Master Forum 19

May 12, 2010

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Human Adaptation and Countermeasures
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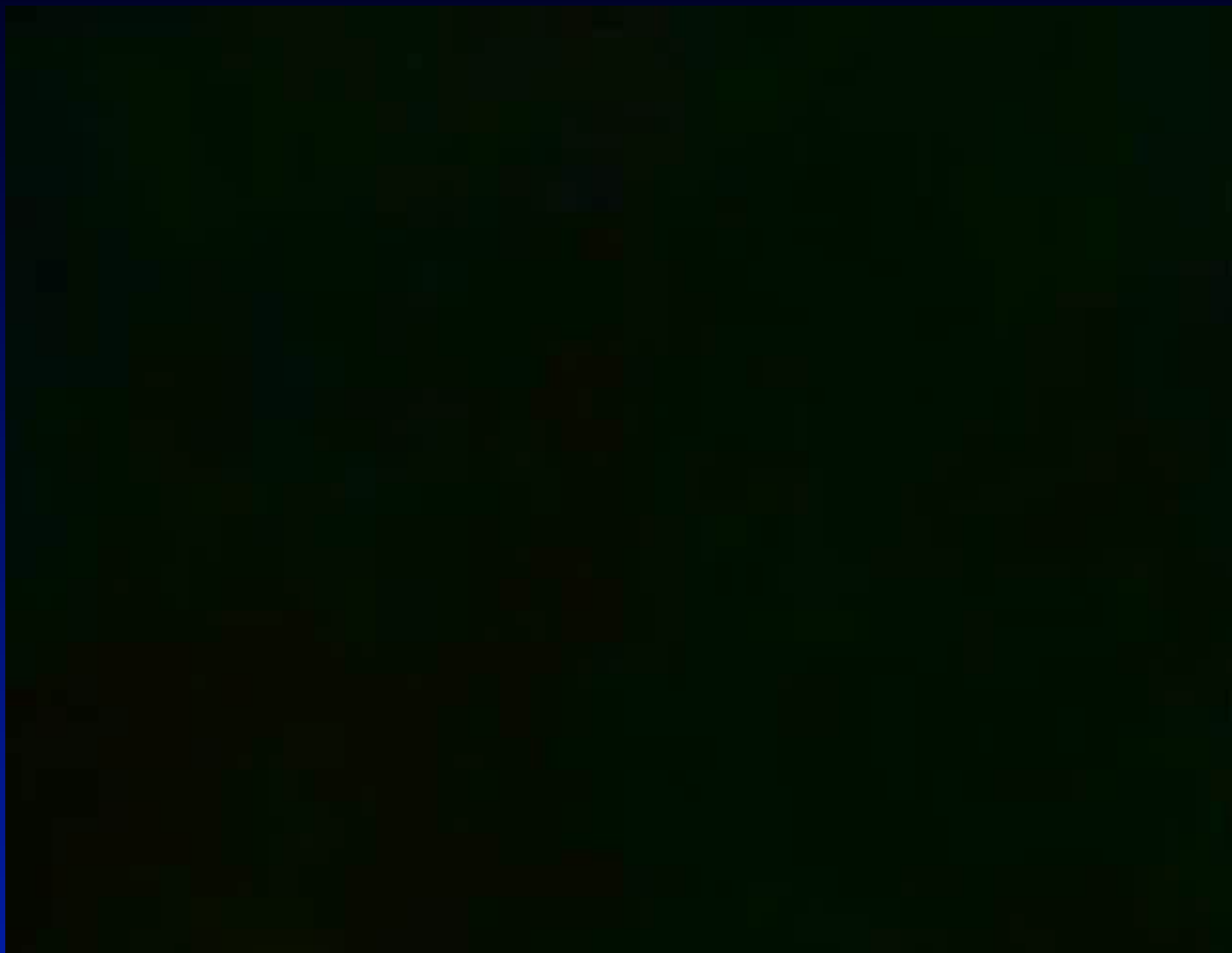
Something Completely Different



No Place In The Sun

From the beginning NASA life sciences was something of an enigma from the highest to the lowest levels of management within NASA. Maybe this was because no one in management had training in the life sciences. Interestingly, little has really changed over the years. Regardless of its history, the discipline of life science within NASA remains a stepchild with little hope of improving in the next several years. It is interesting to note that Newell entitled his chapter, within his book on the early years of space science, on life science as having "No Place In The Sun".

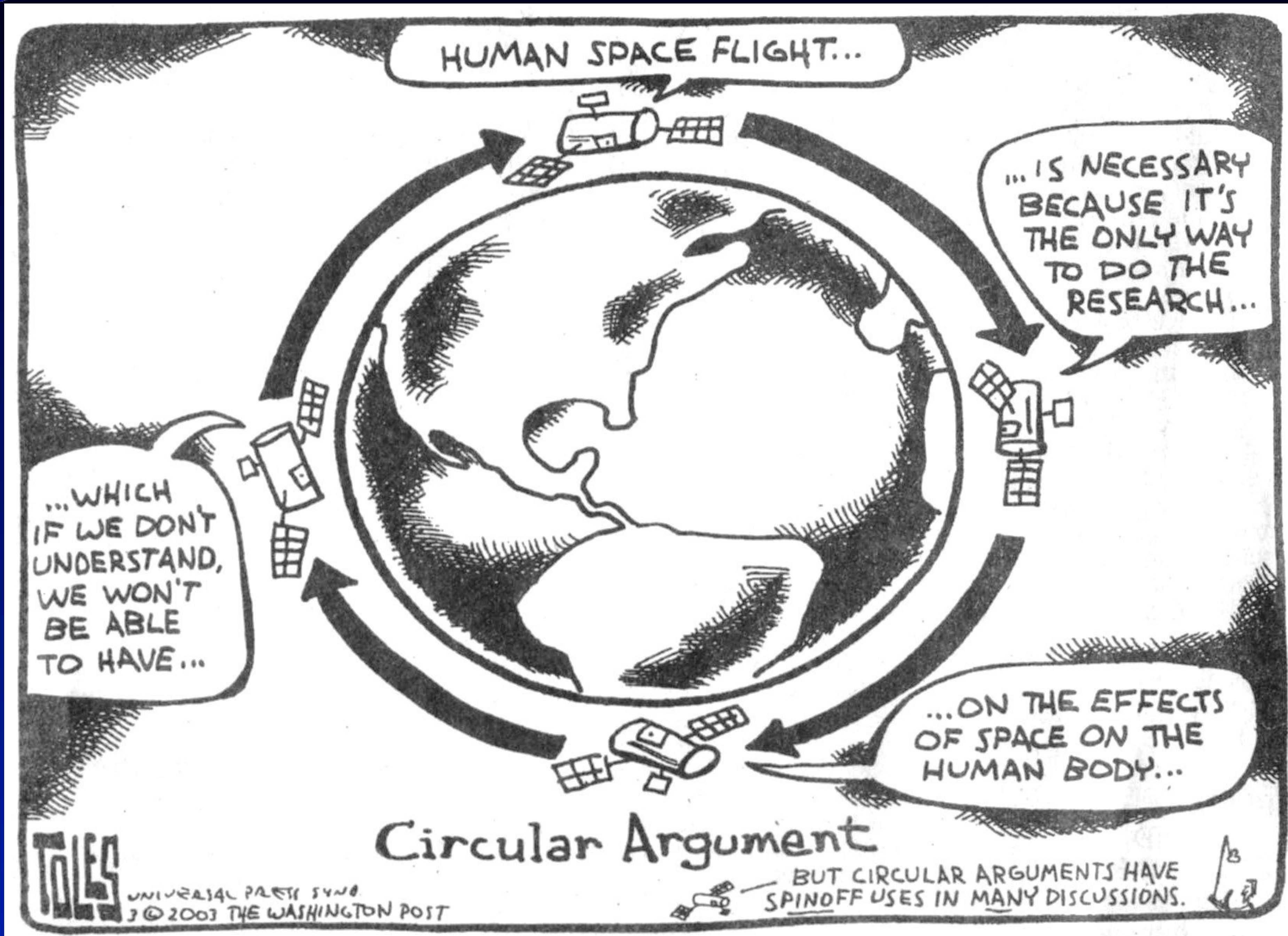
Newell, Homer., *Beyond the Atmosphere: Early Years of Space Science (NASA SP-4211)*. 1980, Government Printing Office, Washington, D.C. p. 274-275.

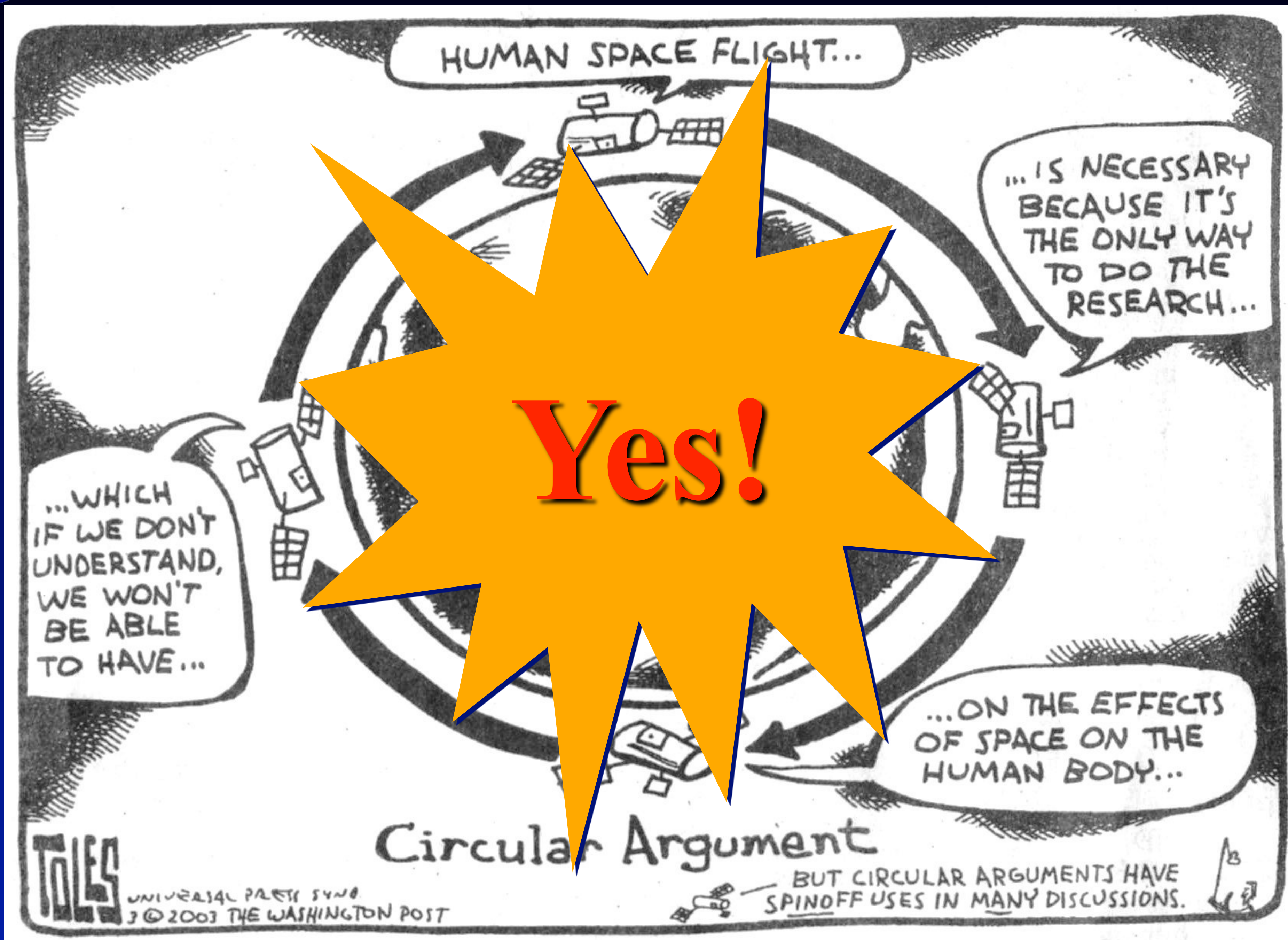
A Circular Argument

Burning Holes In The Sky

Going Around In Circles

The Shuttle Mission: Enabling Science and Exploration – Life Sciences




HUMAN SPACE FLIGHT...
...IS NECESSARY BECAUSE IT'S THE ONLY WAY TO DO THE RESEARCH...
...ON THE EFFECTS OF SPACE ON THE HUMAN BODY...
...WHICH IF WE DON'T UNDERSTAND, WE WON'T BE ABLE TO HAVE...
Yes!
Circular Argument
BUT CIRCULAR ARGUMENTS HAVE SPINOFF USES IN MANY DISCUSSIONS.
TOLES
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What follows is the view through my knothole

Basic Underlying Requirements for life sciences

1. "n" (sample size): subject count
   - Minimize influence of biological variability
2. Consistency: all subjects should be exposed to same set of conditions (stimuli)
   - Minimize independent variables
3. Careful selection of parameters to be measured
   - Minimum number
   - As simple as possible ("elegant")

All deviation from these basics complicates interpretation of research results and delays delivery of the final answer.

