

"Artificial Gravity - Background and Challenges :
To Spin or Not to Spin"

Prof. Laurence R. Young – MIT
FISO Telecon 1/31/18



AG – Do we need to spin our way to Mars?

What *do* we know?

What *don't* we know?

What *must* we do before committing to AG?

We KNOW AG Works

In space (on rats!)

On ground centrifuges on humans

For cardiovascular, muscle
and maybe bone

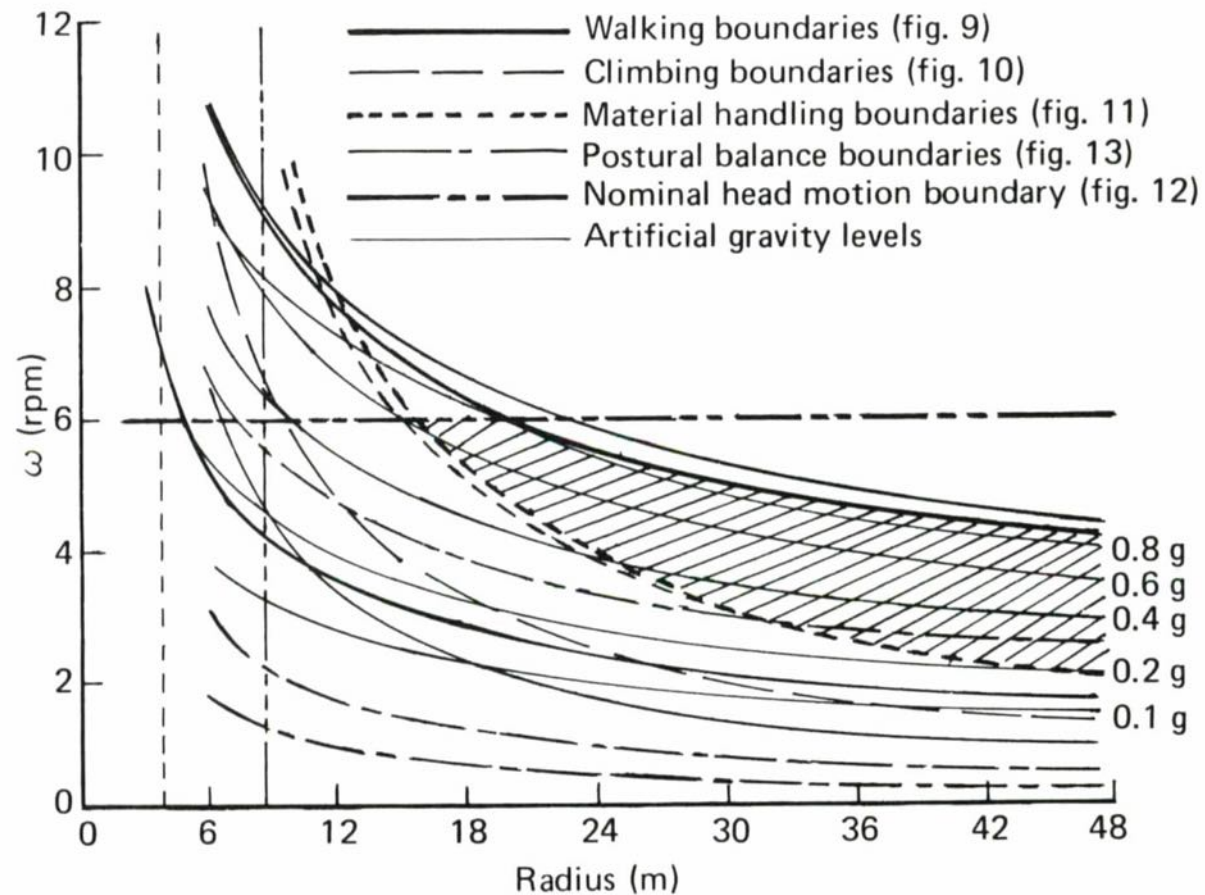
Adaptation allows varying g-levels
to be tolerated without after-effects

Best when combined with exercise.

We DON'T know

- The required AG parameters
 - G- level, radius or spin rate
 - Exposure and exercise
 - G Tolerance

Angular Velocity vs. Radius

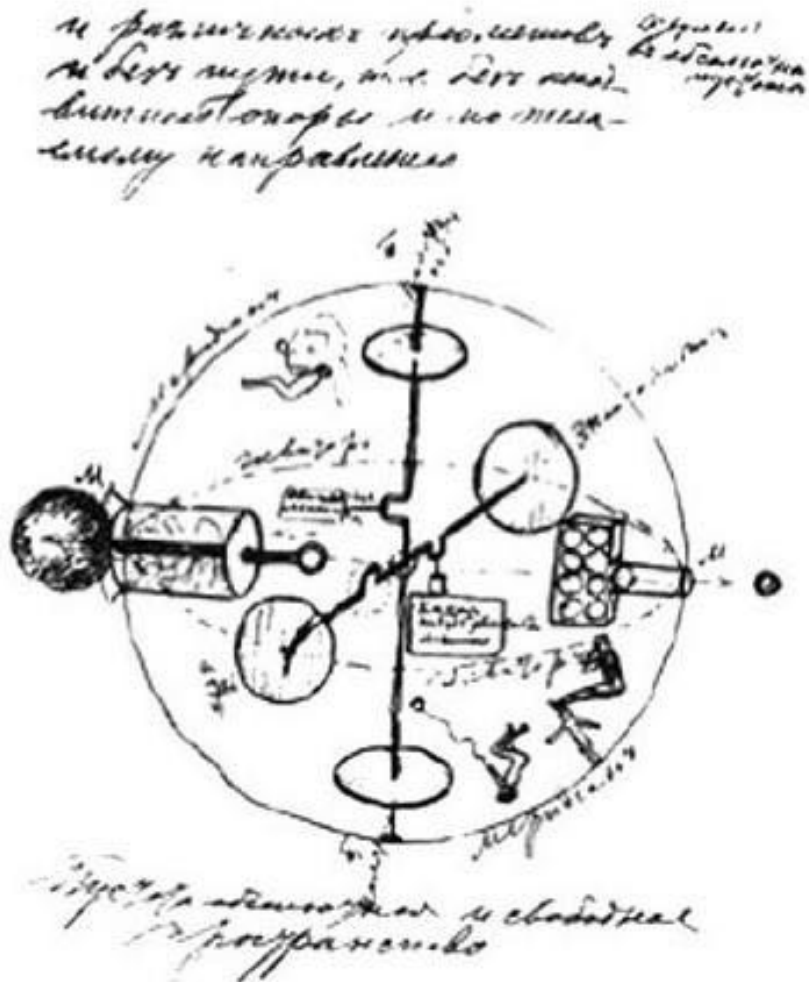


(Stone, 1970)

