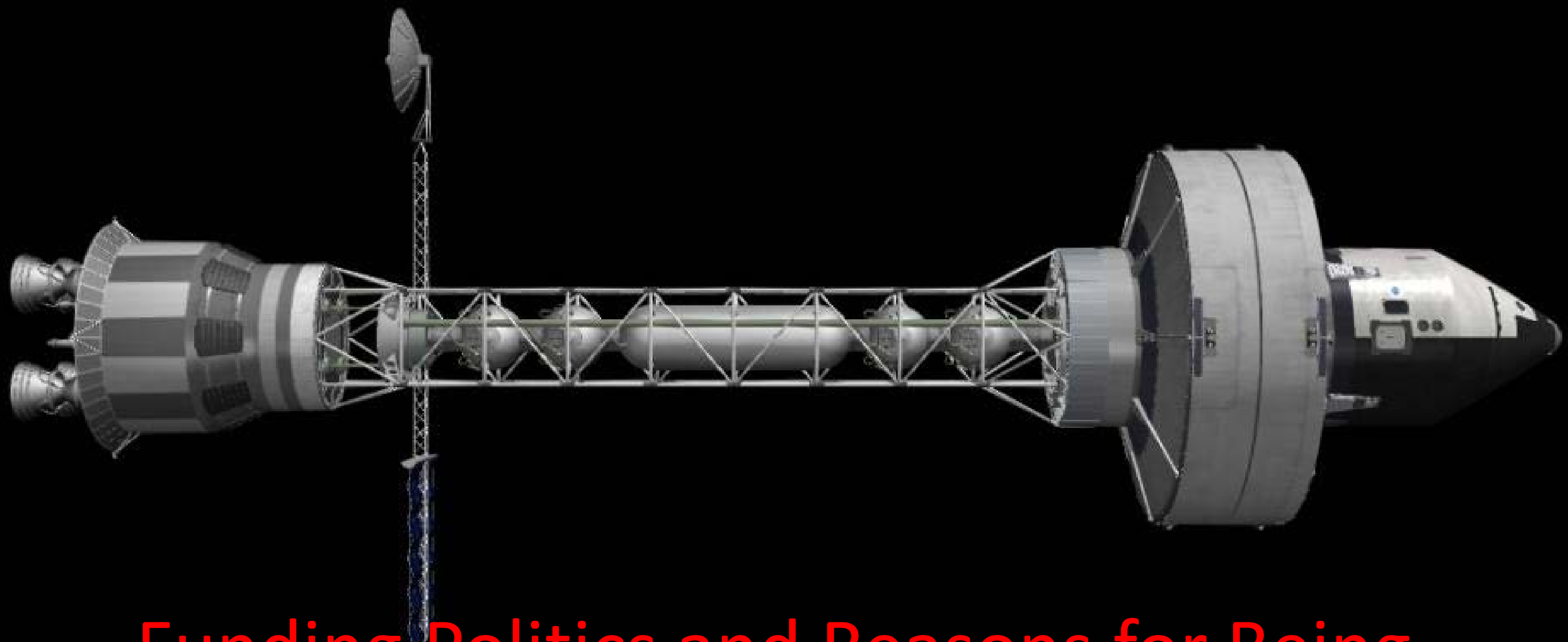


Centrifugal Gravity – Spun Ships

(Mission to Mars)

Our Studies Have Shown that Even Partial Exposure to Gravity
Solves Most Health Issues

So Why Not Do This One Thing?