SOME HISTORY

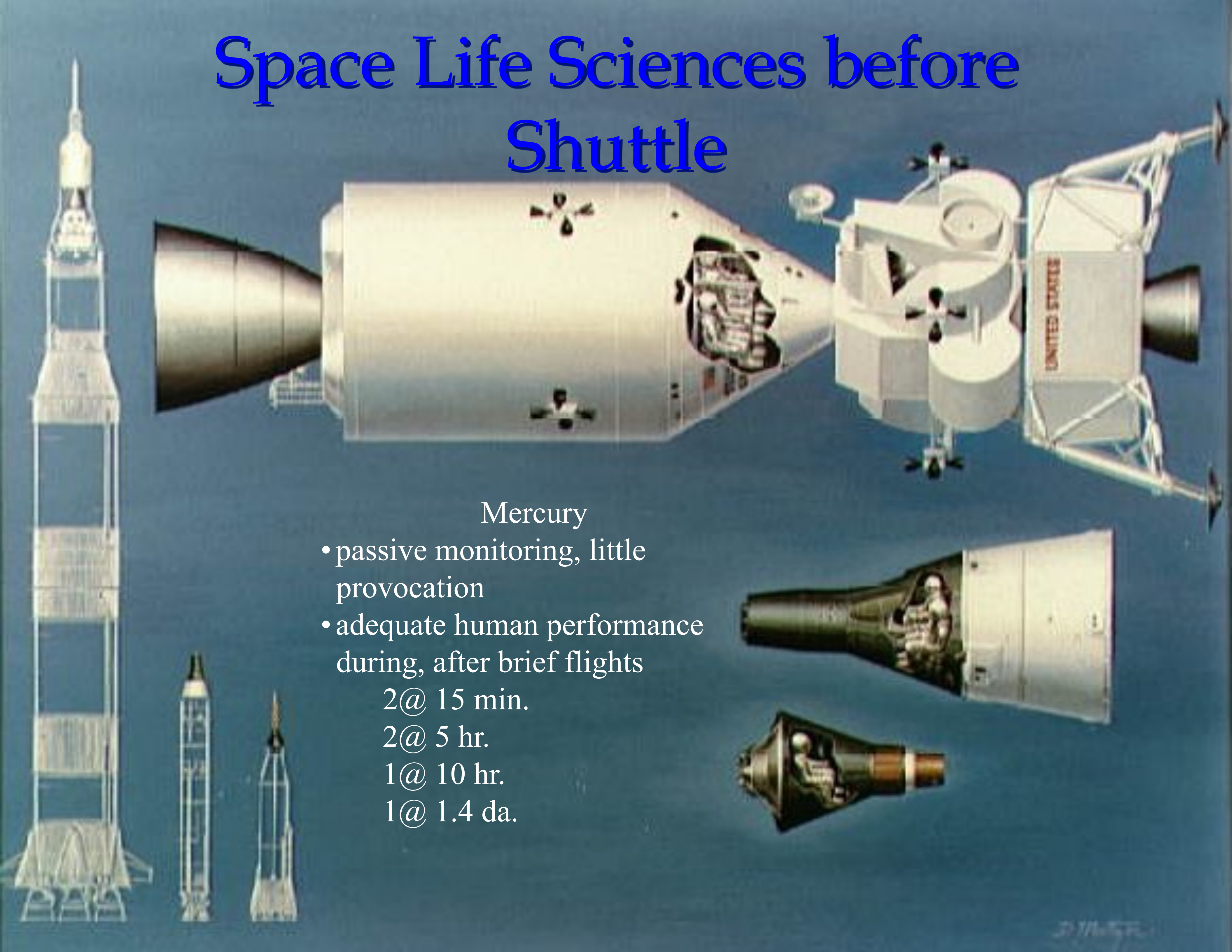
DIRE PREDICTIONS

*Flight physicians were almost unanimous in expressing forebodings about the effect of weightlessness on man's physical and mental performance. Some feared that the body organs depended on sustained gravity and would not function if deprived of the customary gravitational force. Others worried over the combined effects of acceleration, weightlessness, and the heavy deceleration during atmospheric entry. Still other experts were concerned especially about perception and equilibrium. For example, Haber and Gauer, noted that.. "**the brain receives signals on the position, direction, and support of the body from four mechanisms: pressure on the nerves and organs, muscle tone, posture, and the labyrinth of the inner ear. These four mechanisms might give conflicting signals in weightlessness and resulting disturbances "may deeply affect the autonomic nervous functions and ultimately produce a very severe sensation of succumbence associated with an absolute incapacity to act.**"*

O. Gauer and H. Haber, "Man under Gravity Free Conditions," German Aviation Medicine, World War II, I, 641-643.

NASA scientists (almost always an unknown group of individuals in NASA's folklore) were to test an individual's ability to ingest food from the early prototype food in a toothpaste tube during the microgravity portion of parabolic flight. When the flight, made in a military fighter jet at Wright-Patterson Air Force Base, landed the backseat subject with the tube of food had not accomplished the task. The "scientists" thinking that they may have discovered a problem with eating in microgravity, were concerned until they learned that the subject had been so enthralled by the experience of weightlessness, that he had simply forgotten to eat the food.

Space Life Sciences before Shuttle

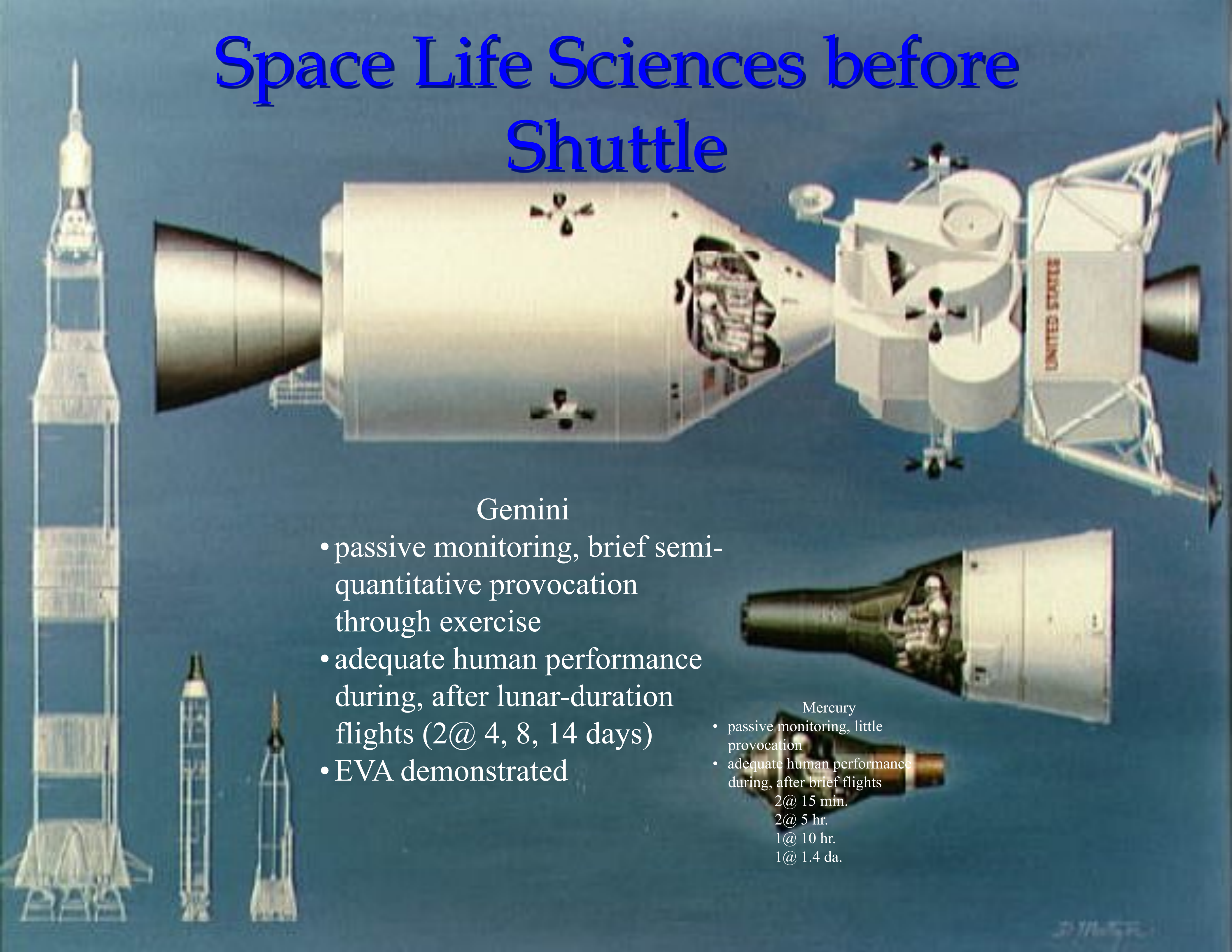


Mercury

- passive monitoring, little provocation
- adequate human performance during, after brief flights

    2@ 15 min.
    2@ 5 hr.
    1@ 10 hr.
    1@ 1.4 da.

Space Life Sciences before Shuttle



Gemini

- passive monitoring, brief semi-quantitative provocation through exercise
- adequate human performance during, after lunar-duration flights (2@ 4, 8, 14 days)
- EVA demonstrated

Mercury

- passive monitoring, little provocation
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  - 2@ 15 min.
  - 2@ 5 hr.
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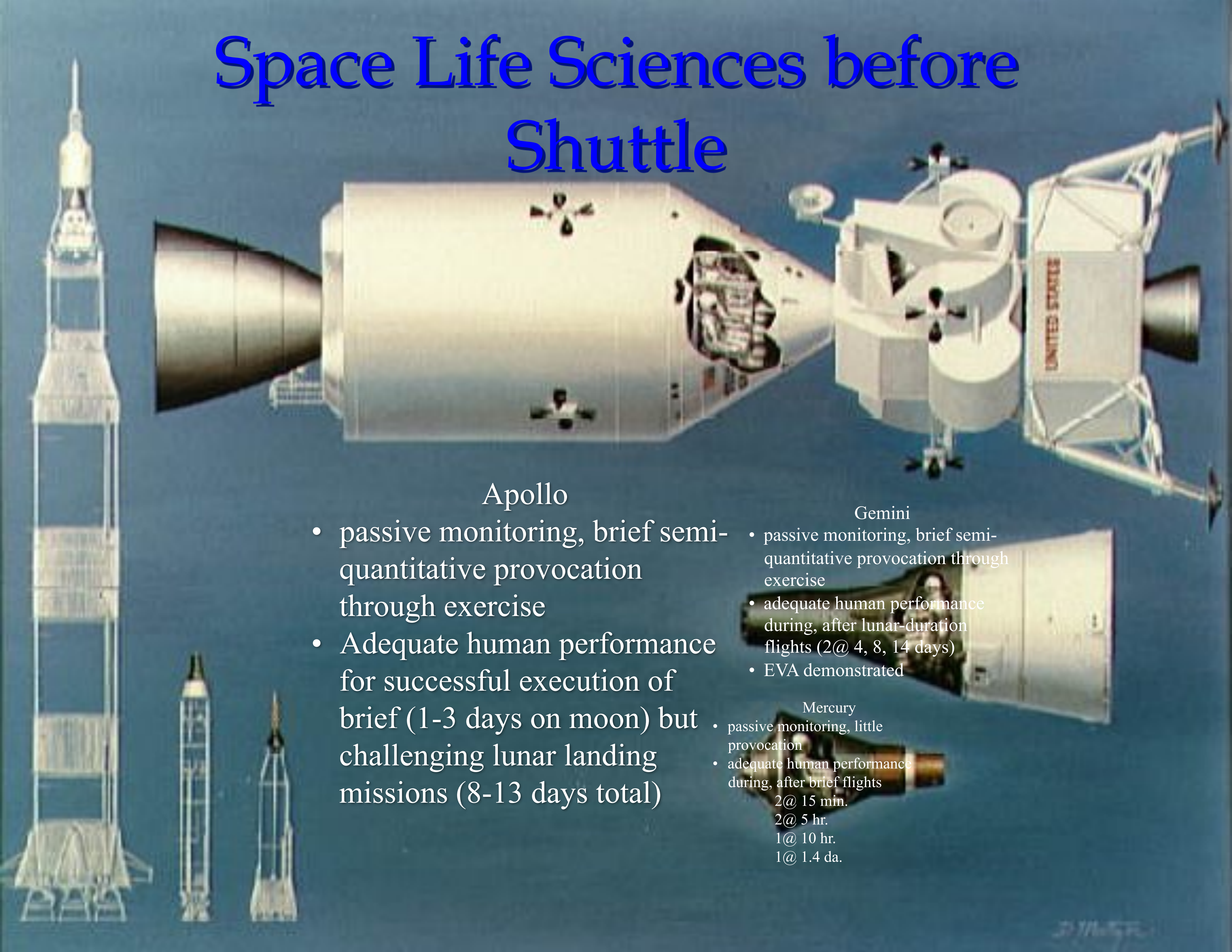
Space Life Sciences before Shuttle