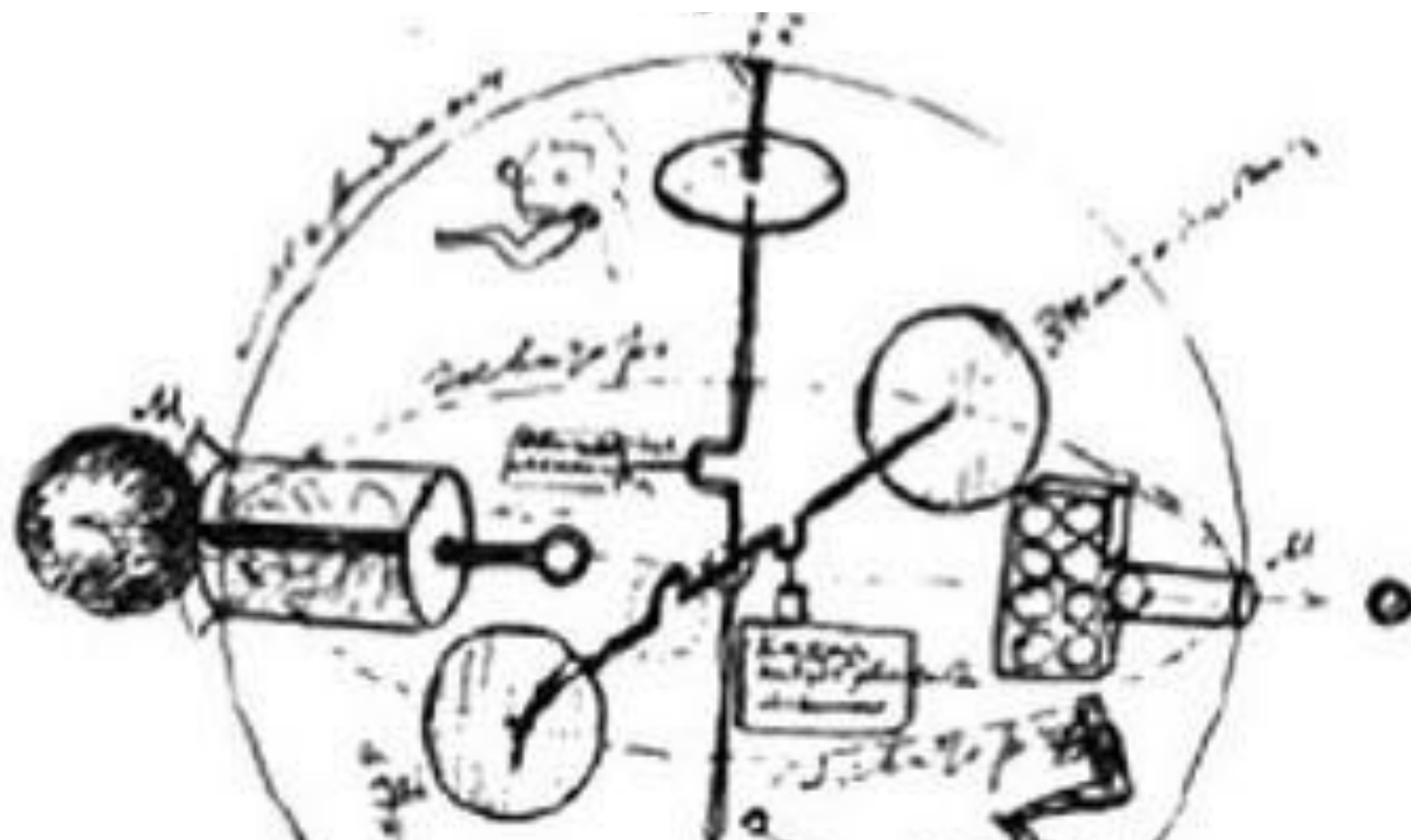
History of Artificial Gravity

Laurence R. Young
Massachusetts Institute of Technology

Very First AG Drawing

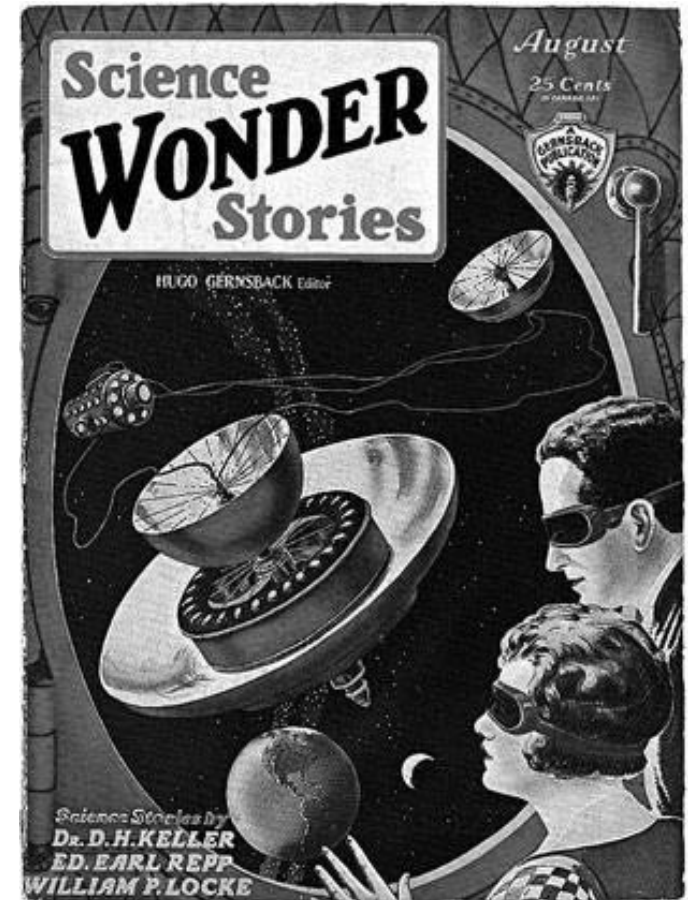


- AG was first discussed by the Russian space visionary Konstantin Tsiolkovsky in his manuscript "Free Space" in 1883.
- The manuscript was first published in 1956

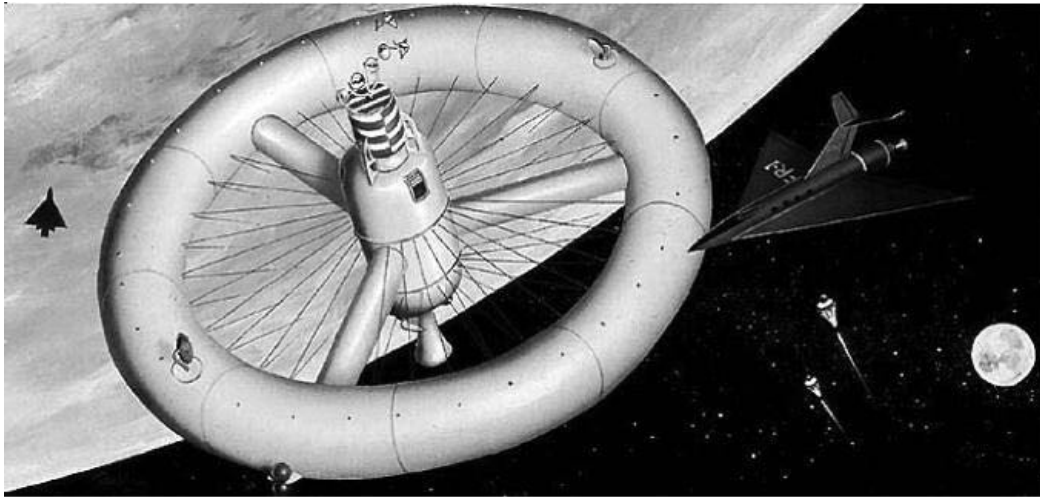


First Artificial Gravity Space Station

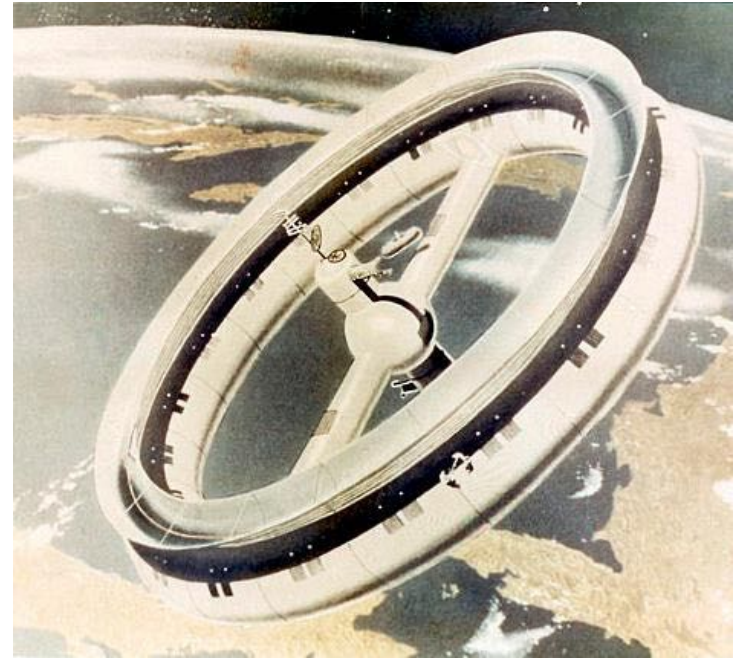
- In 1928, Austrian writer Hermann Noordung proposed an entire artificial gravity space station
 - Wheel-shaped structure
 - Power station attached to the central hub
 - Astronomical observation station



Wernher von Braun rotating wheel



Disney television series “Man in Space”, aired on ABC in 1955

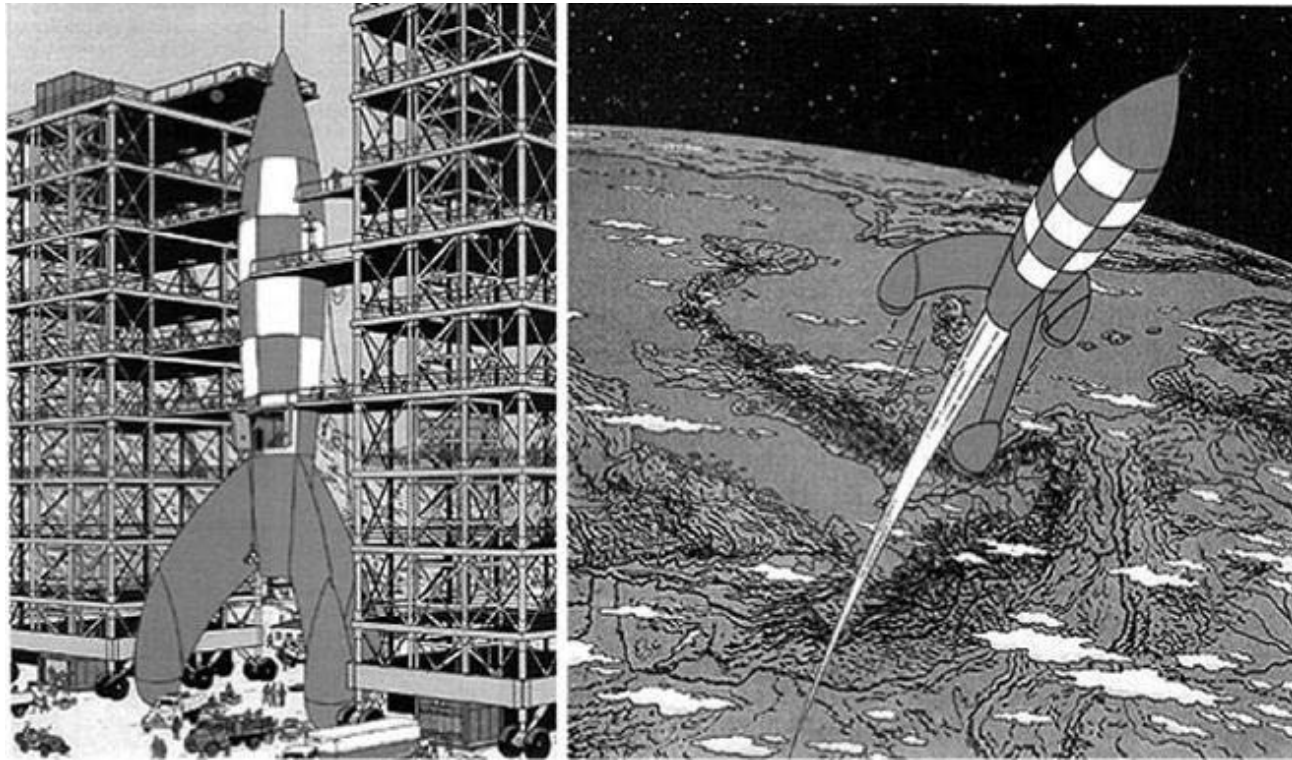


(NASA)