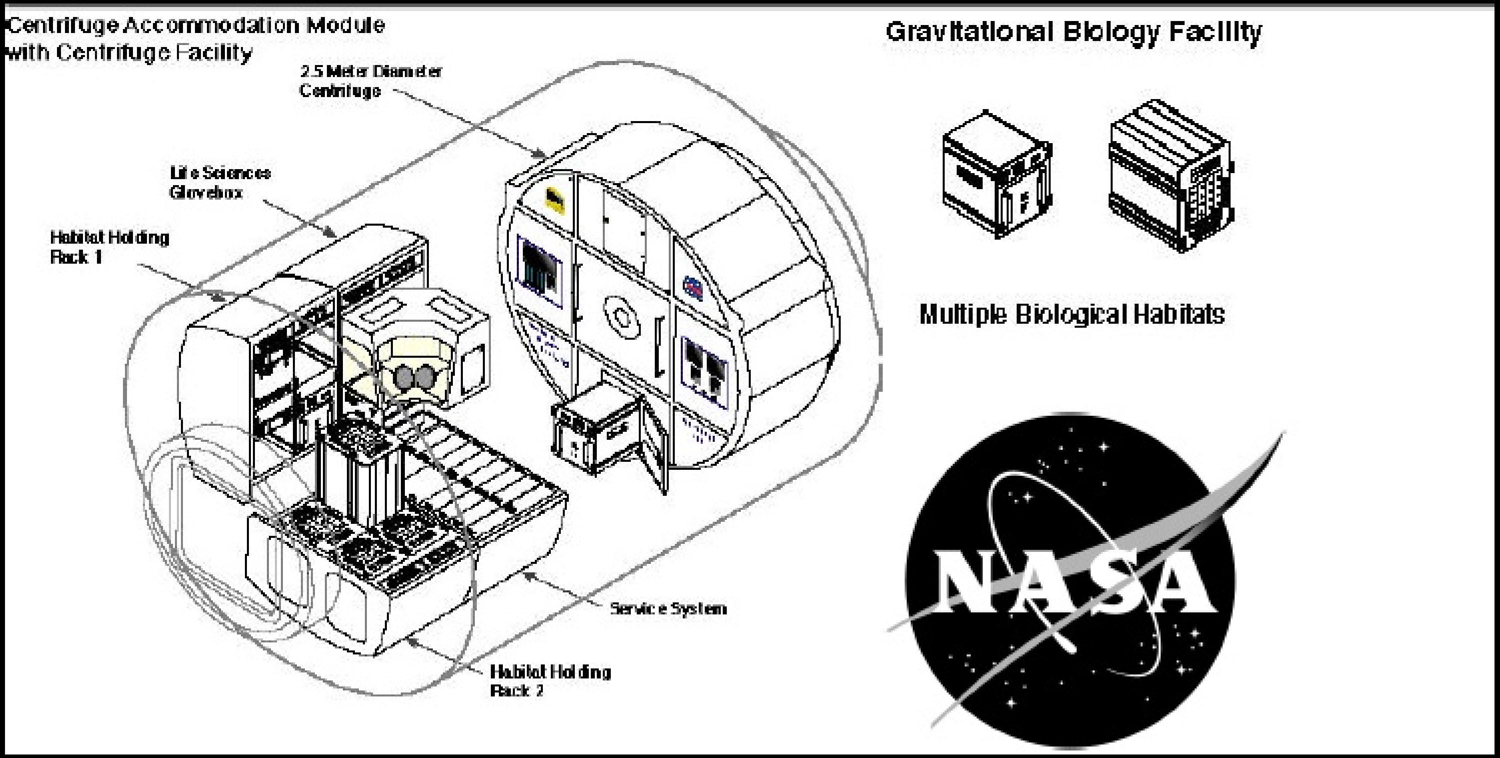
Funding Politics and Reasons for Being

(The 8-year cyclic political argument – we do not go to space to 'explore and colonize' but to study the environment and do basic science.)