Apollo

- passive monitoring, brief semi-quantitative provocation through exercise
- Adequate human performance for successful execution of brief (1-3 days on moon) but challenging lunar landing missions (8-13 days total)

Gemini

- passive monitoring, brief semi-quantitative provocation through exercise
- adequate human performance during, after lunar-duration flights (2@ 4, 8, 14 days)
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Mercury

- passive monitoring, little provocation
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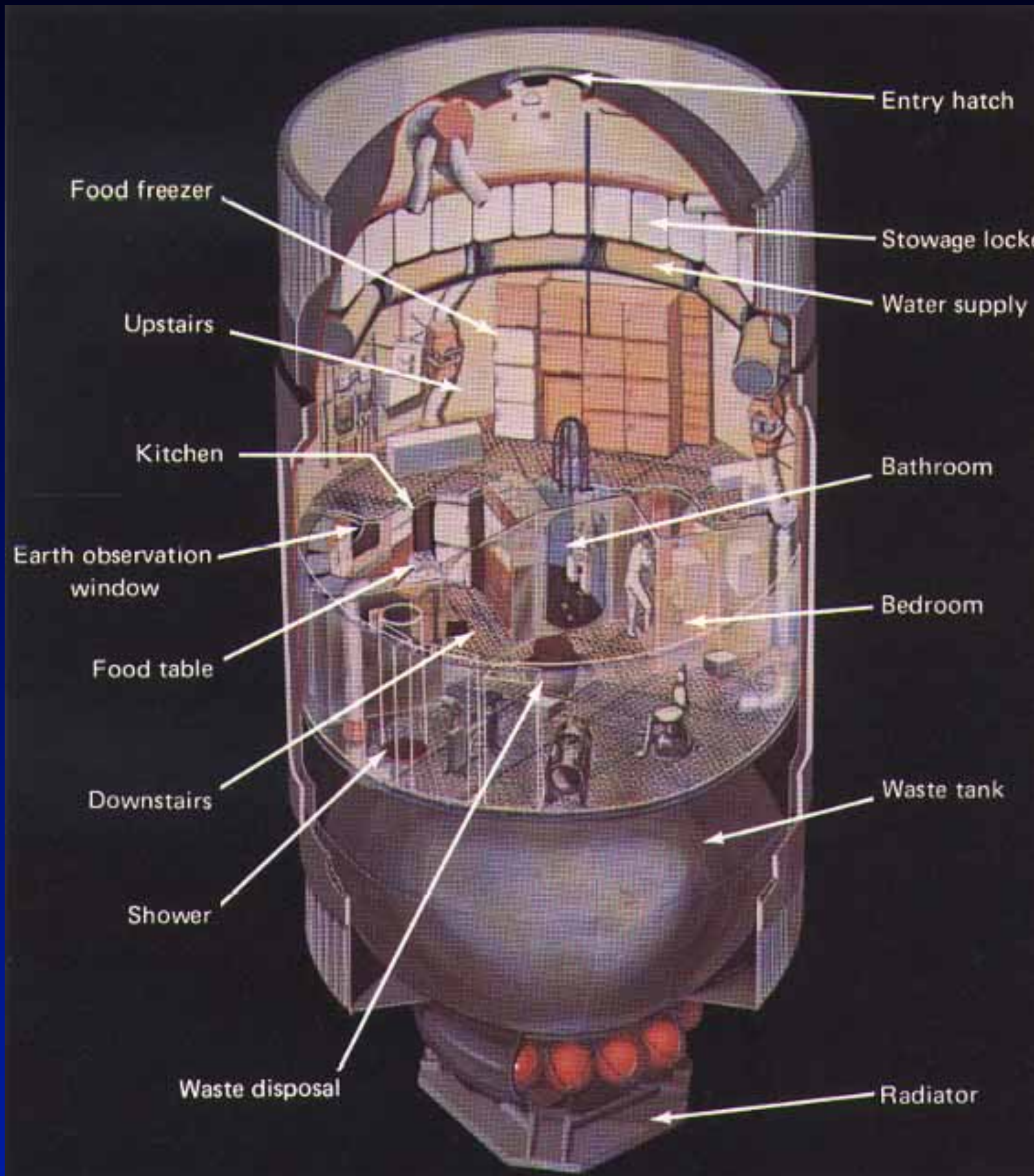
  2@ 15 min.
  2@ 5 hr.
  1@ 10 hr.
  1@ 1.4 da.

Space Craft Volume

American	Volume (m^3)	**Russian**	Volume (m^3)
Mercury	1.7	Vostok	5
Gemini	2.55	Voskhod	5
Apollo Command Module	5.95	Soyuz	10
Apollo Lunar Module	4.5	ASTP	10
Skylab	275	Salyut 5	70
ASTP	5.95	Salyut 6	90
Shuttle	71	Mir	90
		Other Mir modules	50-90



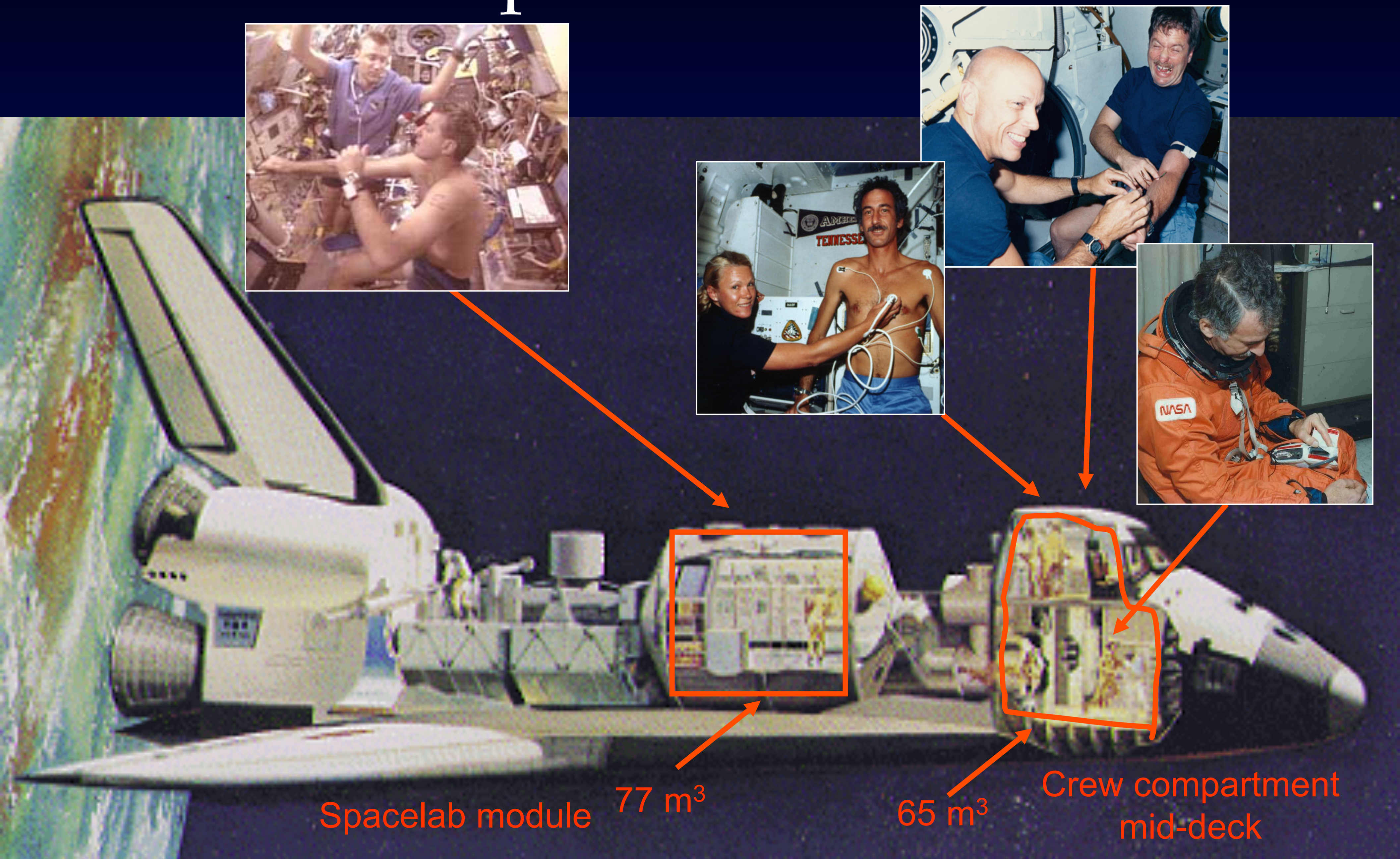
Skylab

- Life sciences as top priority
  - Cardiovascular
    - Exercise
    - Simulated gravity
  - Metabolism and bone changes
  - Neuroendocrine
    - Hormones
    - Blood volume, red cell mass
  - Neurosensory (vestibular)
- Mostly extramural PIs who responded to solicitation
  - Intramural Project Coordinating Scientists

- 3@ 28, 59 or 84 days
- Exercise @ ½, 1 or 1½ hr./da.

- Possible to live, work in space
- Healthy life even for months
- Meaningful work in EVA

Space Shuttle



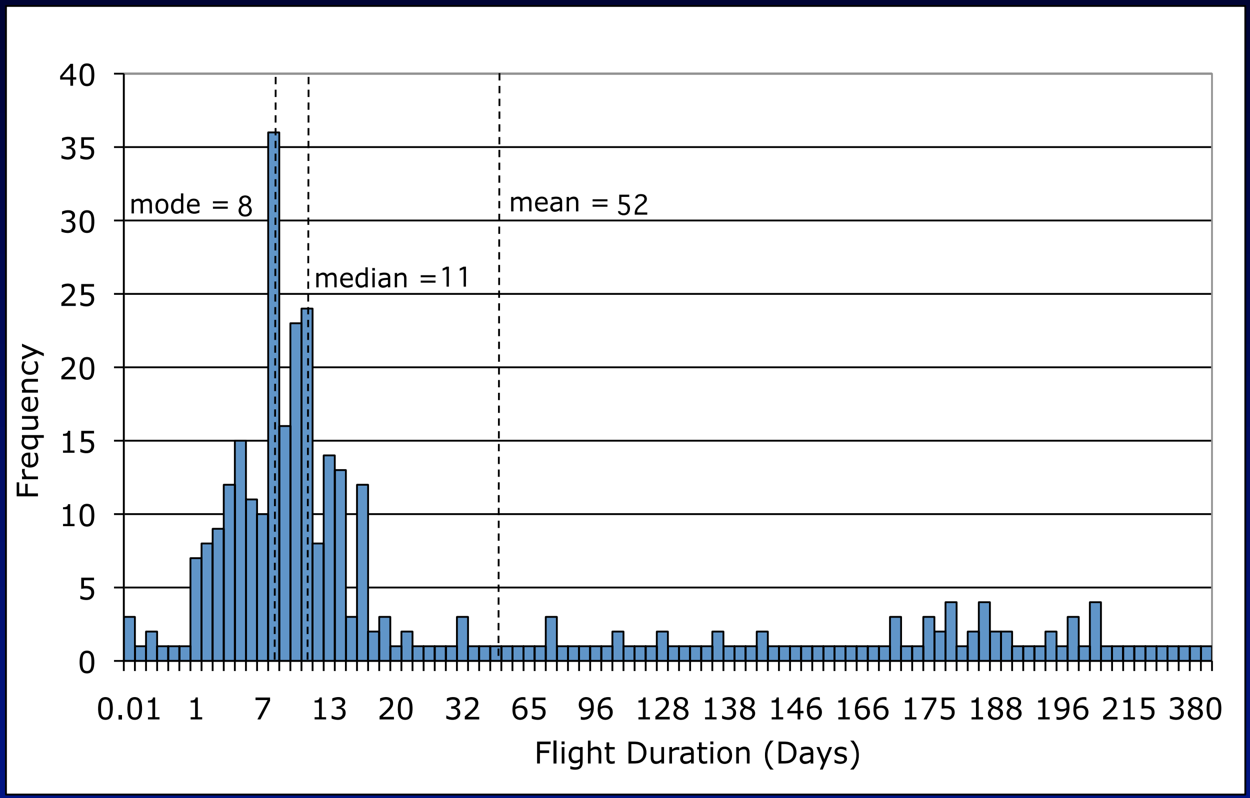
Shuttle Life Sciences Research on Routine Missions

Starting in 1982 routine missions accommodated intramural directed research (EDOMP).