*Artist Chesley Bonestell,
issue of Collier’s magazine,
1952*

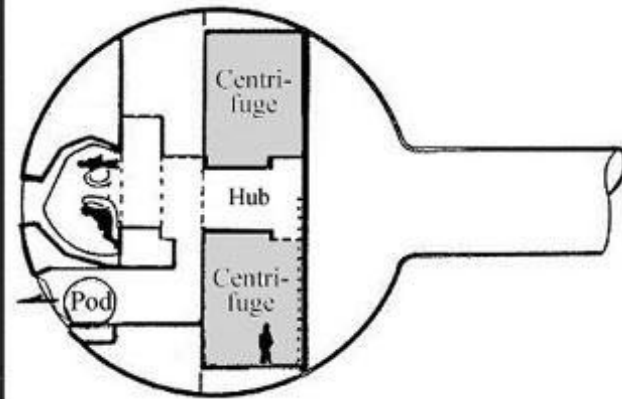
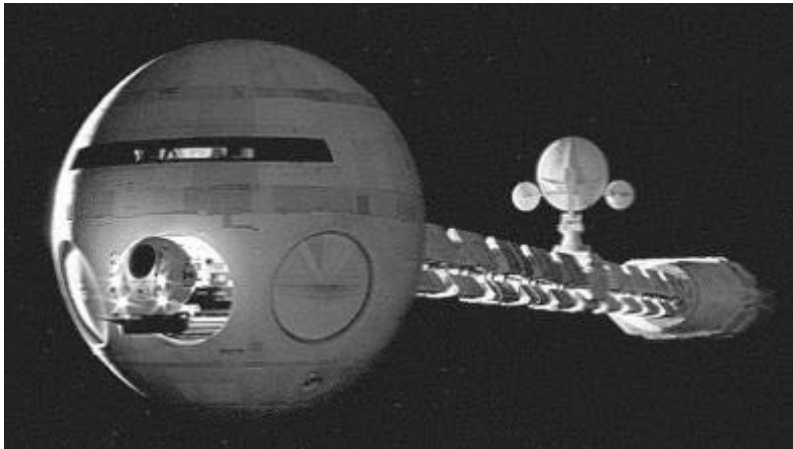
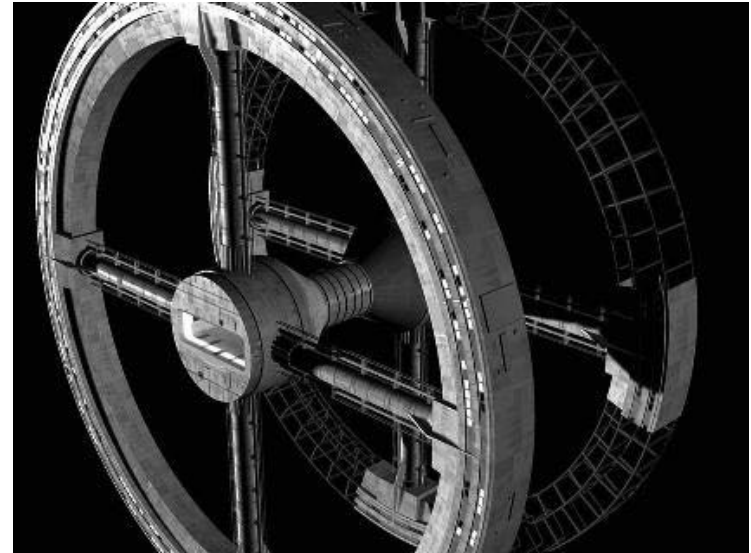
Artificial Gravity also in Cartoons

- In 1953...
 - Tintin: Destination Moon
 - Tintin: Explorers on the Moon

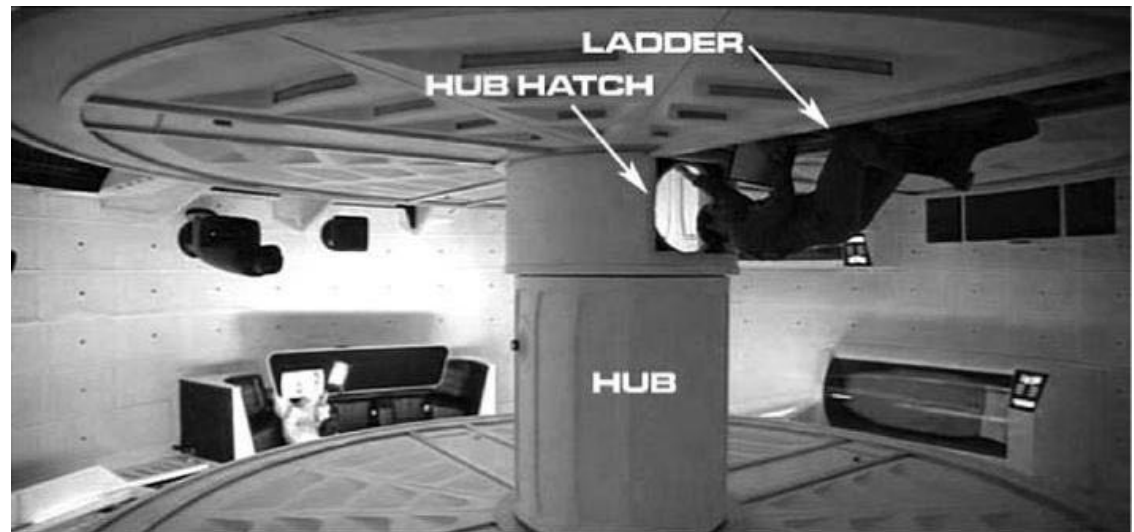
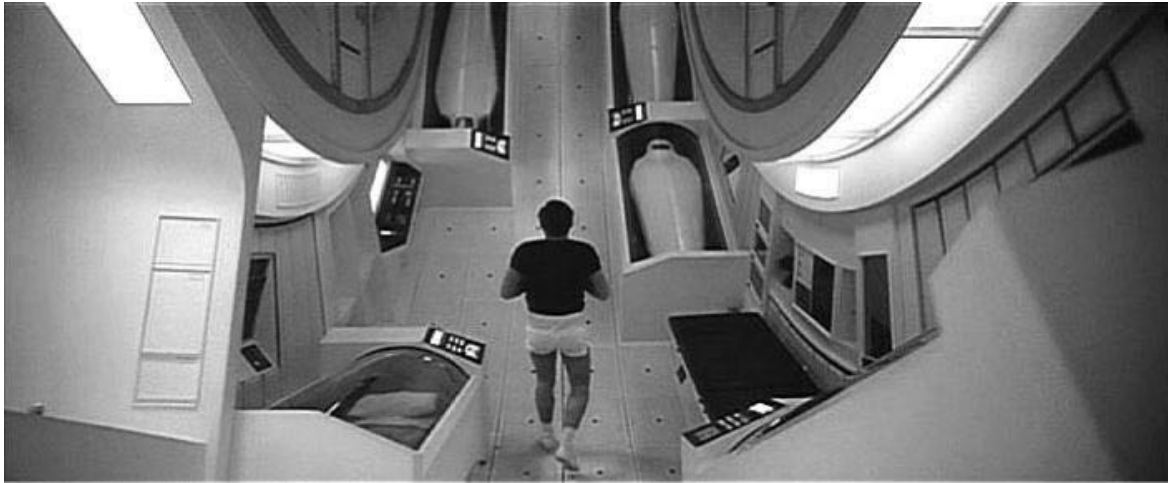


and science fiction!

- **“2001: A space Odyssey”,**
by Stanley Kubrick (1968)
 - Paired of wheels
 - Diameter: 300 m
- **“Discovery one” spacecraft**
 - Internal centrifuge



“Discovery one” centrifuge



Similar filming technique

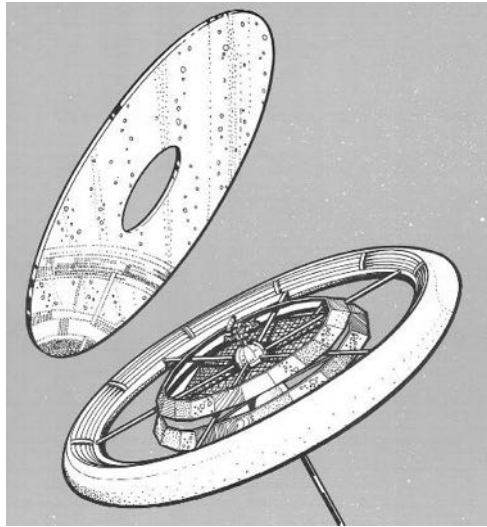
- “The Royal Wedding”, by Stanley Donen (1951)

<https://www.youtube.com/watch?v=tNrEwrlmHNQ>

1:06:30

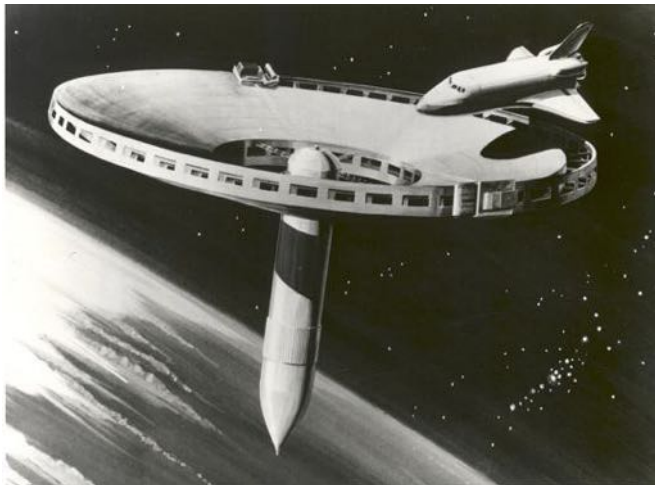


More rotating-wheel concepts



Gerard O'Neill's
vision of a space
colony with artificial
gravity, 1969

(NASA)