History of Scientific Turf Wars –

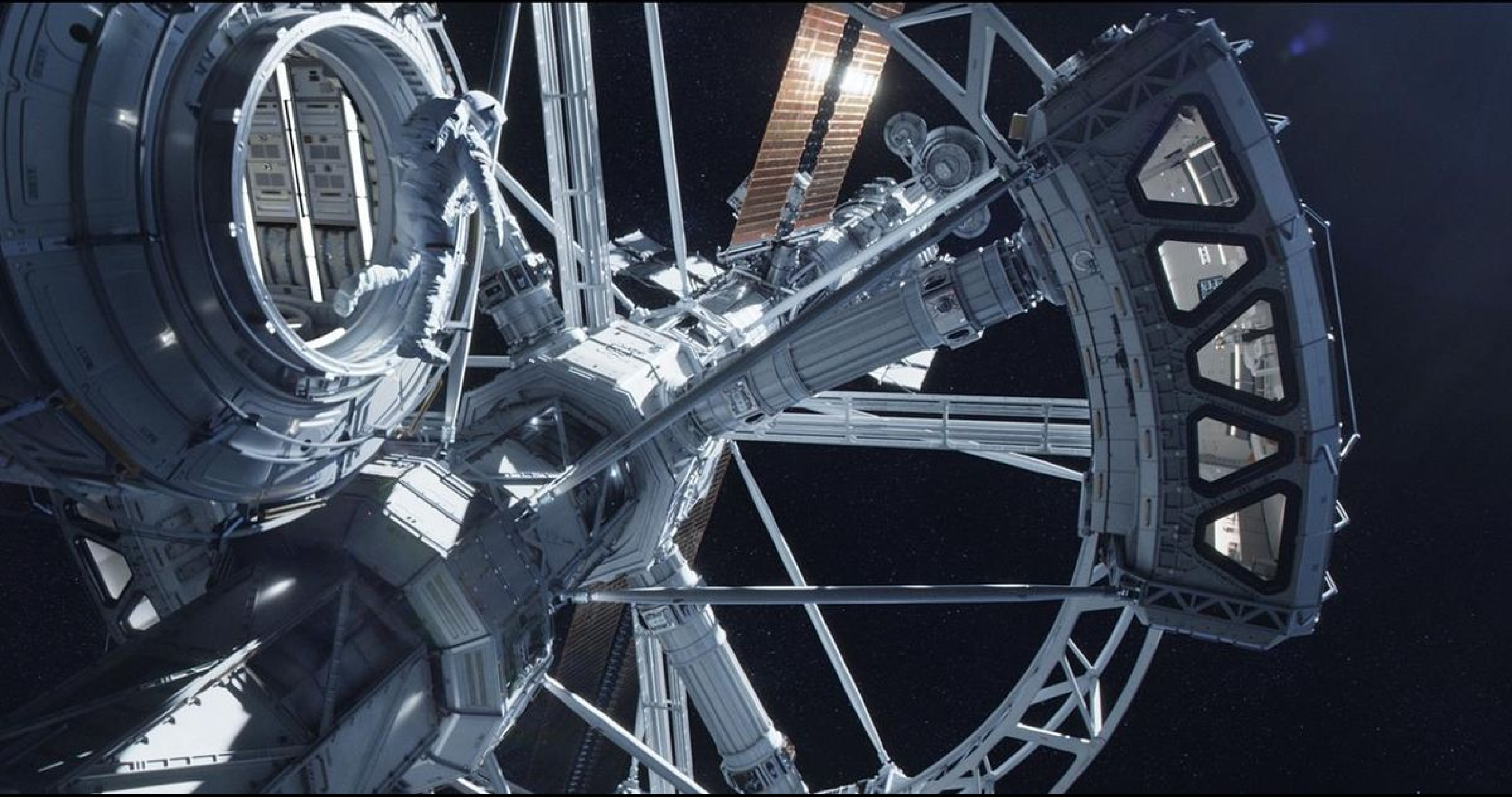
Microgravity vs. Everything Else

2.5 Meter Centrifuge War



The microgravity interests won the battle in the early '90's

Feasibility of Spun Ships