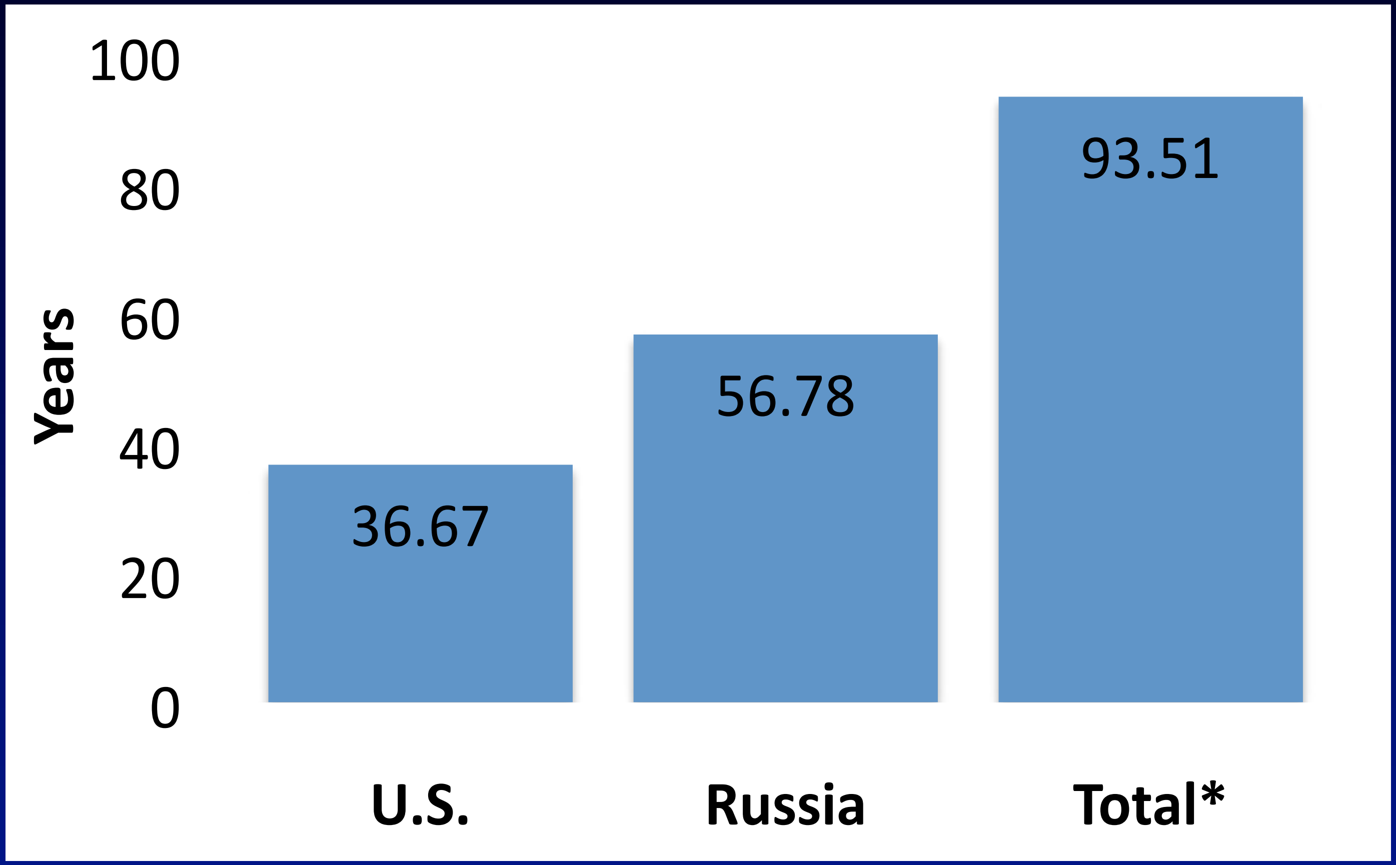
- Space-available, non-interference as supplemental activities (medical DSOs)
- Science reviewed via standing extramural committees
- Usually a small number per mission
- Mostly intramural researchers
- Lasted through the early 90's
- Carried forward on Shuttle-Mir and NASA-Mir
- Operationally-driven to address crew safety, health and performance issues
- Potential for large cumulative *n*

The mission is not over just because the wheels stop rolling

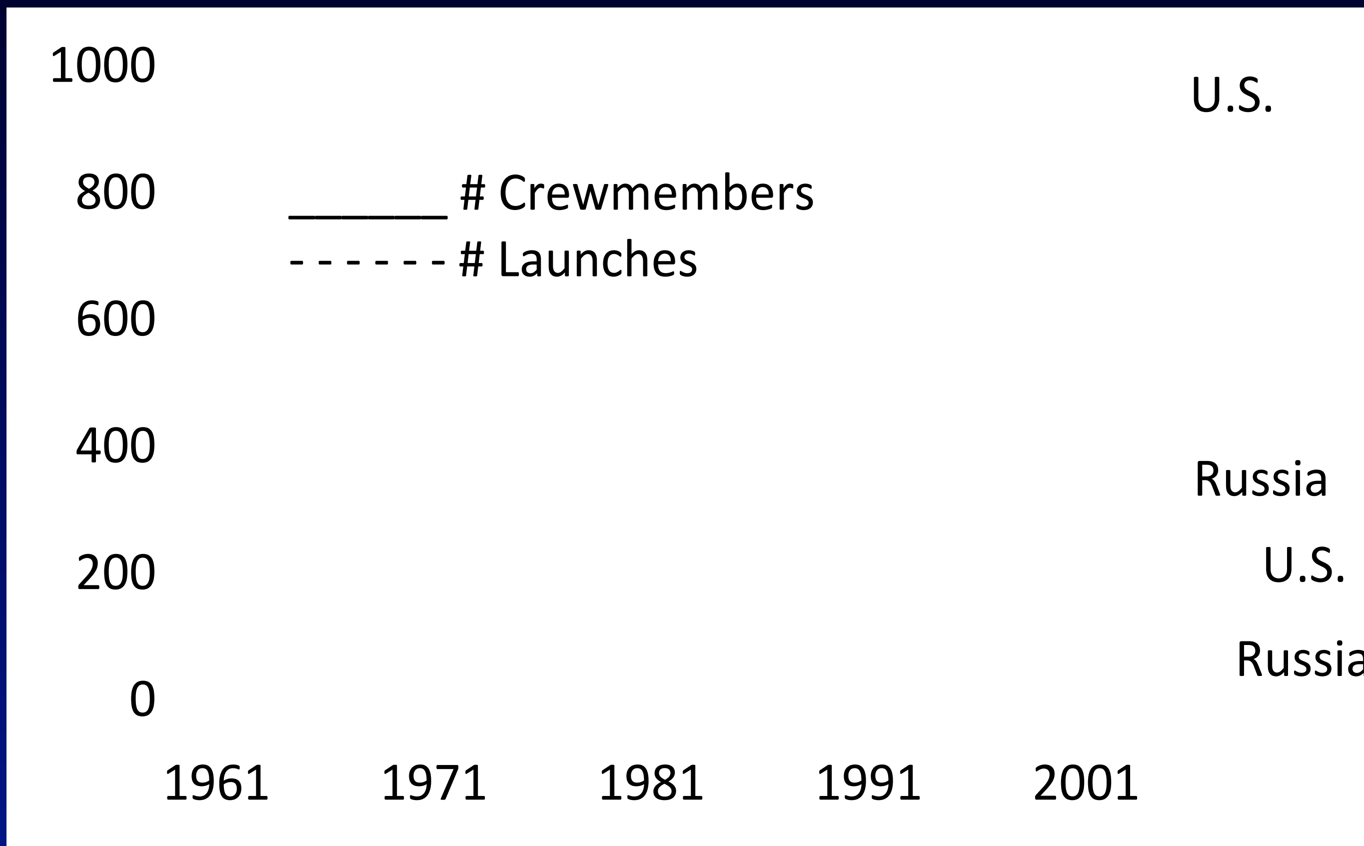
- "Easiest" to acquire
  - The astronauts have to land anyway—just be there when they do!
  - Trained personnel as operators
  - Standard laboratory equipment
- Primary operational medical concern is health after flight
  - Indicates physiological capacity for unaided post-landing emergency egress or pre-landing bail-out
  - Suggests condition at time of de-orbit, entry, descent, piloting and landing
  - Research data collection to support medical assessments, evaluate efficacy of countermeasures
- Comparison to preflight baseline data
  - Difference is error signal
  - Recovery, rehabilitation to reduce error signal, restore fitness for duty
  - Research data to identify mechanisms of changes, indicate areas for countermeasures