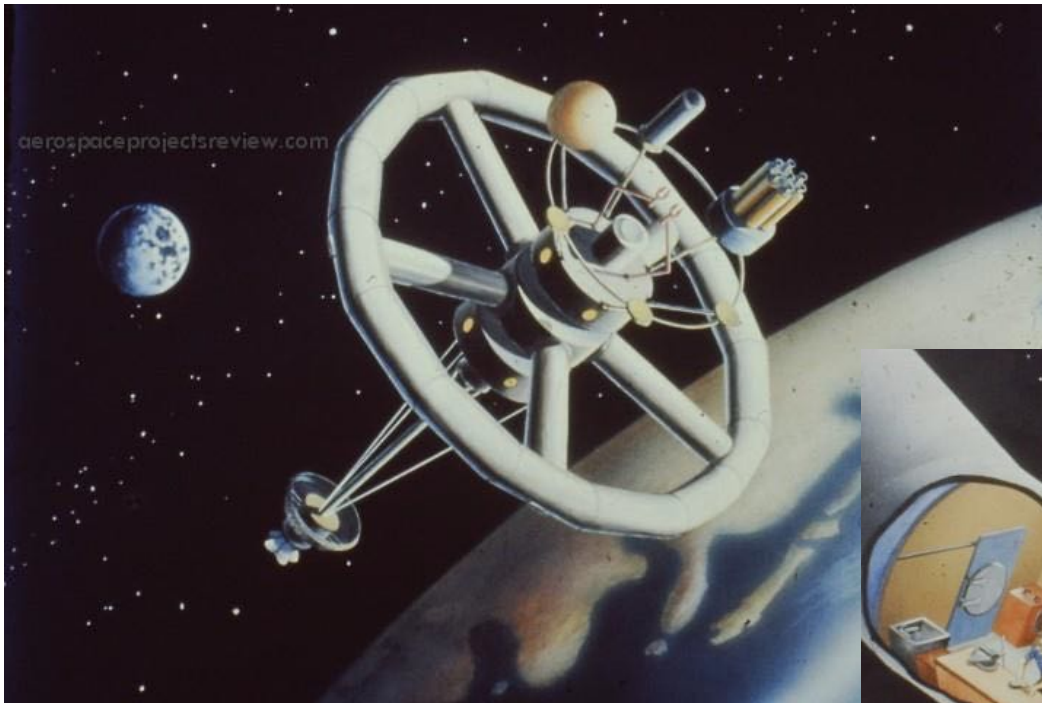


Space Station
Concept from
1977 – Spider
concept

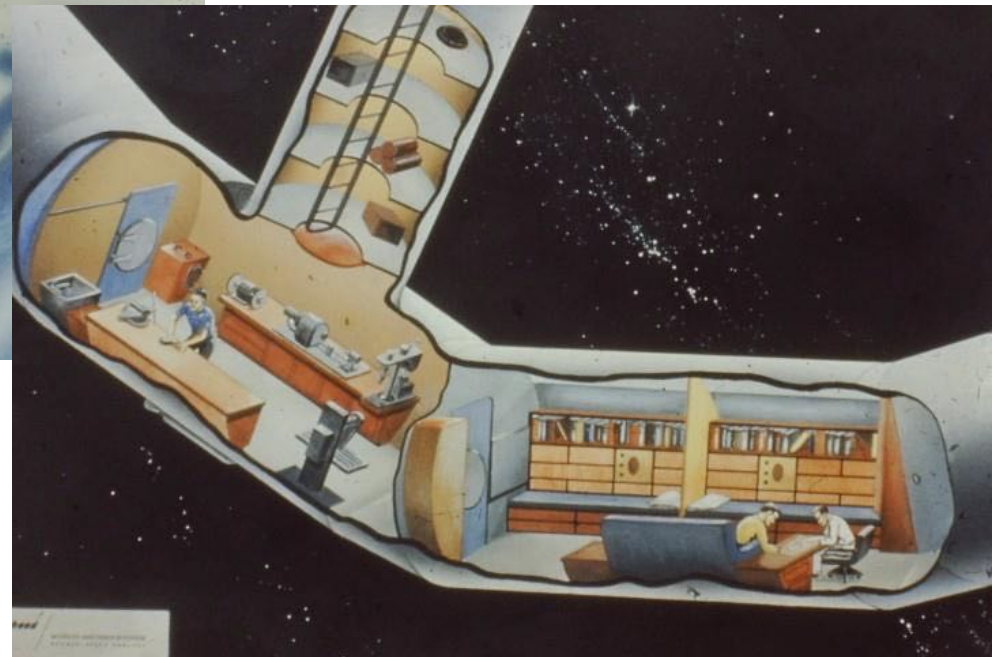


Artist conception of the inside
of a Stanford torus, 1977 (NASA)

Lockheed rotating space station (1960s)

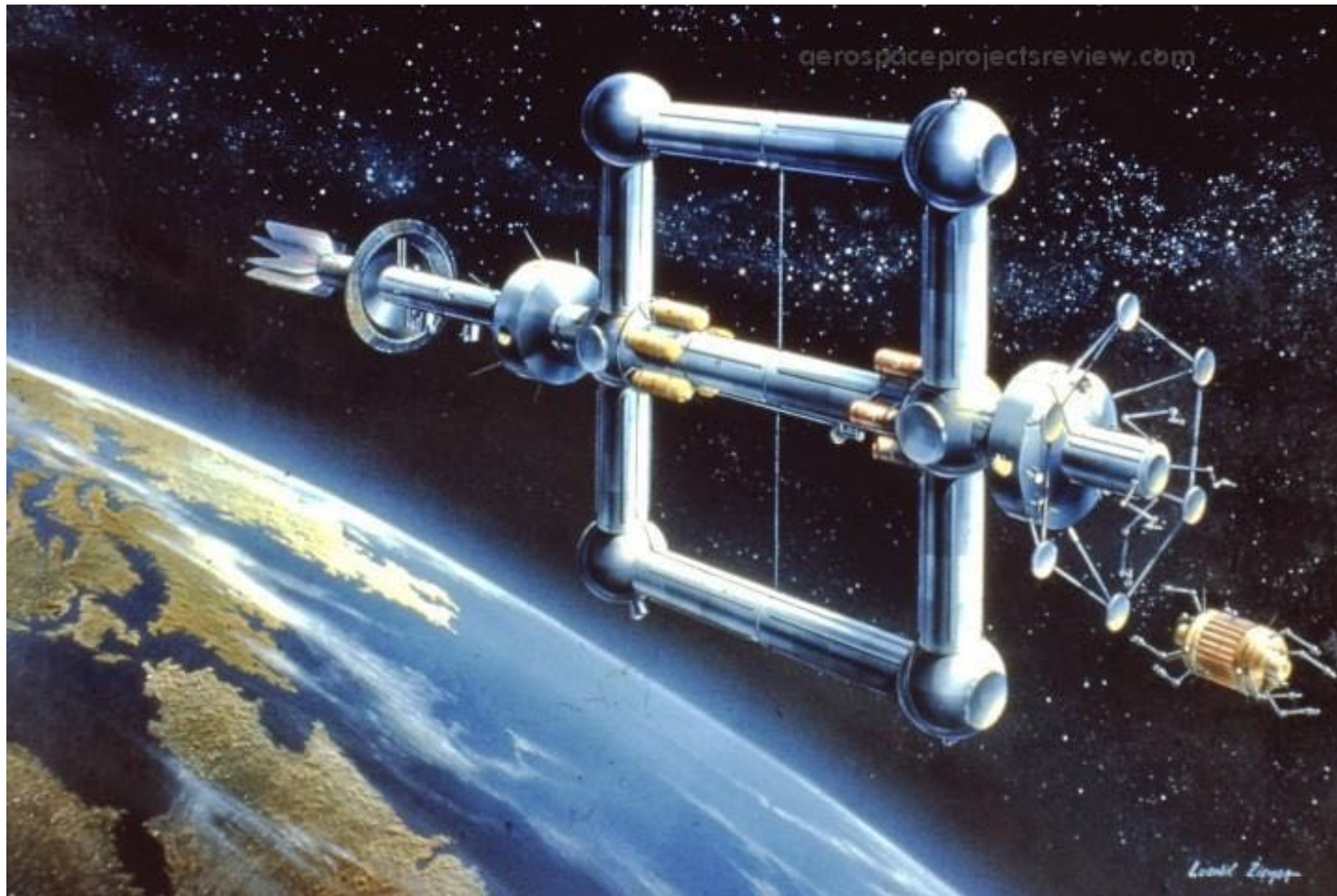


(NASA)

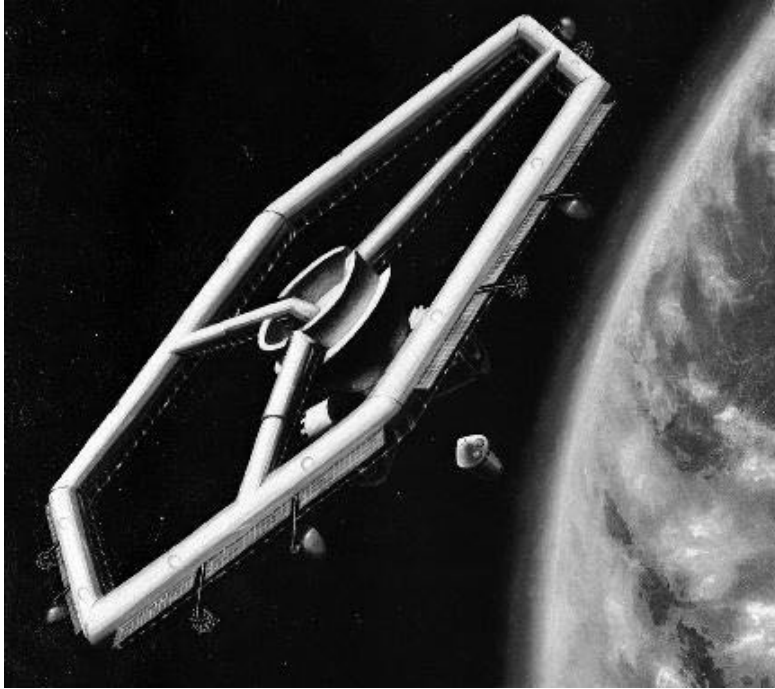


(NASA)

Lockheed modular space station – 1960s

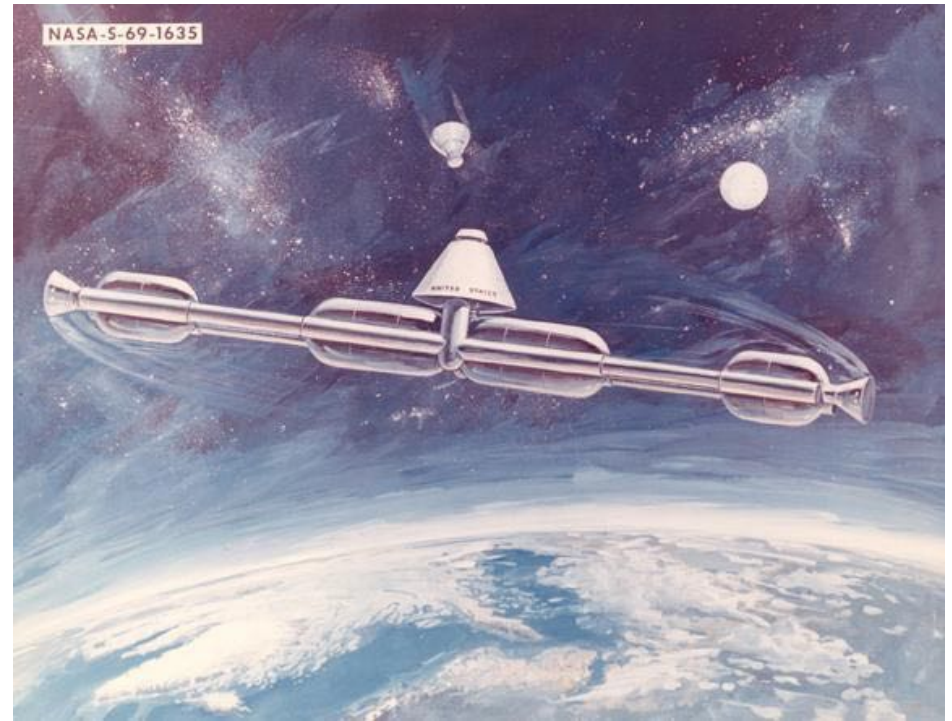


NASA Concepts



(NASA)