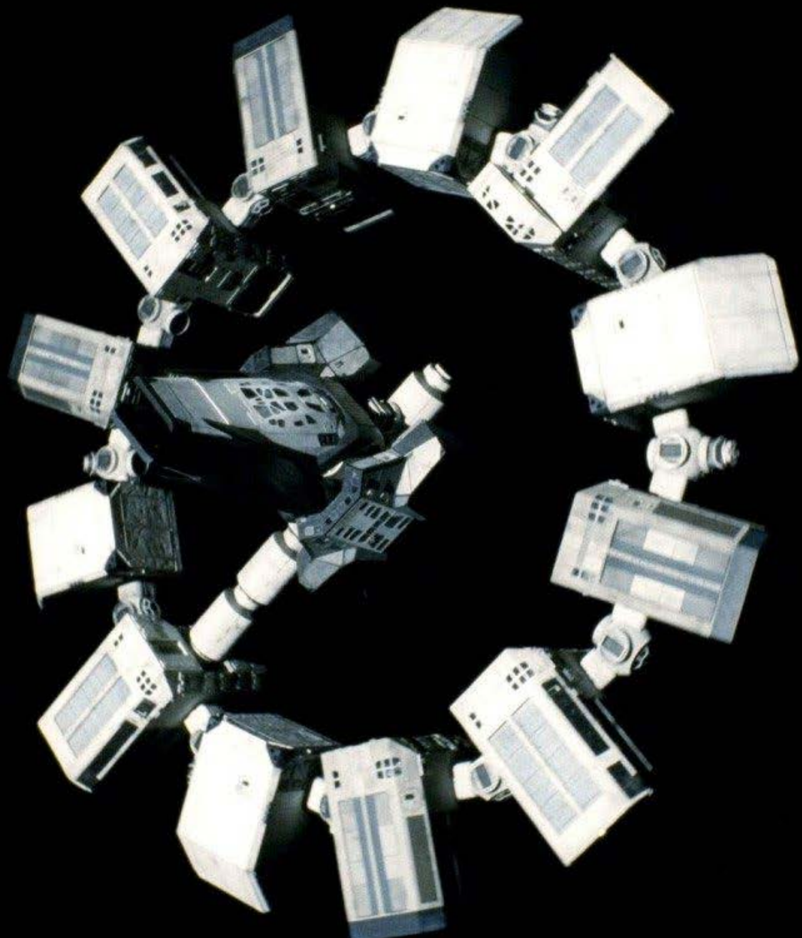


1990 Princeton Space Institute Study – 25% Gross Mass Penalty – Not Net!

The wider the arm – the fewer Coriolis force issues.

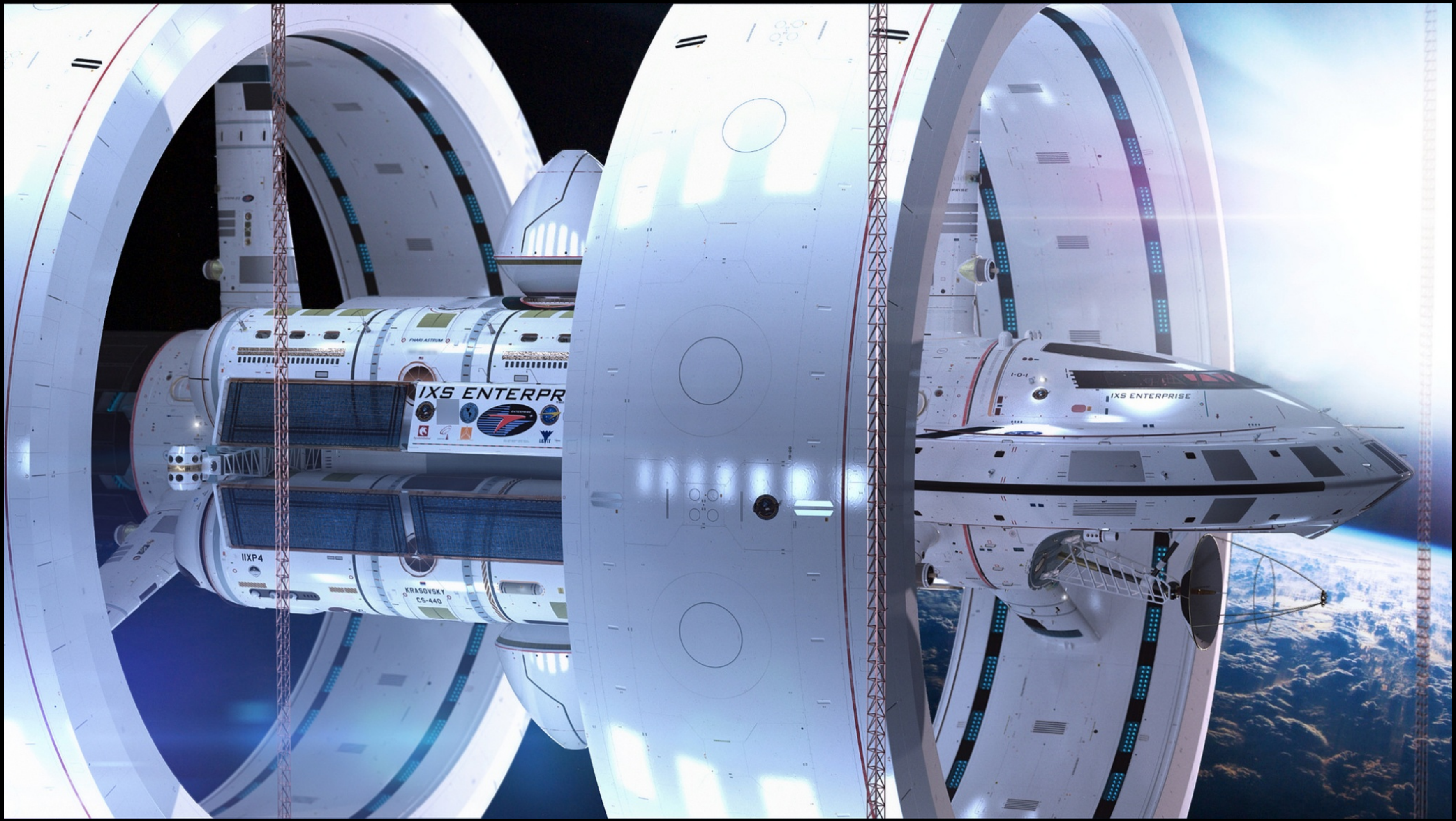
(The Martian)