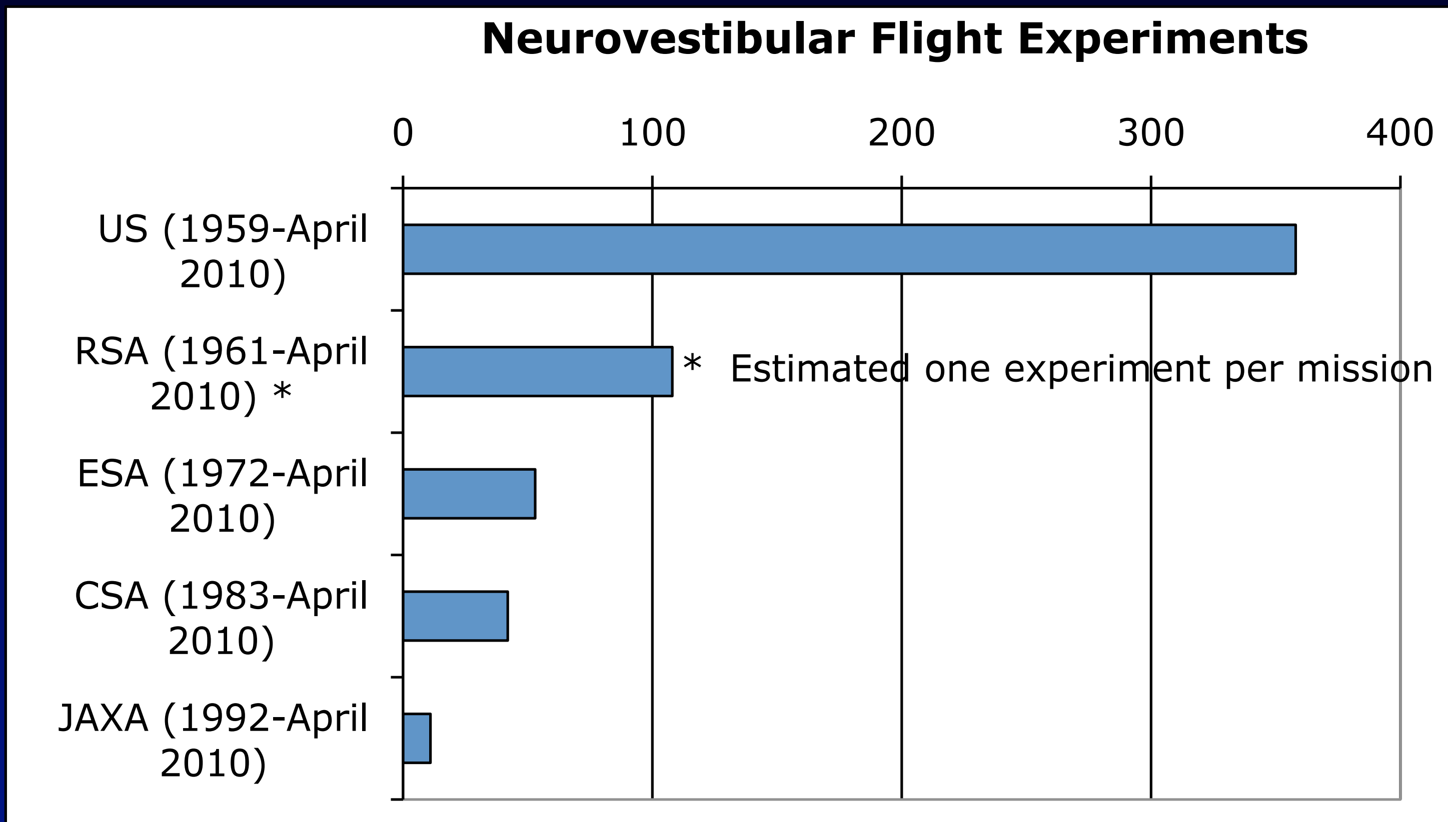


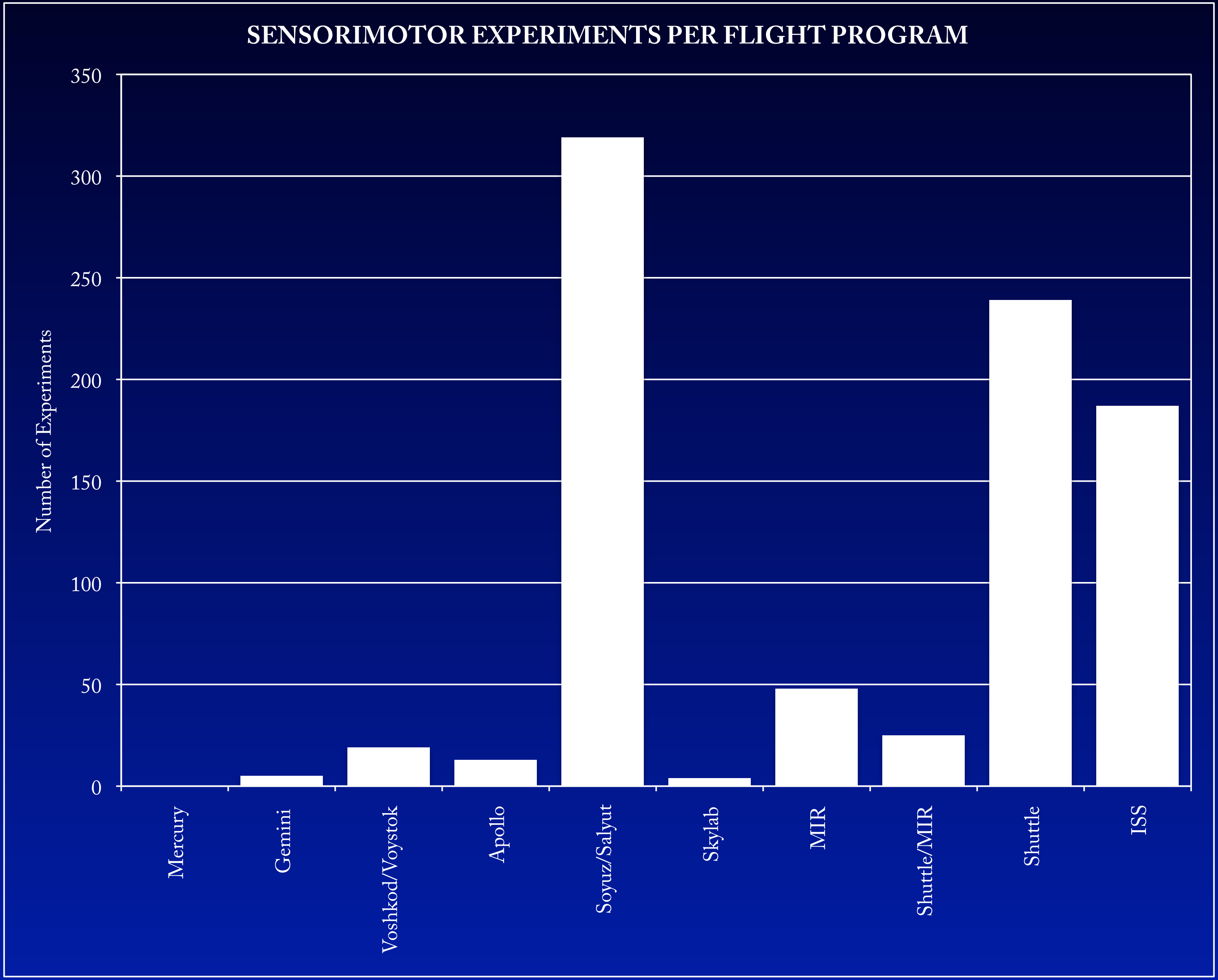
Frequency
40
35
30
25
20
15
10
5
0
mode = 8
median =11
mean = 52
0.01
1
7
13
20
32
65
96
128
138
146
166
175
188
196
215
380
Flight Duration (Days)

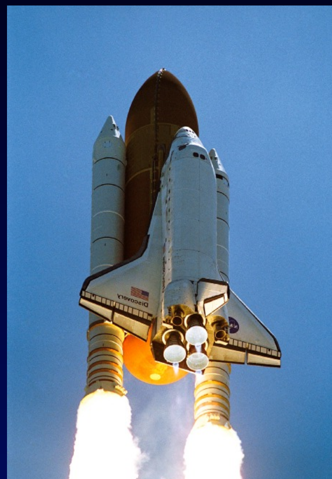


* Includes China


1000
800
600
400
200
0
______ # Crewmembers
- - - - - - # Launches
U.S.
Russia
U.S.
Russia
1961
1971
1981
1991
2001


Neurovestibular Flight Experiments
0
100
200
300
400
US (1959-April 2010)
RSA (1961-April 2010) *
ESA (1972-April 2010)
CSA (1983-April 2010)
JAXA (1992-April 2010)
* Estimated one experiment per mission


SENSORIMOTOR EXPERIMENTS PER FLIGHT PROGRAM
Number of Experiments
350
300
250
200
150
100
50
0
Mercury
Gemini
Voshkod/Voystok
Apollo
Soyuz/Salyut
Skylab
MIR
Shuttle/MIR
Shuttle
ISS



1-g   0-g   1-g

Preflight	Inflight	Postflight

g-transition   *g-transition*

Performance decrements occur during and after g transitions

Sensorimotor function during adaptation to g-transitions

- Postural and gait instability
- Visual performance changes
- Manual control disruptions
- Spatial disorientation
- Space motion sickness

Risk Factors:

- Length of flight
- Adaptability
- Workload and task complexity
- Crew experience
- Neural decompensation
- Individual variability
- Use of medication
- Spacecraft architecture
- Suit Design

Vehicle control
Loss of productivity
Work under influence of drugs
Impaired emergency egress capability
Falls during planetary EVAs

Entering 0-G

- At 0-G onset, some experience a 1-2 sec somersaulting sensation, particularly with eyes closed.

Thereafter:

- Most people feel upright, with eyes open or closed.
- <u>No</u> sensation of “falling”.
  - “Falling” is visually and cognitively mediated.
- Visual scene appears stationary during head movement (i.e. no abnormal oscillopsia).

Inversion Illusions

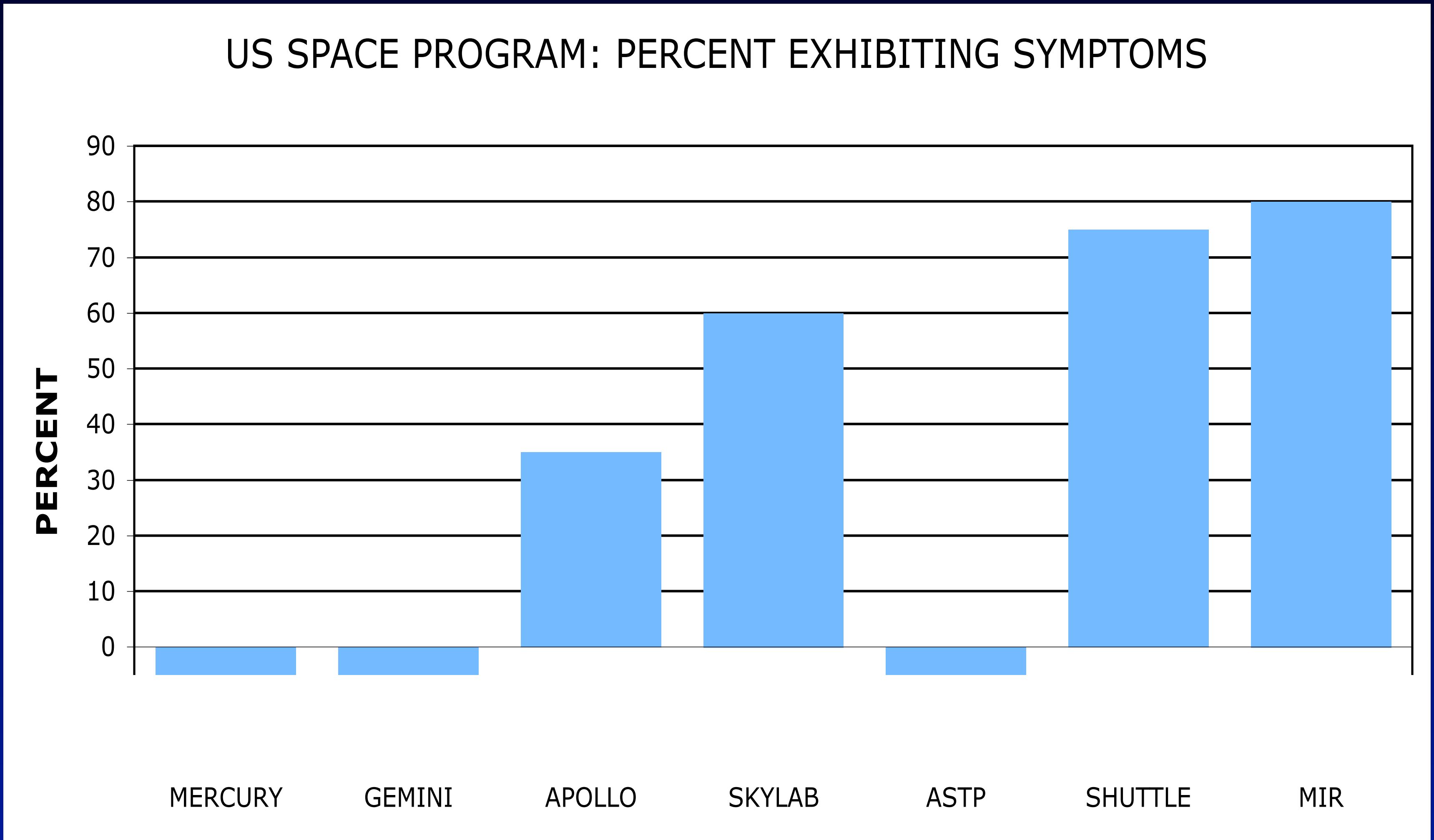
- 0-G inversion illusion. (Titov, 1962)
- Paradoxical sensation of being continuously gravitationally upside down, even when visually upright in the cabin.
- Persists with eyes closed.
- Fluid shift, visceral elevation and otolith unloading likely contribute.
- Temporarily reversible with proprioceptive or visual cues.
- Uncommon after flight day 2
- < 25% of crew experience it.

Courtesy of C. Oman

Visual Reorientation Illusion

- Surface nearest your feet seems like a “floor”. Surfaces parallel to body seem like “walls”.
- The orientation of your own body – or that of a person you look at – redefines “down”.
- Probability of illusion depends on visual vertical cues, visual attention and your familiarity with the interior.
- Occurs spontaneously, but can be cognitively initiated and reversed.
- Incidence is almost universal.
- Susceptibility persists for months.

Courtesy of C. Oman


US SPACE PROGRAM: PERCENT EXHIBITING SYMPTOMS
PERCENT
90
80
70
60
50
40
30
20
10
0
MERCURY
GEMINI
APOLLO
SKYLAB
ASTP
SHUTTLE
MIR