Self-inflating rotating hexagon;
NASA early concepts, 1962

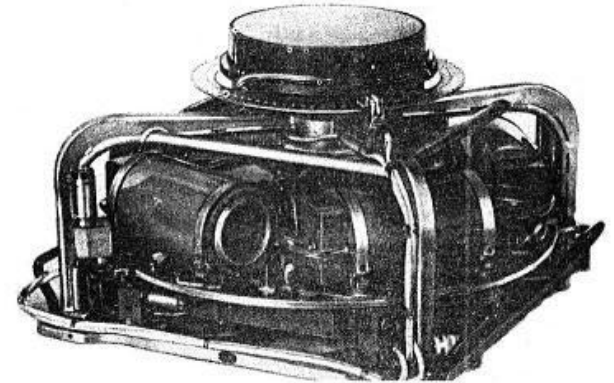


(NASA)

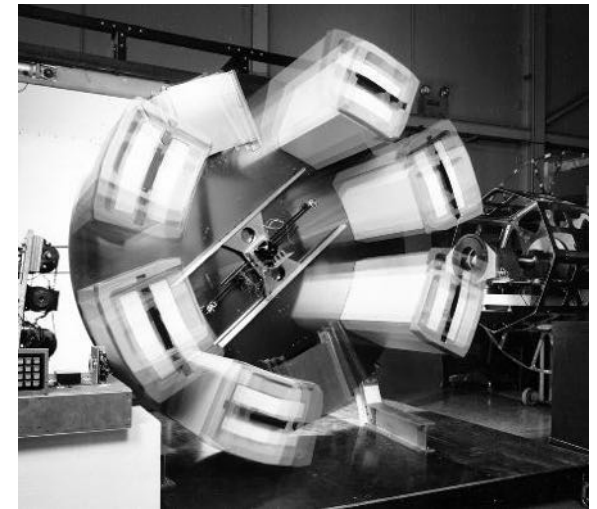
NASA space station concept, assembled
on-orbit from spent Apollo program
stages, 1969

Flight Animal Experiments

- **COSMOS missions**
 - 20-day Cosmos 782 (1975): fish and turtles centrifuged at 1g (52 rpm)
 - 19-day Cosmos 936 (1977): rats centrifuged at 1g (53.5 rpm)
- Other experiments have flown in the Spacelab (Shuttle), Skylab, Salyut, and MIR.
 - Bacteria, cells, and other biological specimens
- Project to install a 2.5m-radius centrifuge on the ISS
 - Large range (0.01 to 1g) and huge variety of species
 - Unfortunately cancelled



Centrifuge for housing rats on Cosmos missions (Adamovich et al.)



Ground test of the 2.5 m centrifuge at AMES (NASA)

Humans under Artificial Gravity

- **Gemini-11 (1966)**

- First (and only) attempt of an artificial gravity space station
- Spacecraft connected to an Agena rocket casing using a tether
- 0.15 rpm; 0.0005g of AG for 4h

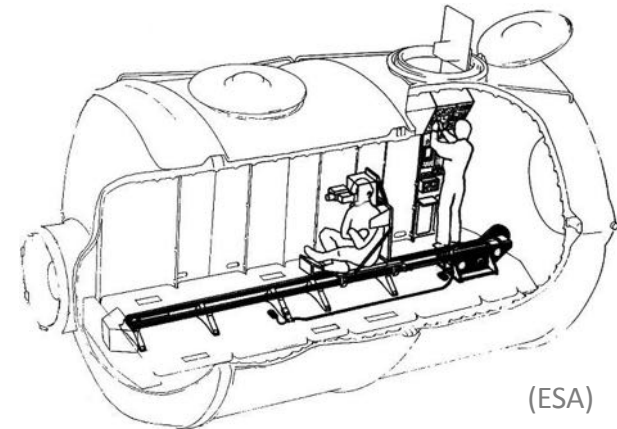


(NASA)

Astronauts Charles Conrad and Richard F. Gordon, from Gemini-11

- **Spacelab D-1 (1985)**

- Linear accelerations from 0.2 to 1g
- Limited track length of 2.5 m
- Interaural & longitudinal directions

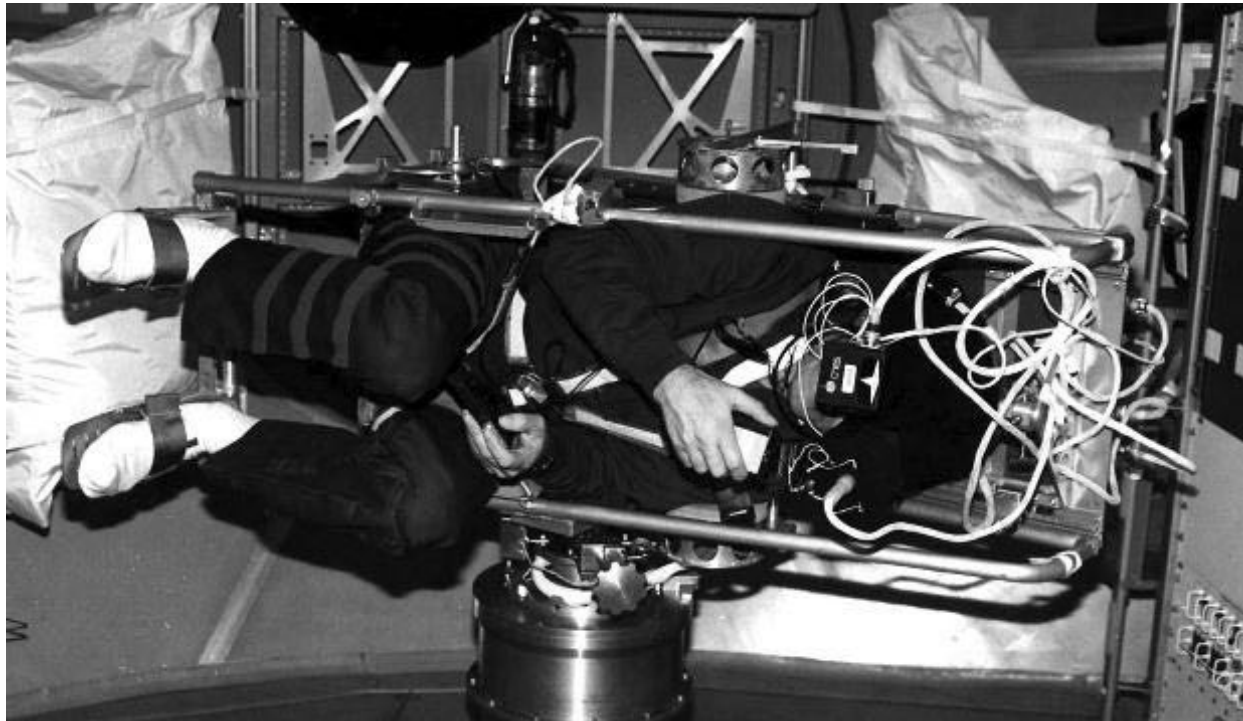


(ESA)

ESA linear sled on board the Spacelab D-1

IML-1 STS-42

- **Microgravity Vestibular Investigations (1992)**
 - Spacelab International Microgravity Laboratory (IML-1)

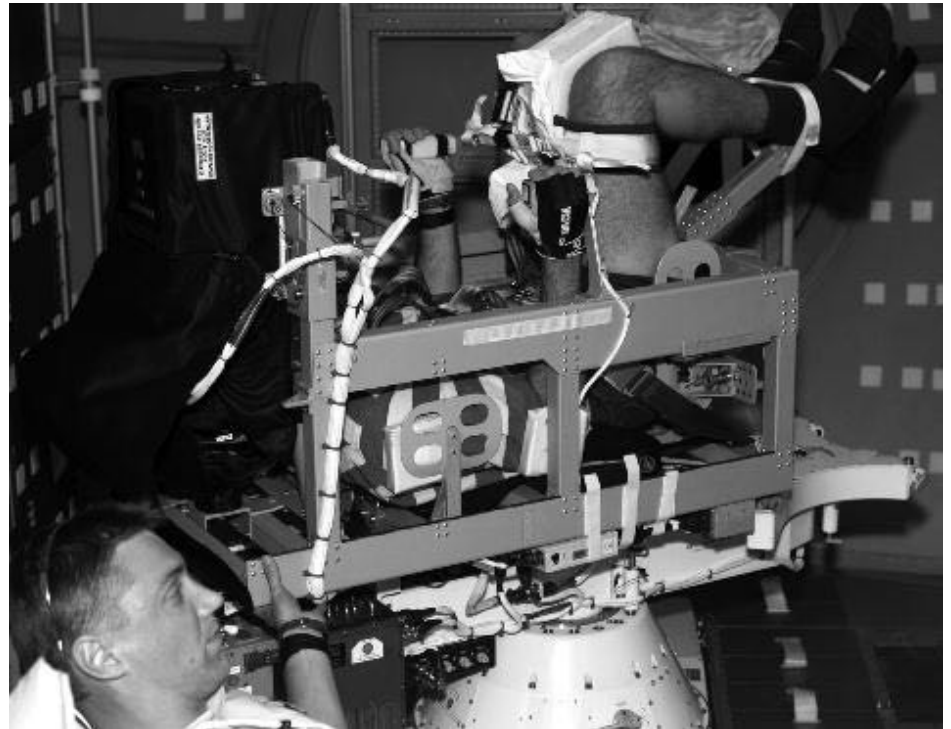


(NASA)

Neurolab mission STS-90

- **ESA off-axis rotator (1998)**

- Eyes movement and perception were recorded
- Total exposure of subjects to AG during 16-day mission: 45-60 min
 - Radius: 0.5-0.65 m;
 - Artificial Gravity: 0.5g & 1g
 - Directions: $\pm G_y$, $-G_z$

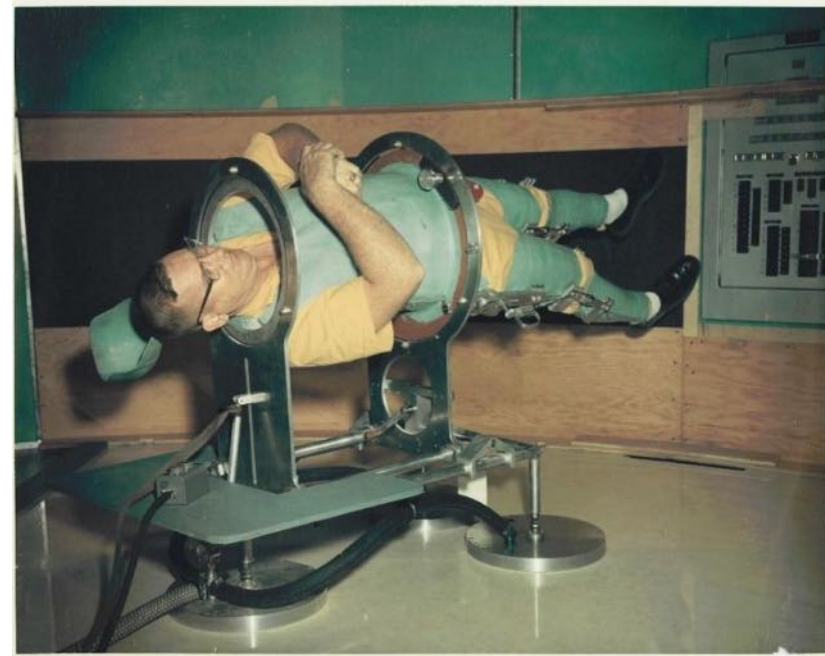


(NASA)