It Doesn’t Even Have to Be Pretty



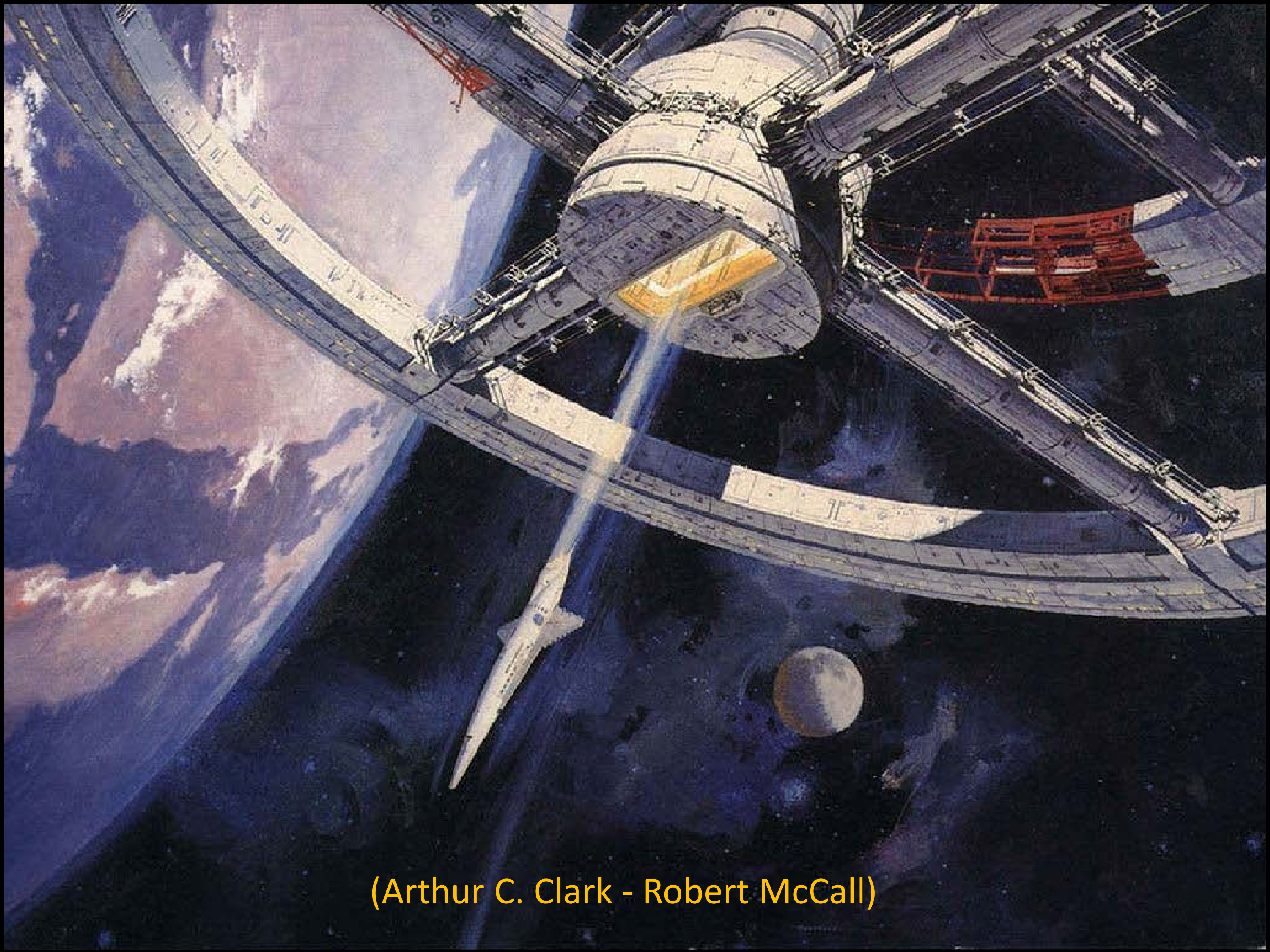
(BBC)