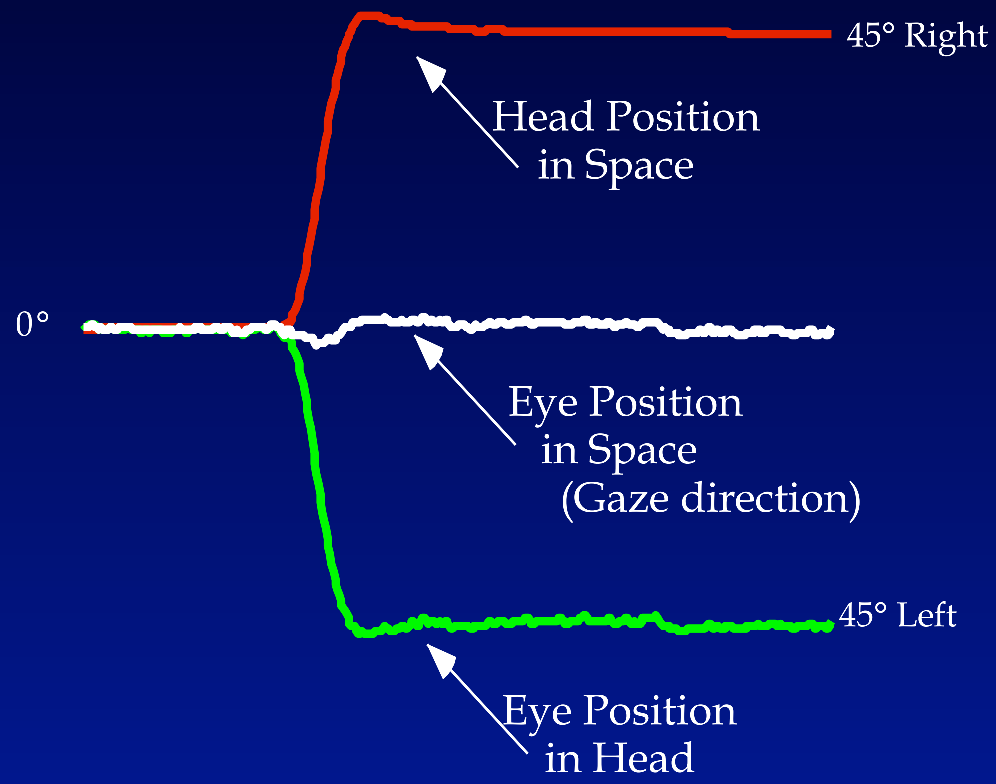
Functional Classes Of Eye Movements

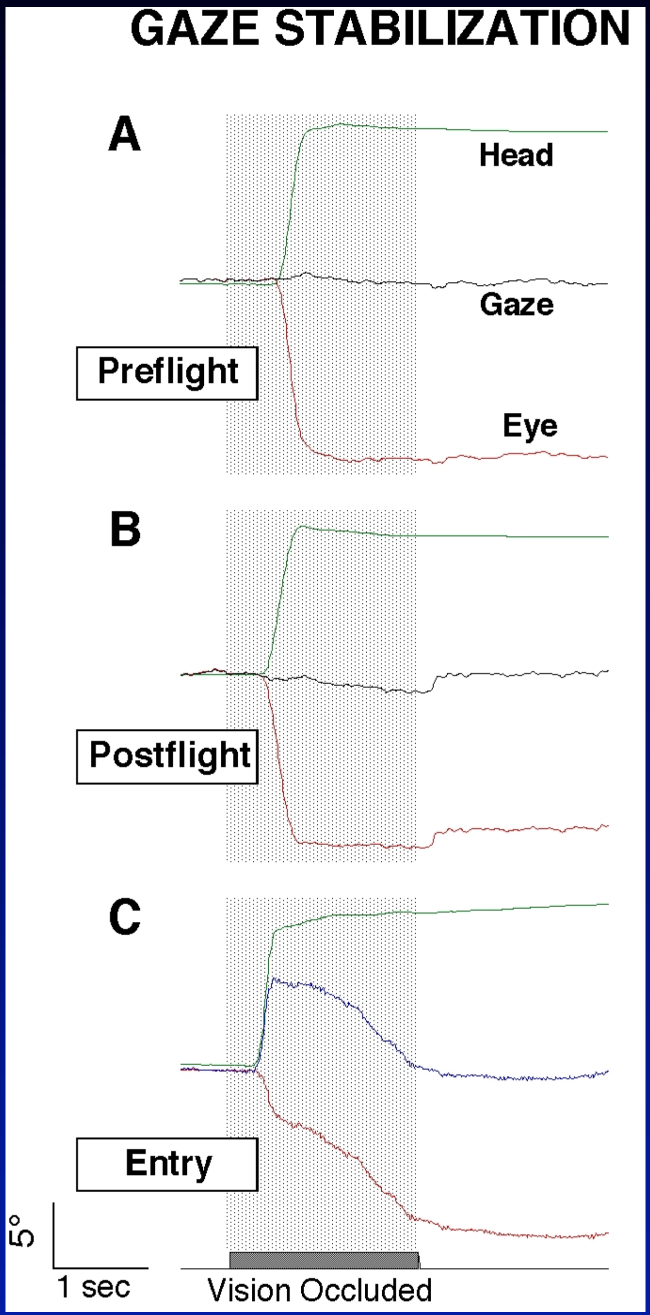
Class of Eye Movement	Main Function 
Vestibulo-ocular reflex	Holds images of world steady on the retina during brief head motion using vestibular input
Optokinetic	Holds images of world steady on the retina during sustained head motion using visual input
Smooth Pursuit	Holds the image of a small moving target on the fovea (image sensitive part of retina)
Saccades	Brings images of objects of interest onto the fovea quickly and is voluntary.
Gaze-Holding	Holds the image of a stationary object on the fovea when the eye is off-set
Nystagmus	Redirects the eye during prolonged rotation toward the oncoming visual scene

Space flight related changes have been observed in all types of eye movements

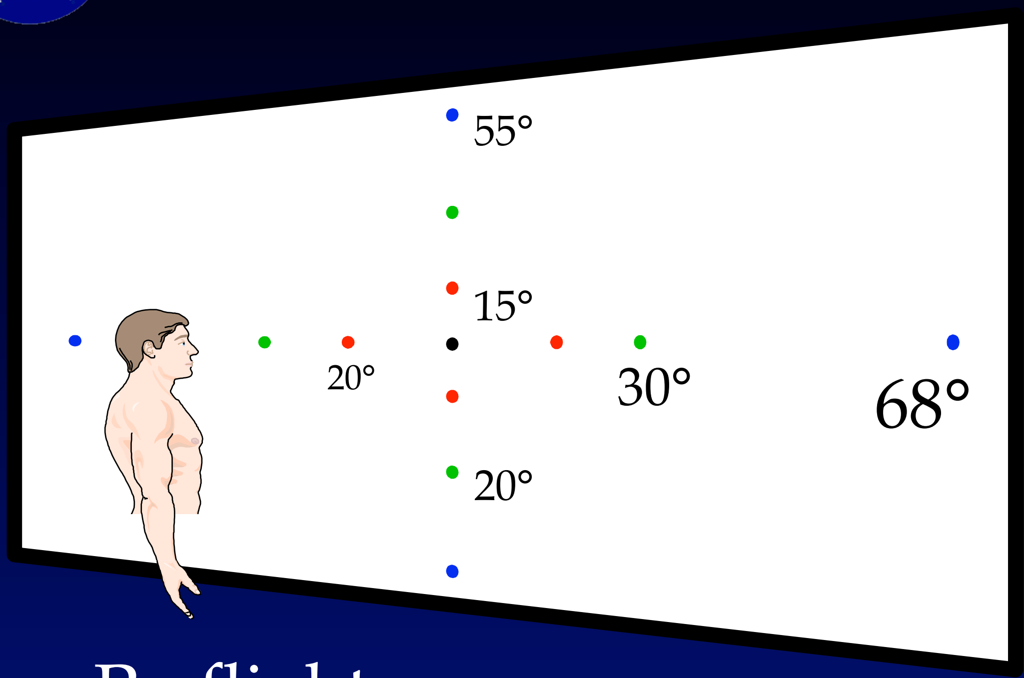
Reduction in dynamic visual acuity

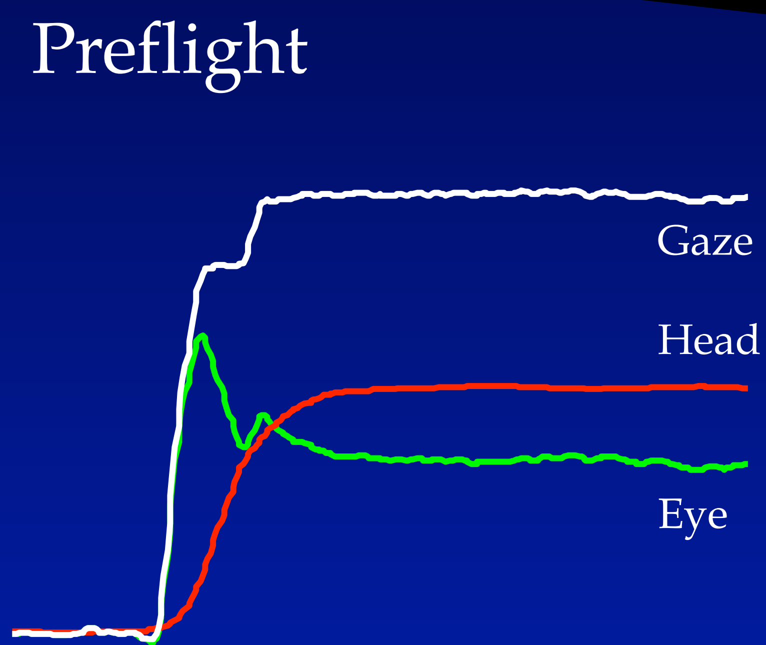
Compensatory eye movements maintain a stable retinal image during head movements

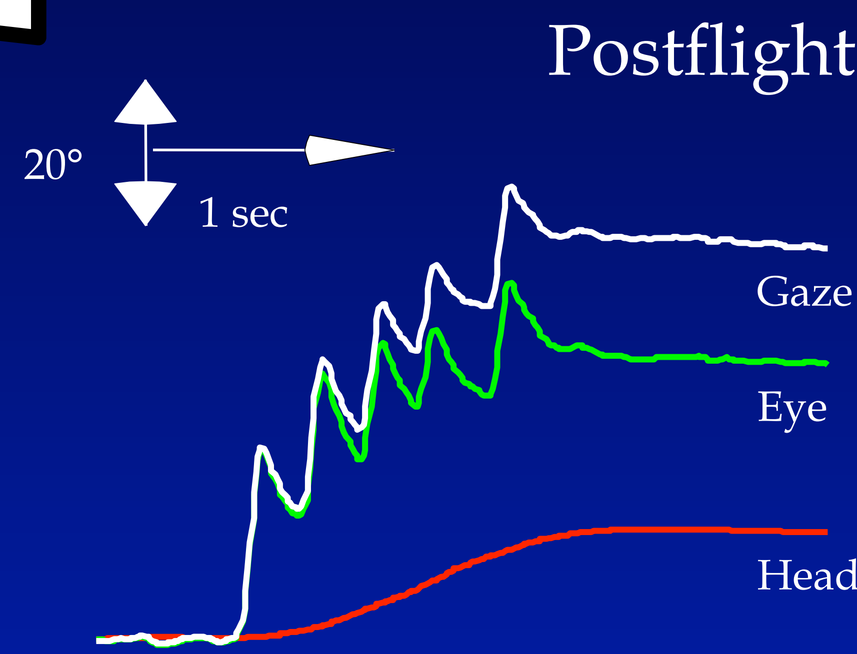



GAZE STABILIZATION
A
Head
Gaze
Preflight
Eye
B
Postflight
C
Entry
5°
1 sec
Vision Occluded

Visual Target Acquisition







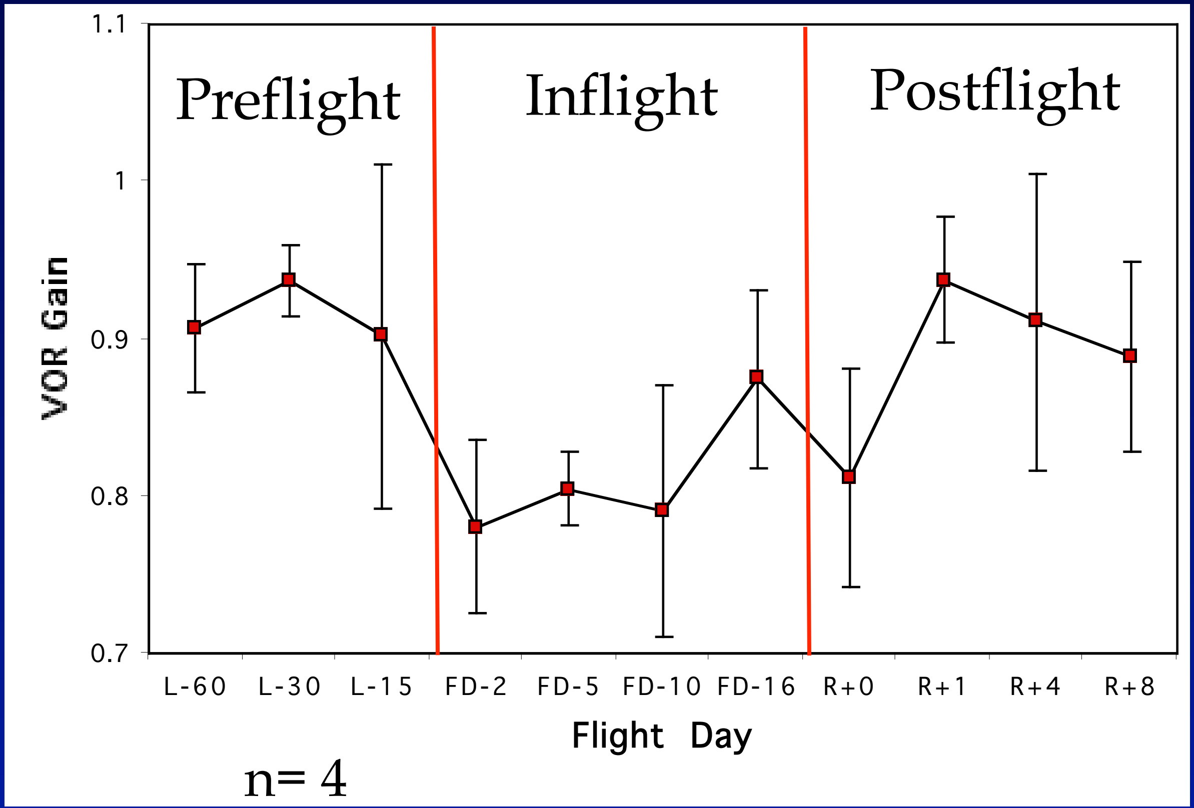
Effects of Space Flight on VOR Function

Task: Subjects moved head at a specific frequency while fixating on a stationary target.

Life and Microgravity Spacelab Mission LMS, STS-78

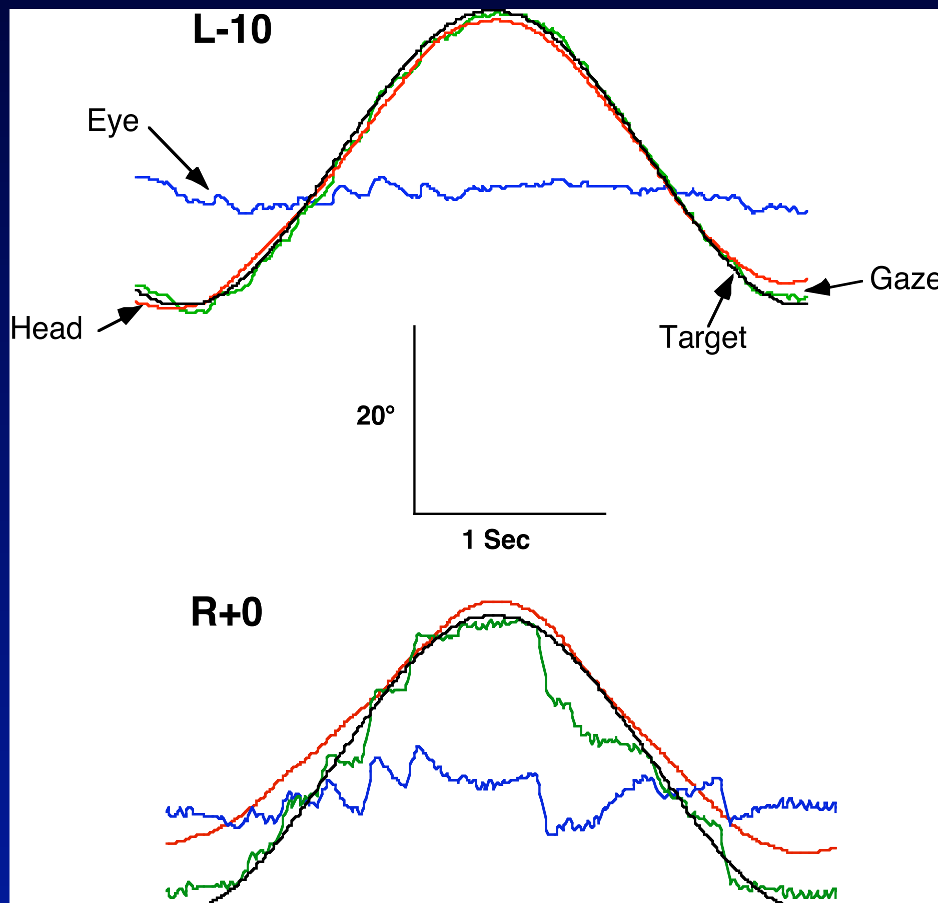
Measurements: Head and eye movements measured and VOR gain was assessed.