Brandeis Slow Rotating Room



(Lackner)



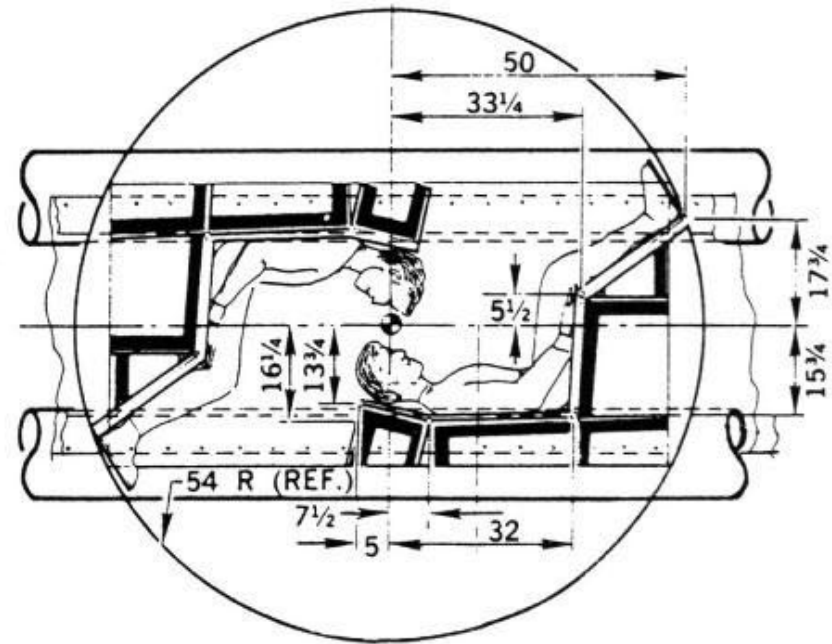
- [VTS 02 1.VOB](#)
- [VTS 05 1.VOB](#)
- [Graybiel NOVA Clip.mov](#)

Short-radius centrifuges



- “Artificial gravity is an idea whose time has come around, ...and around, ...and around, ...”
- --Prof Laurence R. Young, Department of Aeronautics and Astronautics, Massachusetts Institute of Technology.

- **Douglas Aircraft Co. short radius centrifuge** (White et al. 1965)
 - Two subjects simultaneously
 - Heads slightly off-center

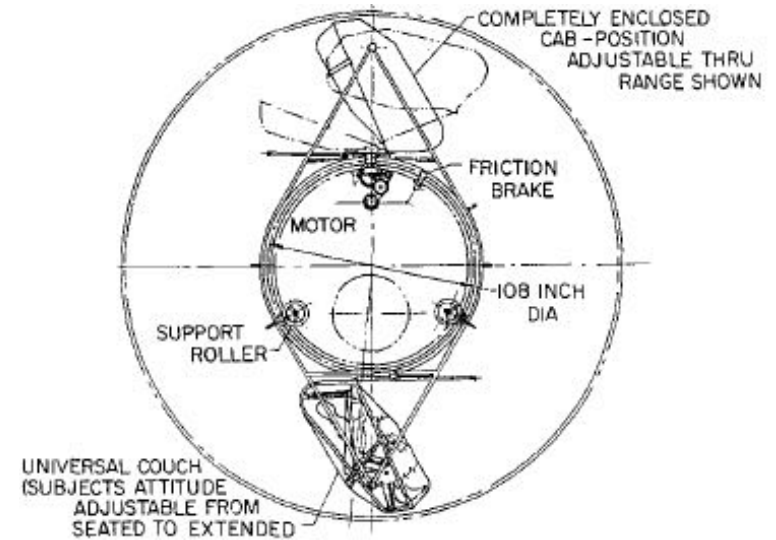


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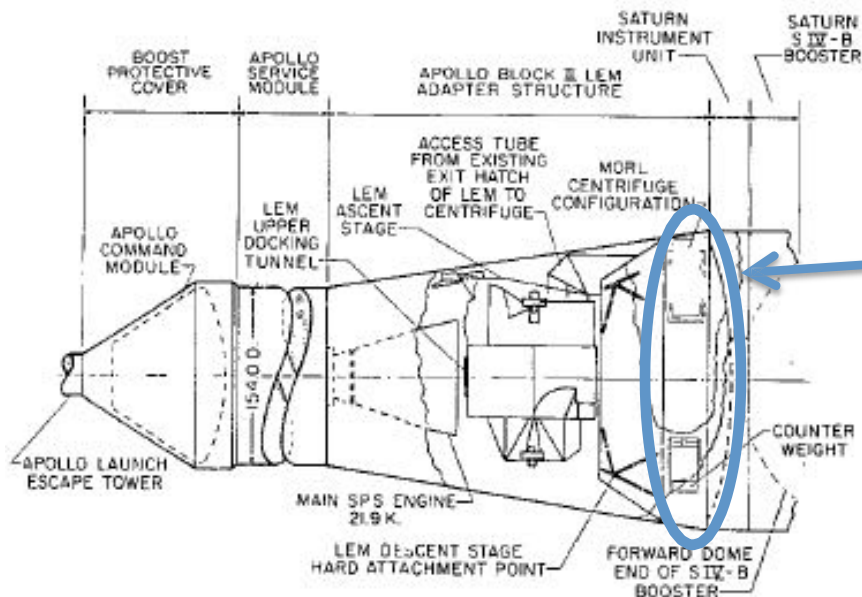
Flight concepts

- Manned Orbital Research Laboratory (MORL)

- Flight vehicle concept developed by Langley Research Center
- Onboard centrifuge in the proposed spacecraft
 - 22-foot diameter
 - Two enclosed and adjustable cabs



MORL internal centrifuge



- Centrifuge on Apollo-LEM vehicles

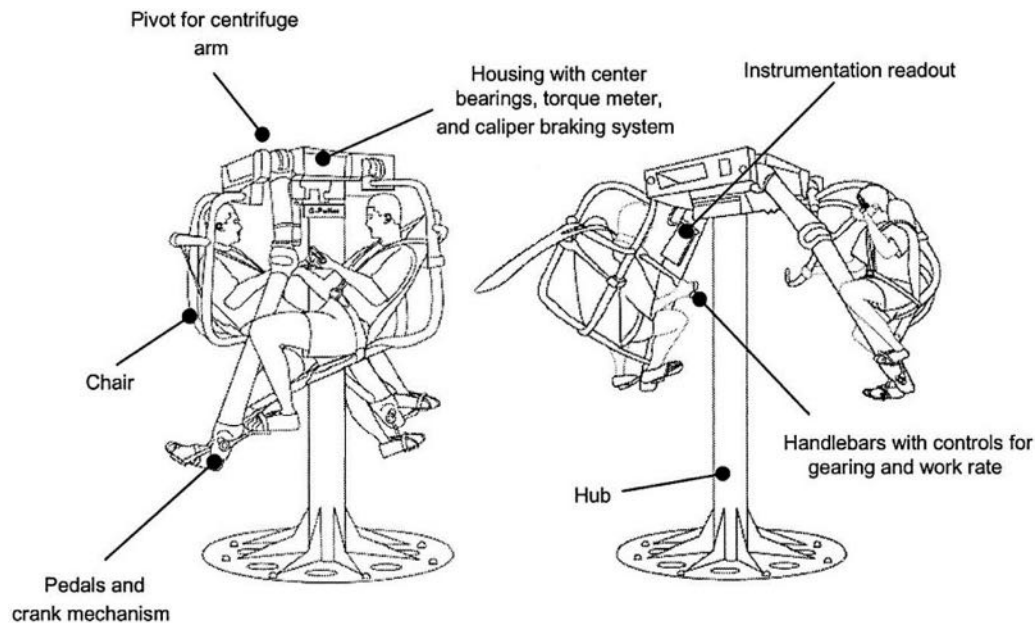
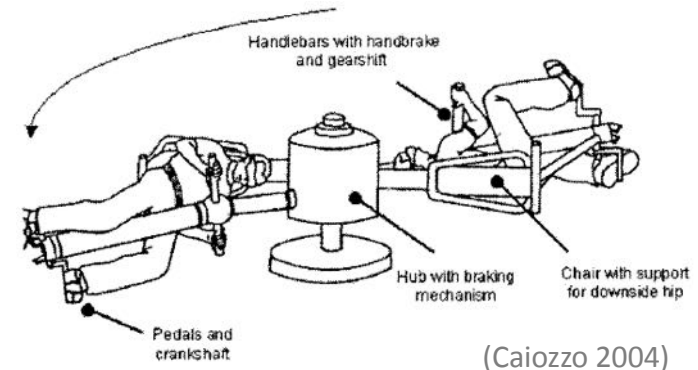
- Similar characteristics as MORL
- Only for one subject
- A counterbalance is required

Possible centrifuge on the Apollo LEM vehicle

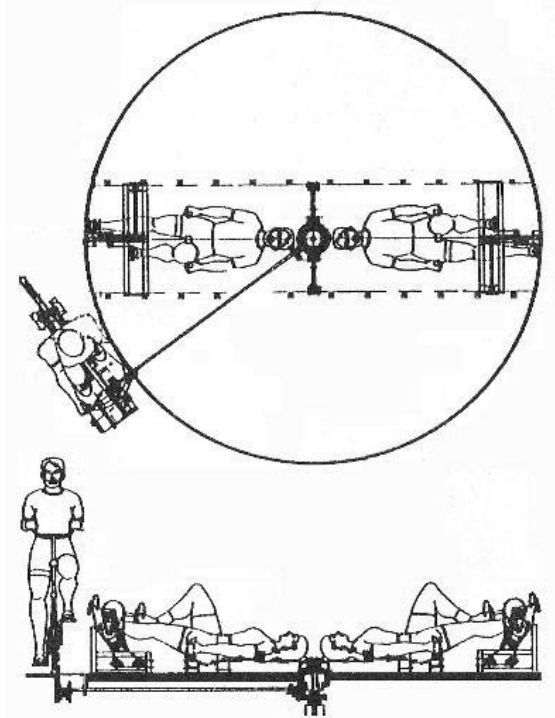
(Stone 1966)