The Enterprise Warp Ship



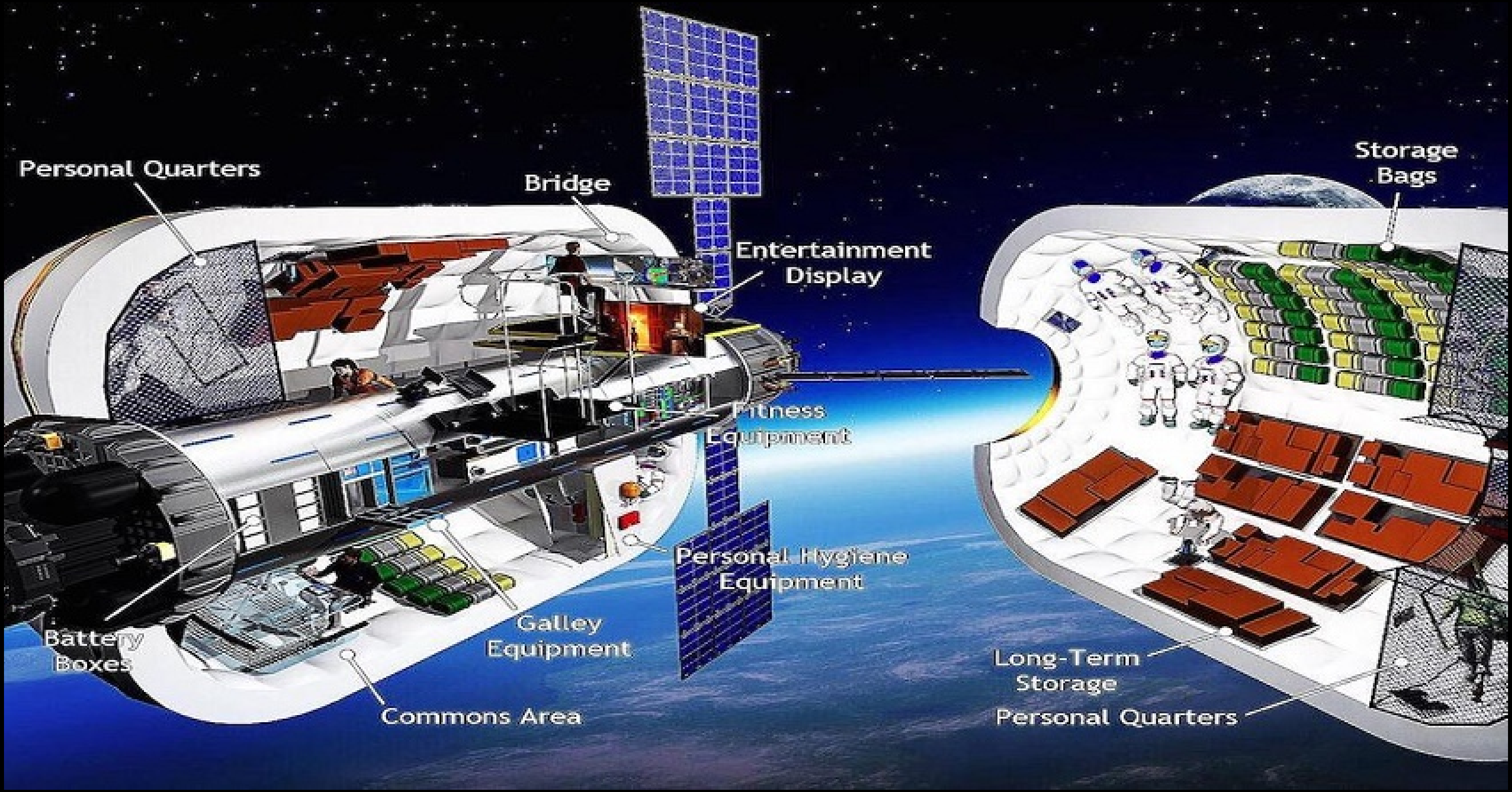
(NASA engineer and physicist Harold White)