VOR gain = $\frac{\text{eye velocity}}{\text{head velocity}}$

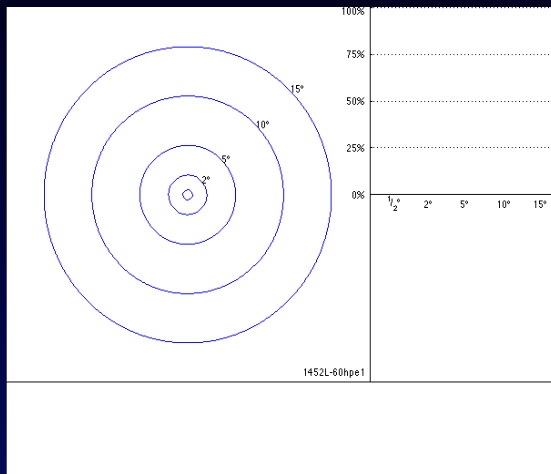


Summary: VOR gain reduced during space flight and on R+0 indicating a change in eye-head coordination.

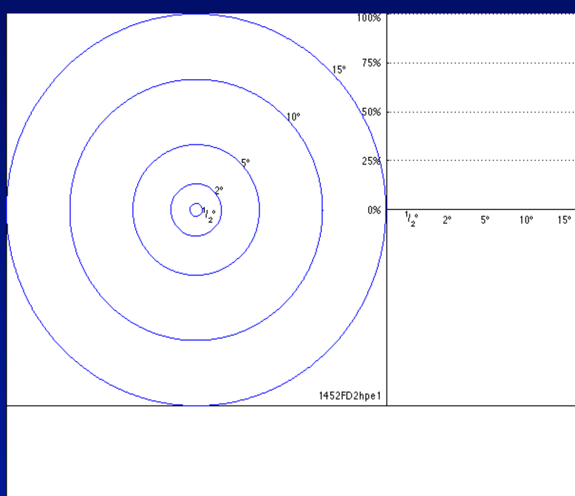
Vertical Pursuit: Eyes and Head



Pursuit Tracking

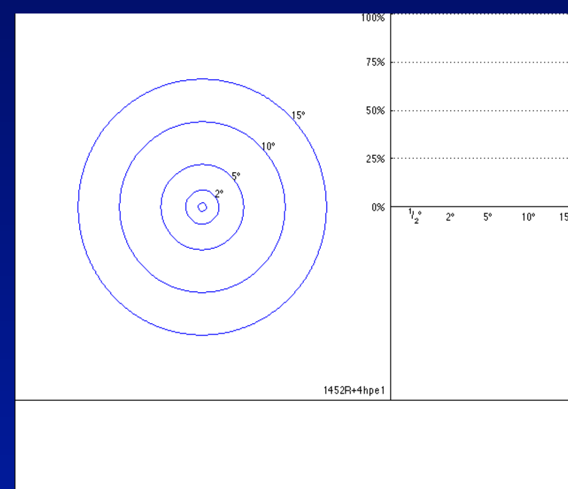


Preflight



Inflight
(FD2)

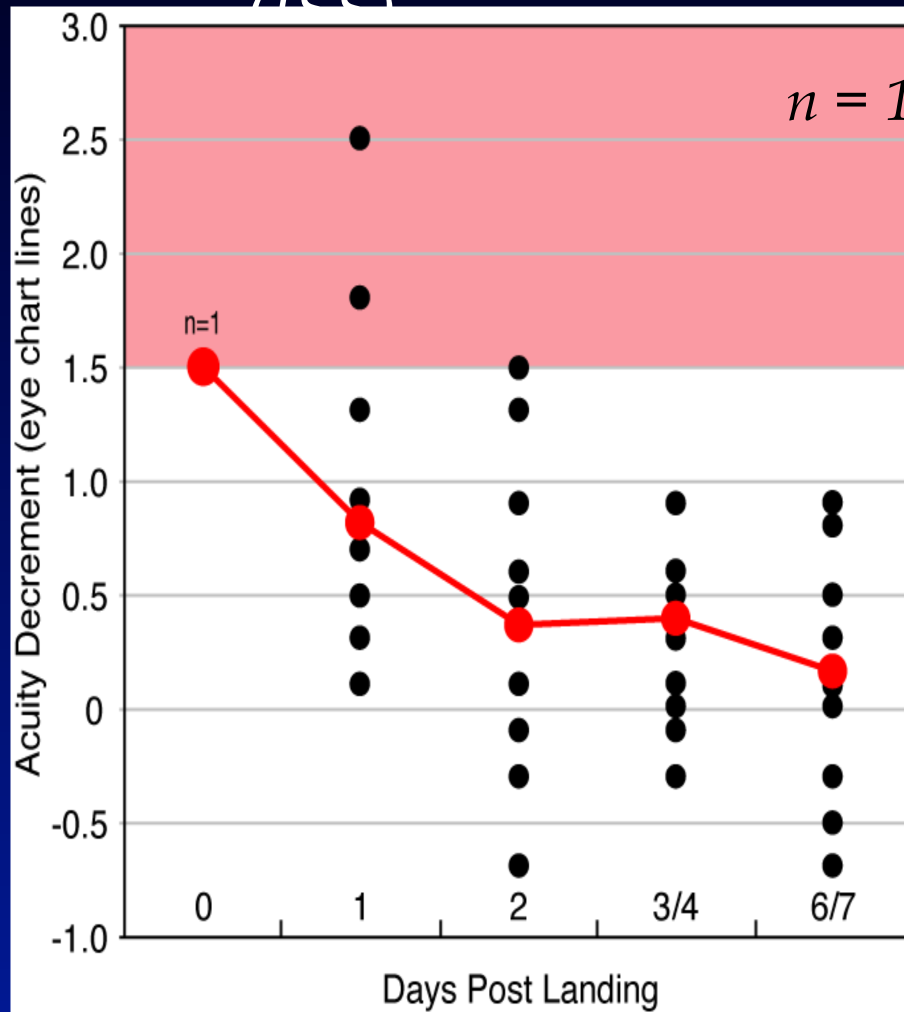
Postflight (R+4

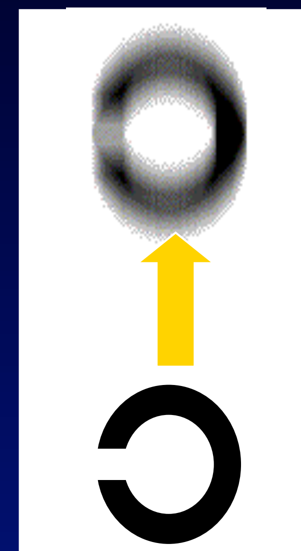


Dynamic Visual Acuity after Long-Duration Space Flight (ISS)

Astronauts show reduction in visual acuity during postflight walking

n = 18

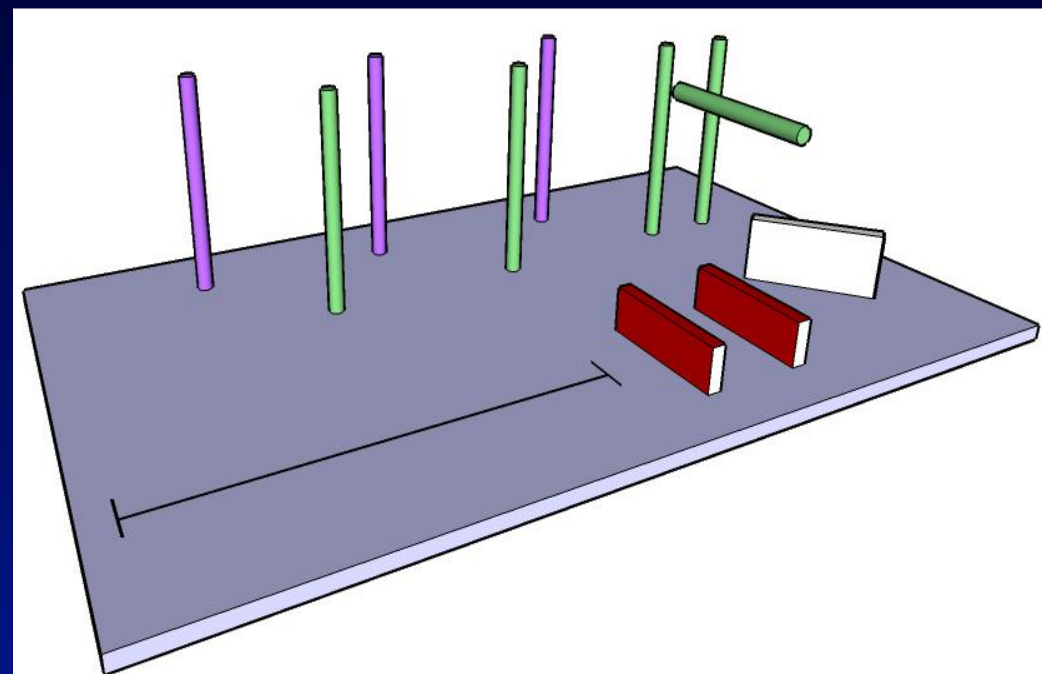




Locomotor Disturbances after Space Flight

- Loss of stability when rounding corners
- Deviation from a straight trajectory
- Wide stance gait to increase base of support
- More visual dependence postflight
- Reduced visual acuity during walking
- Illusions of self and/or surround motion associated head movements
- Increased vigilance to maintain balance