Ground based - Space Cycle

- University of California Irvine
- Human Powered Centrifuge
- 1 to 5 g
- Squats or other type of exercise

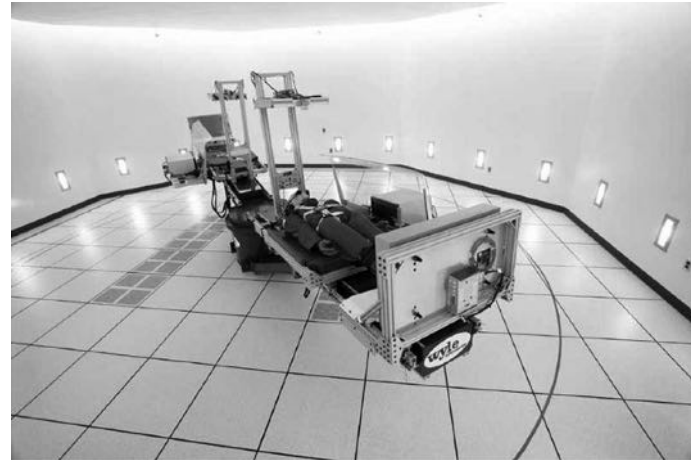


More Short-Radius Centrifuges



(Greenleaf et al. 1996)

- **NASA Ames**
 - Powered by the subjects or and off-board operator



(NASA)

- **NASA/Wyle University of Texas**



- **ESA bed rest centrifuge** (ESA)

Long-Radius Centrifuges



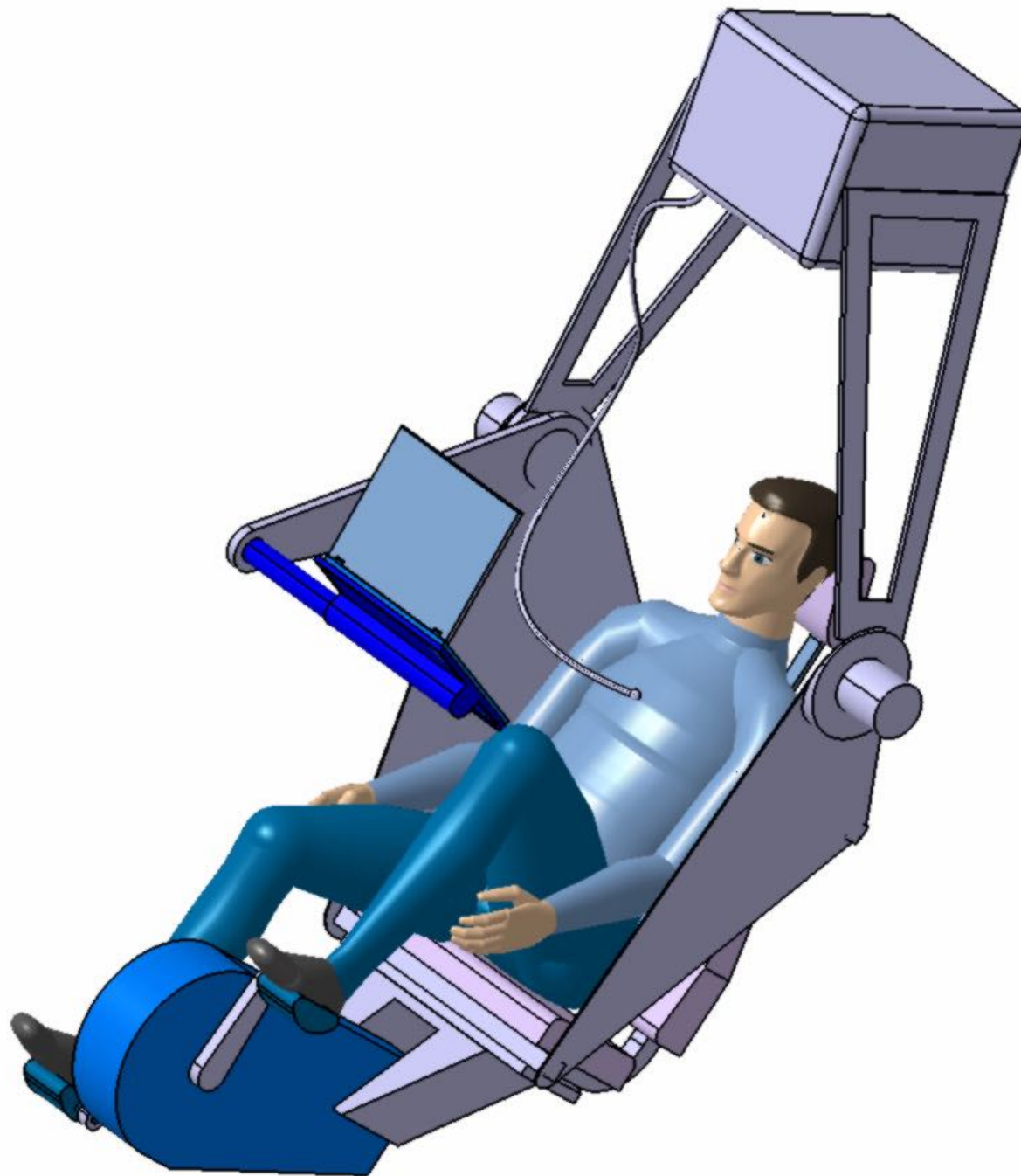
(NASA)

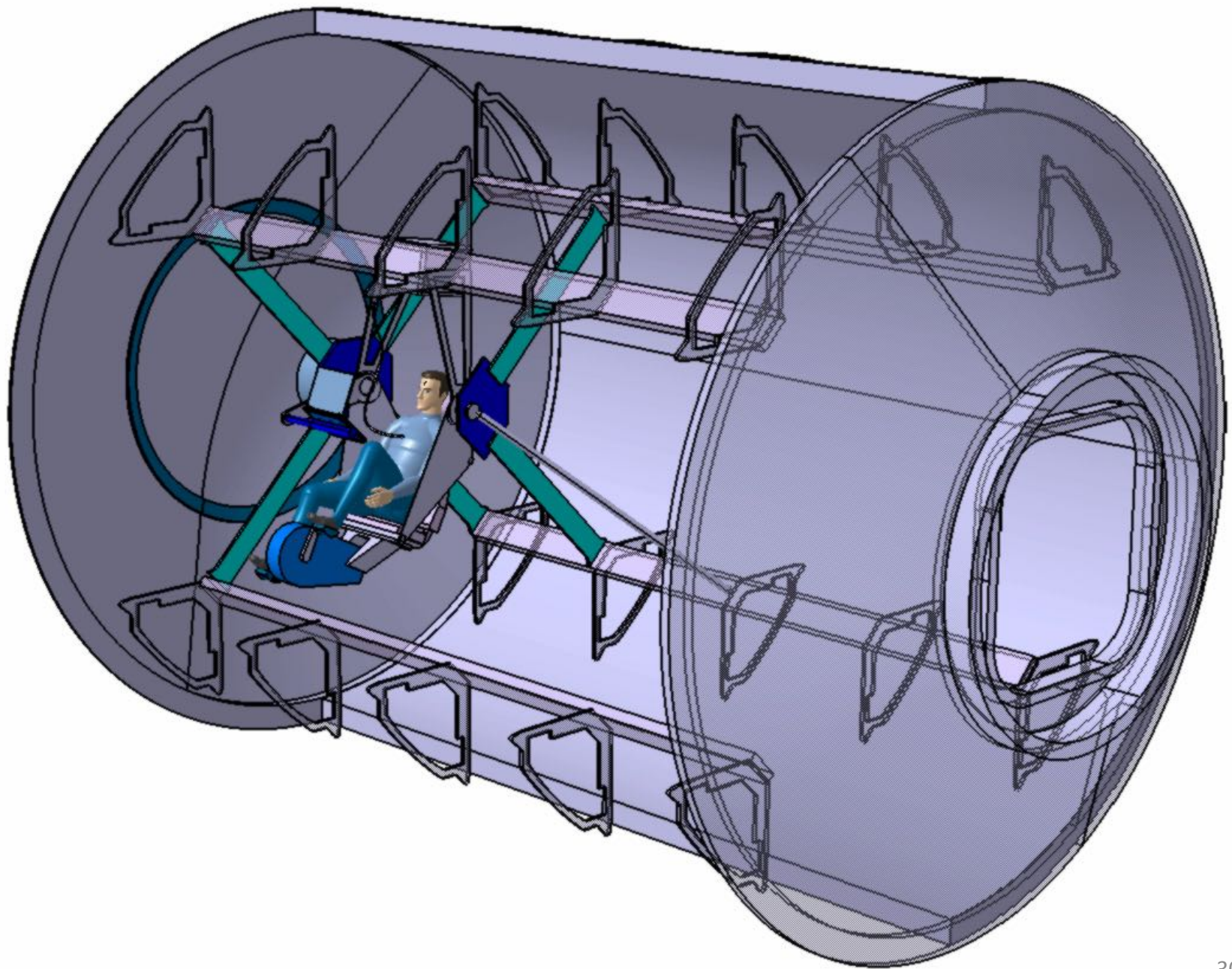
- **US Navy Aviation Medical Acceleration Lab, Johnsville**
 - First long-radius human-rated centrifuge
 - Mercury astronauts training