“2001” Space Station



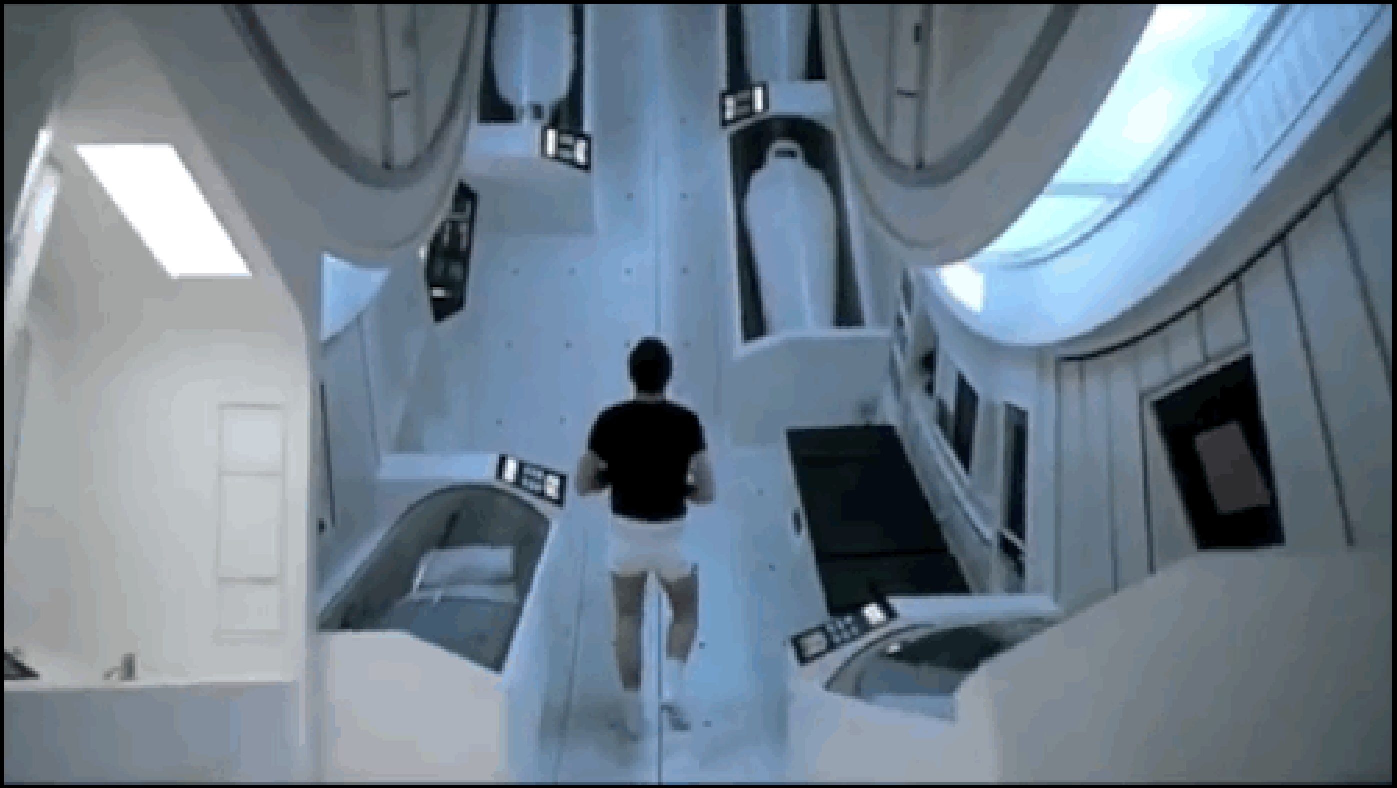
(Arthur C. Clark - Robert McCall)

Bigelow Spun Inflatable



(Robert Bigelow – some Elements Under Construction)