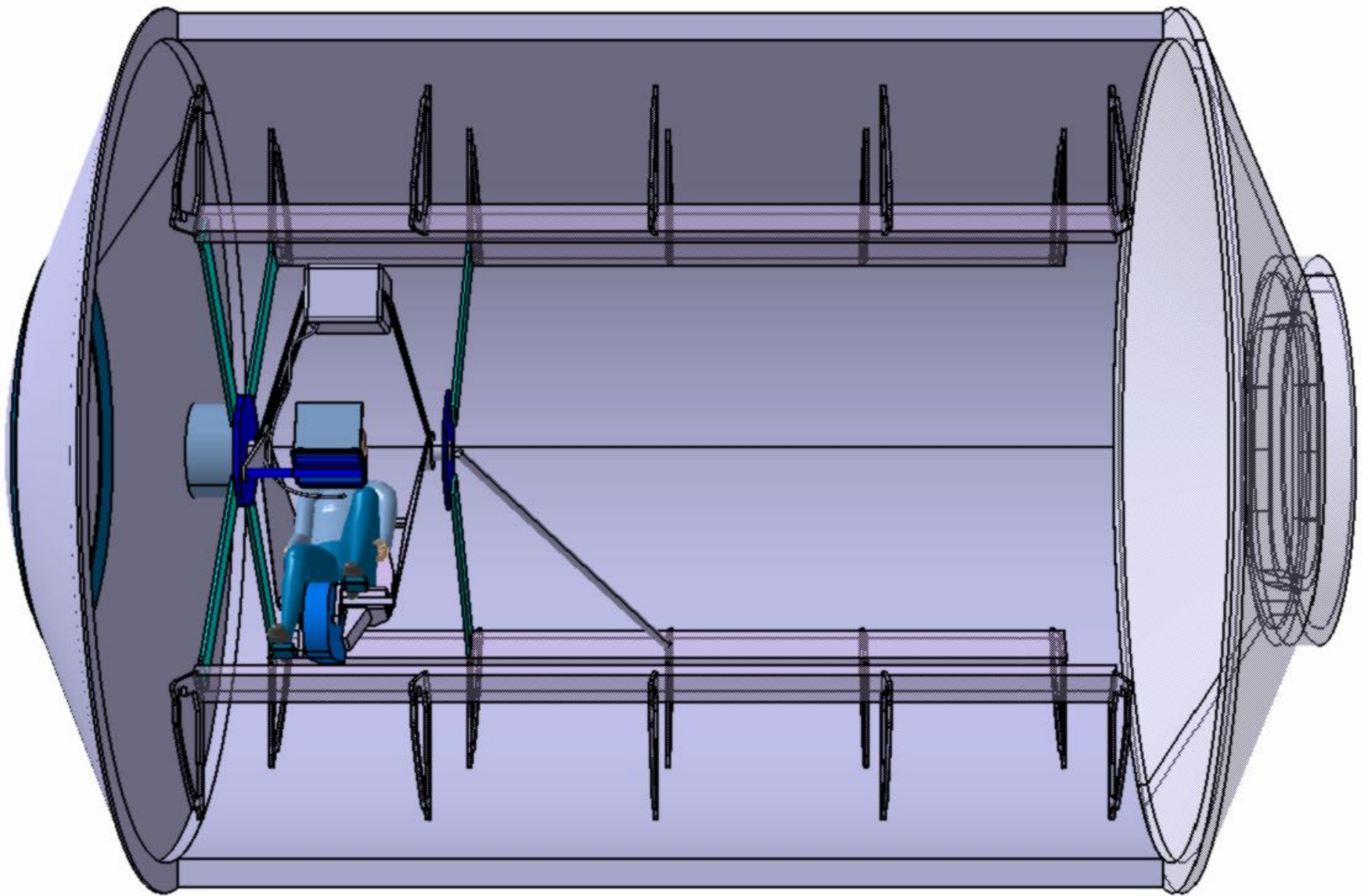


(NASA)

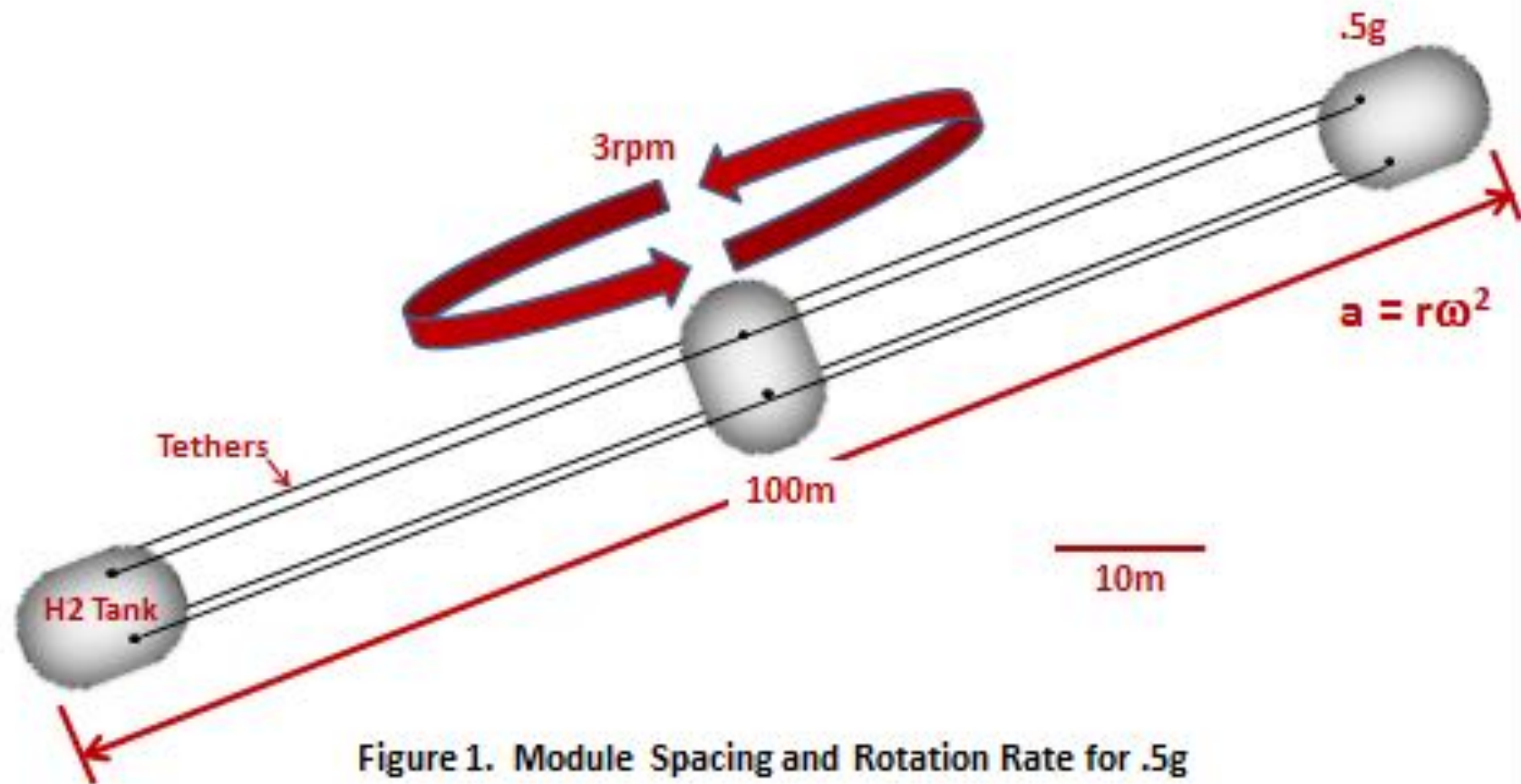
- **Brooks Air Force Base, San Antonio**



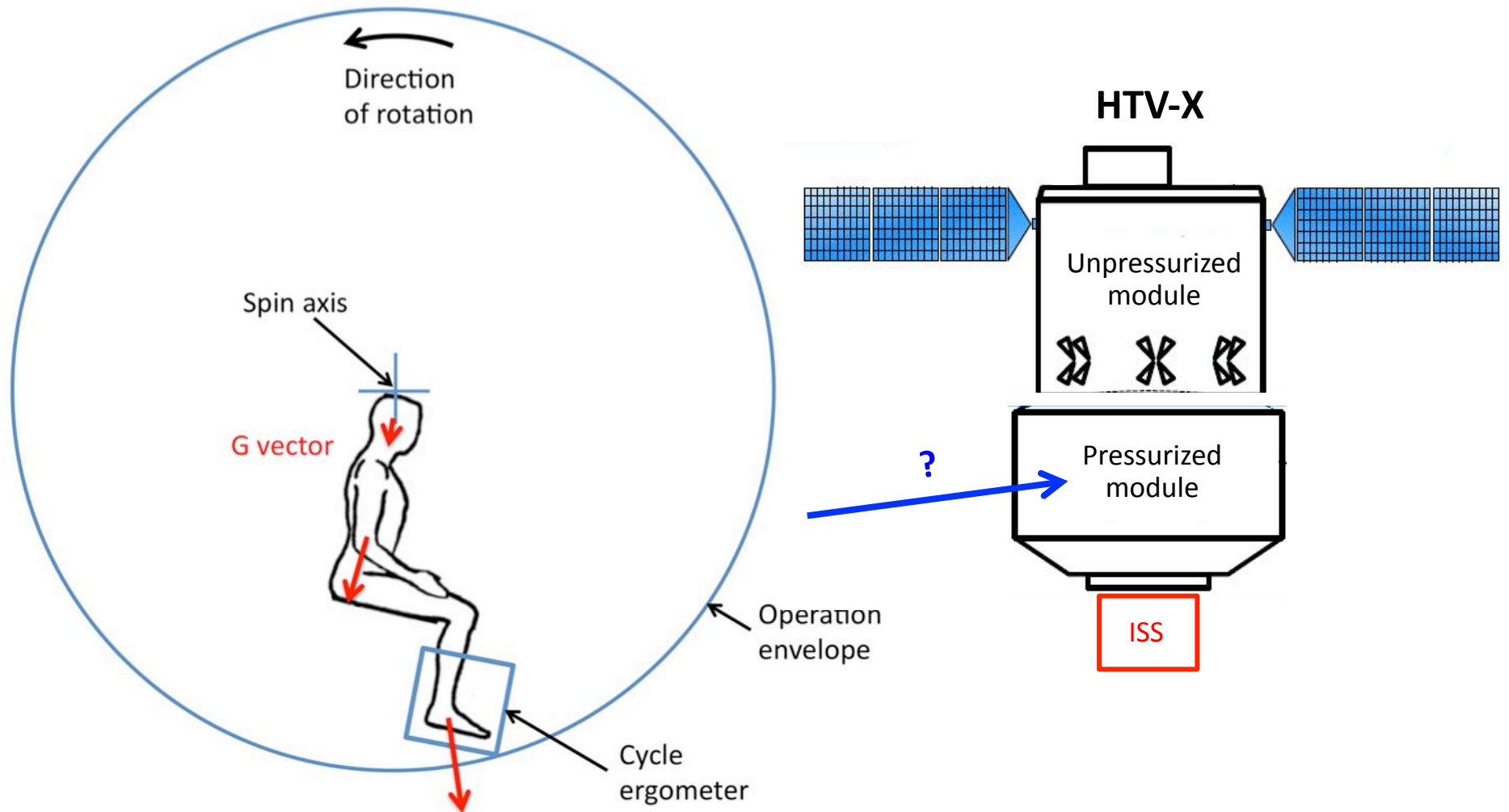




SKYLAB 2g (Savage)



Preliminary Design for HTV-X



Now – What Remains

- Conduct animal AG testing on the ISS
- Prepare an AG Countermeasure Demo
- Plan for a short and mid-radius AG for H2M
- *This work is supported by the National Space Biomedical Institute through NASA NCC 9-58*

Let's Go to Mars!