But The Winner Is…



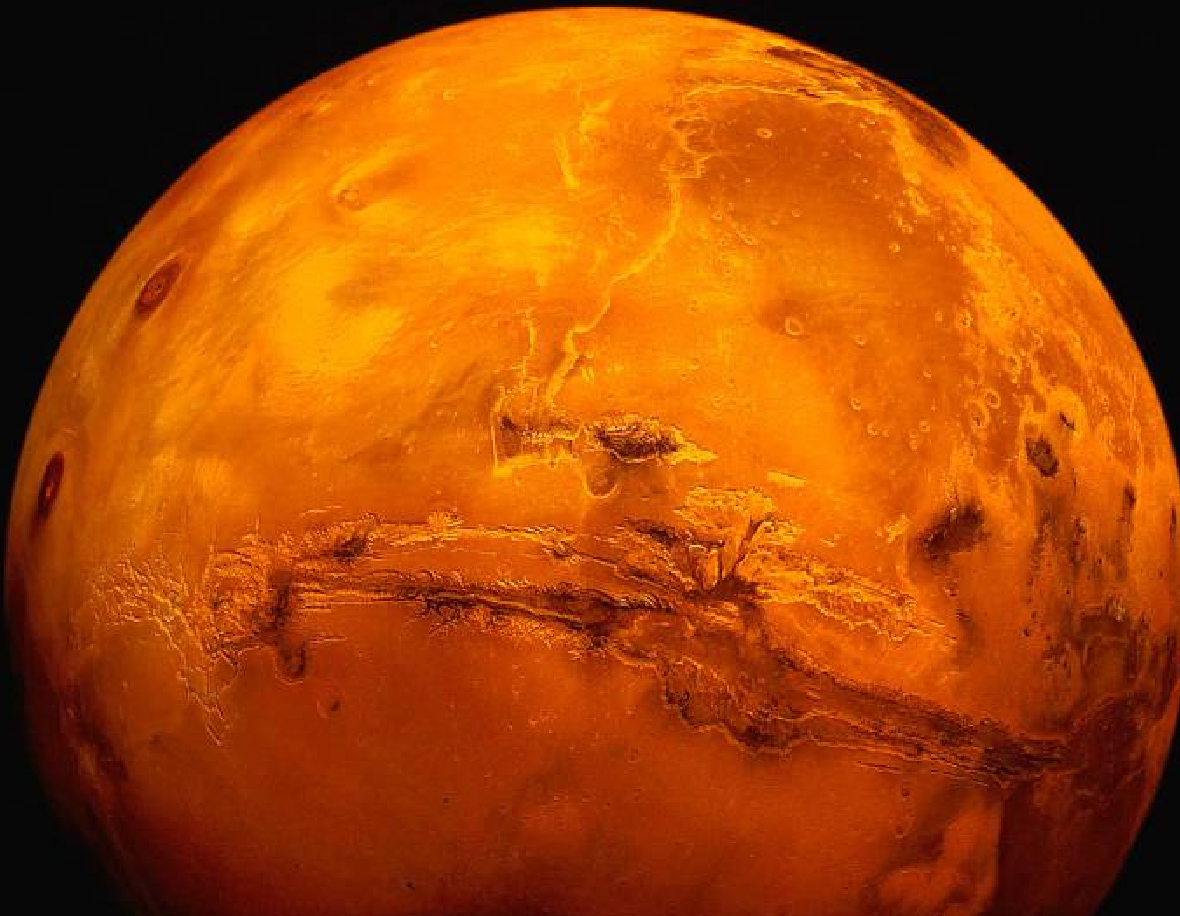
(Circa 1969 – Arthur C. Clark and Stanley Kubrick)

What Artificial Gravity Completely Resolves

- Some Space Adaptation Syndrome (replaced by some Coriolis force issues)
- Visual Impairment Inter Cranial Pressure Syndrome and Blindness
- Brain Squeezing and CNS Tissue Reconfiguration
- Cardiac Muscle Atrophy
- Musculature Atrophy
- Bone Loss
-Body Fluid Shifting – Chronic Cold Syndrome
-Partially Reduces Immunological Dysregulation
- Increased Microbiologic Virulence
- Sleeplessness
- Endemic Surface Tension Problems
- Microgravity Induced Engineering Work-Arounds
- Permanent Injuries with Lifetime Effects on Return to Earth

One Primary Lesson Learned From 57 Years of Manned Spaceflight

ALARA Is the Key to Achieving a One Normal Engineering Philosophy



The Ultimate Discovery from Scott Kelly's Findings on ISS:

NO ONE is going to Mars without Artificial Gravity!

(i.e., It's redesign time at NASA, SpaceX and Boeing!)

It is now an ETHICS issue as well as a safety and health priority.

Questions?