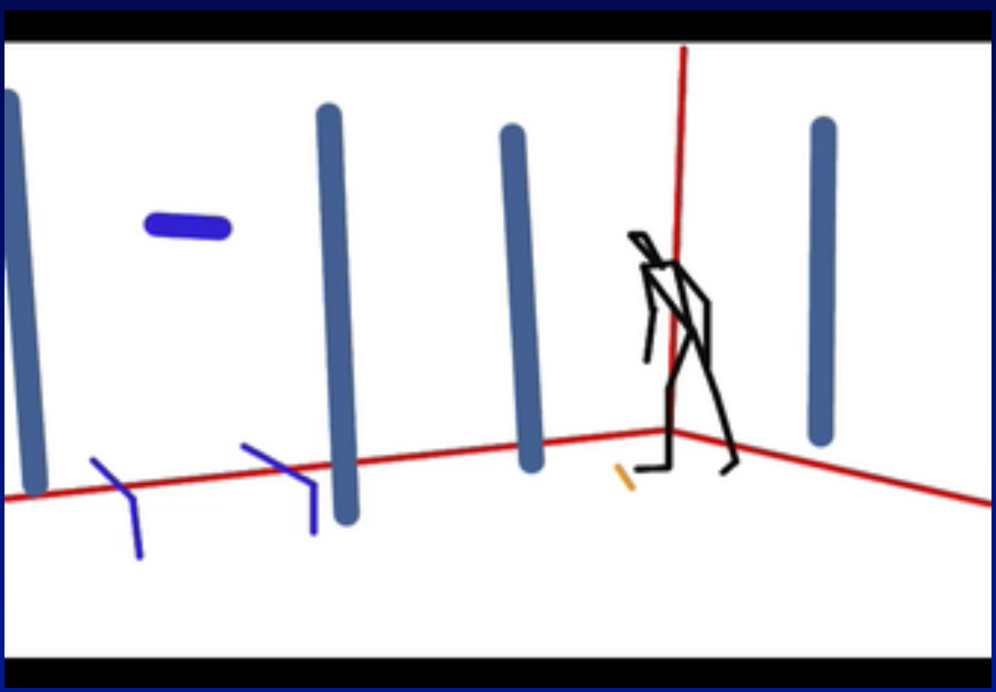
Functional Mobility Test



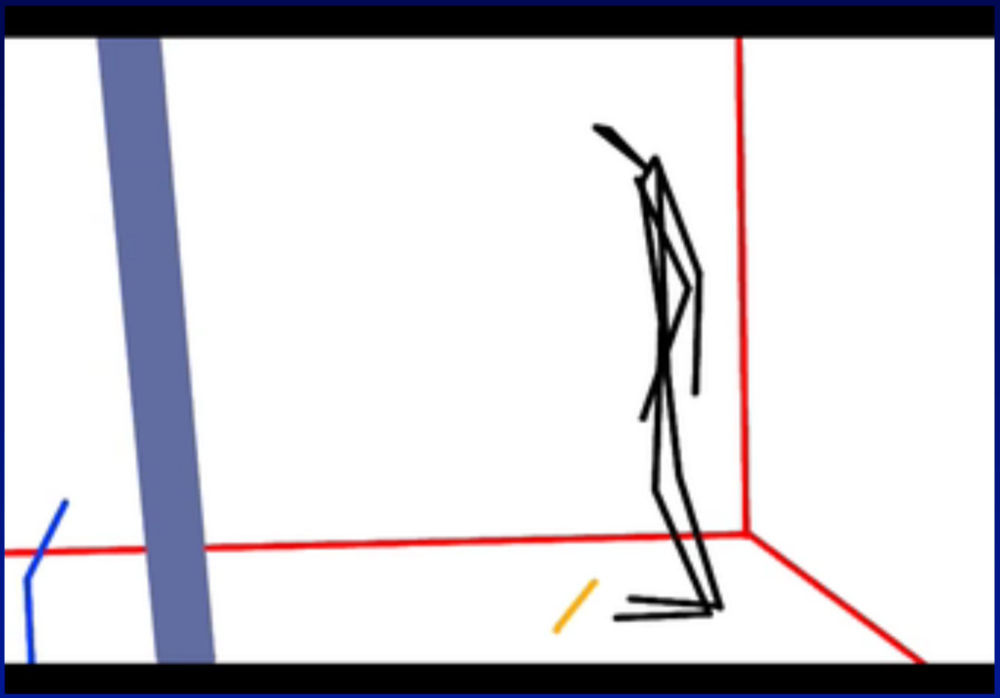
Provides information on the functional and operational implications of postflight locomotor dysfunction

Functional Mobility Test

Preflight

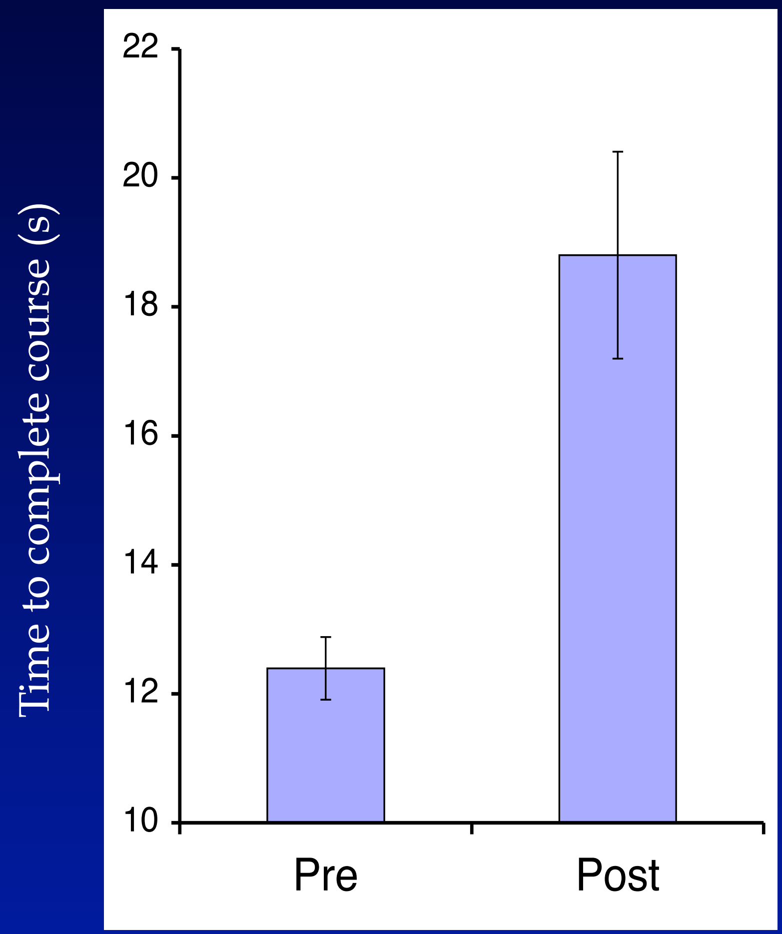


Postflight



Functional Mobility Test

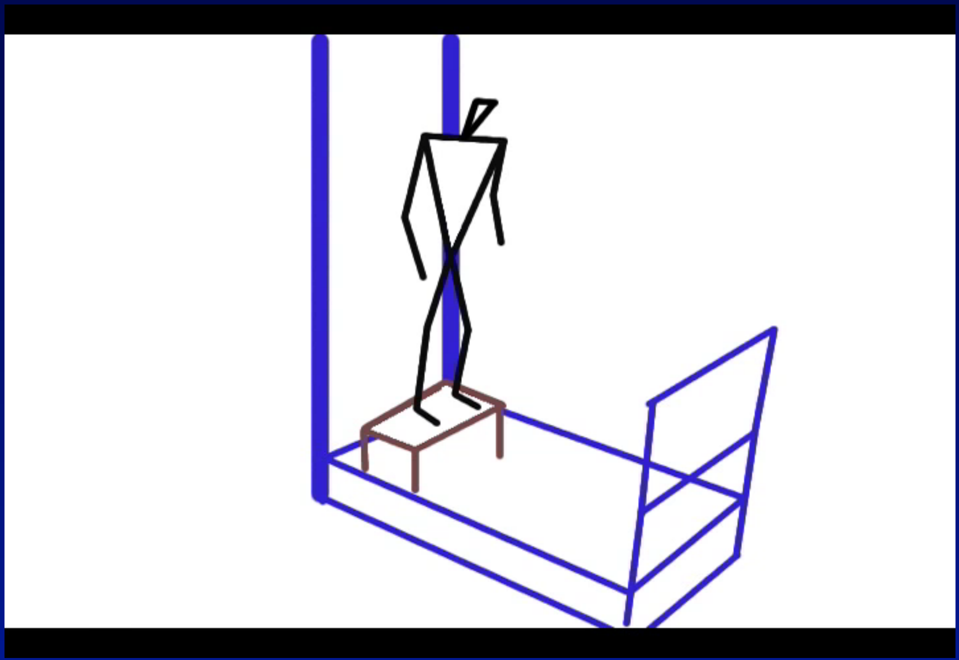
n = 16



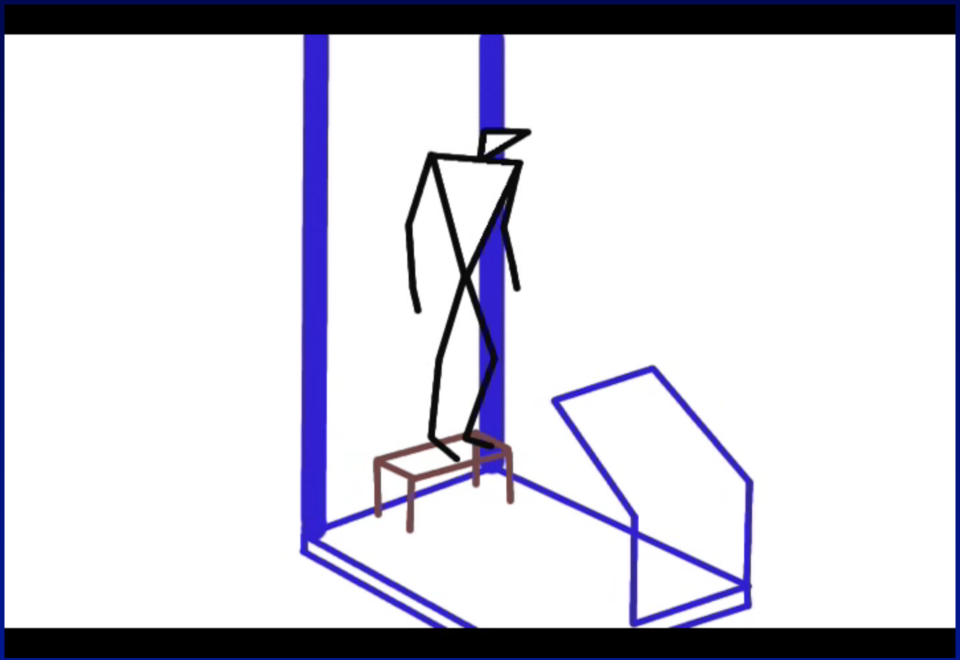
R+1

Simple Jump Task

Preflight



Postflight



"Test What You Fly

Fly What You Test"

Thanks Jody!

Whether the dawn of life sciences' contribution to space flight began with primitive man gazing upon the heavens or with the fatal flight of Icarus, we know that modern man predicted our escape from Earth as early as 1911 when Tsiolkovsky noted in a letter to a friend that:

'Humanity will not remain on the Earth forever, but in the pursuit of light and space will at first timidly penetrate beyond the limits of the atmosphere, and will then conquer all the space around the Sun.'

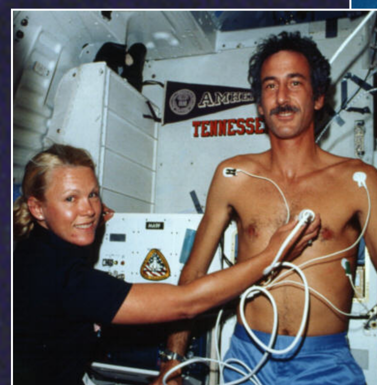
Sam after his ride aboard Little Joe-2. U.S. Navy recovered Sam after he experienced 3 min of microgravity during the flight.

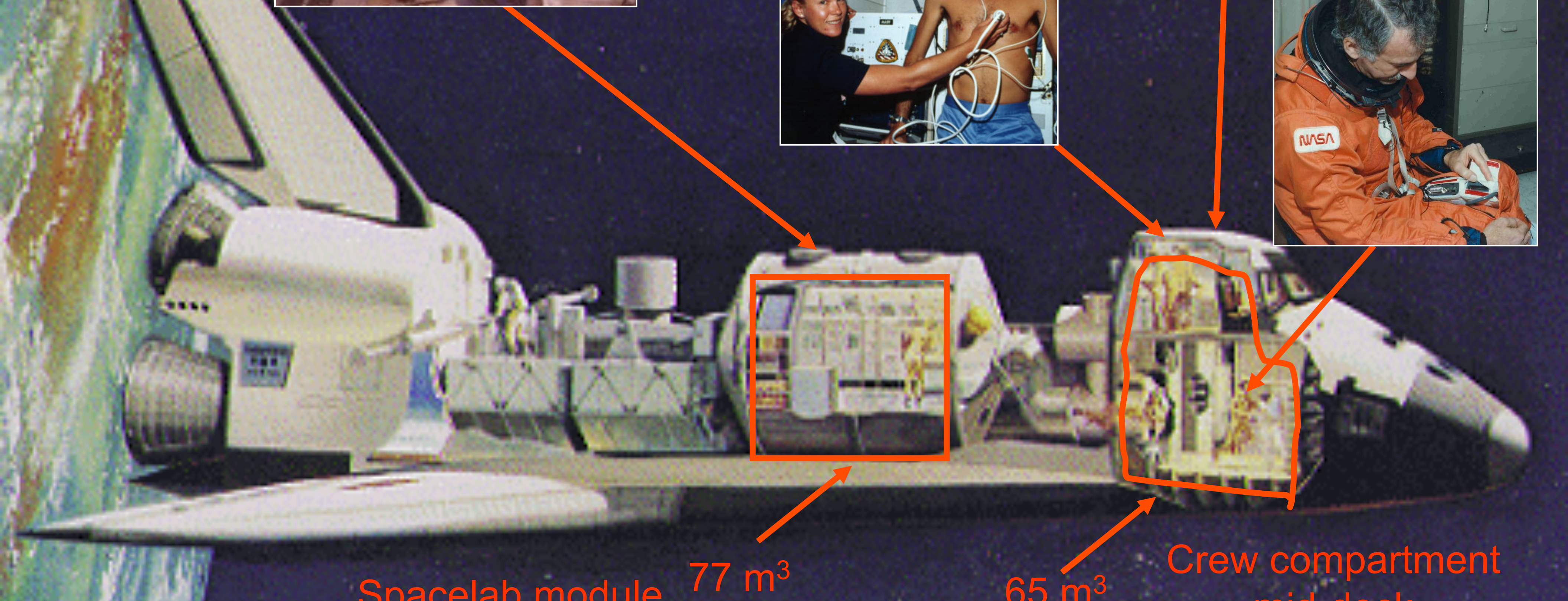
Regardless of the mythology of Daedalus and Icarus, the physics of Archimedes, Newton, Galileo and Copernicus, the foresight of DaVinci, Jules Verne and H.G. Wells, to the realization of space flight by Tsiolkovsky, Oberth, Von Braun, Korolev, Yuri Gagarin and Neil Armstrong; the history of modern space travel with its effect on sensory function began in the fifth decade of the twentieth century.

EVA Height Vertigo

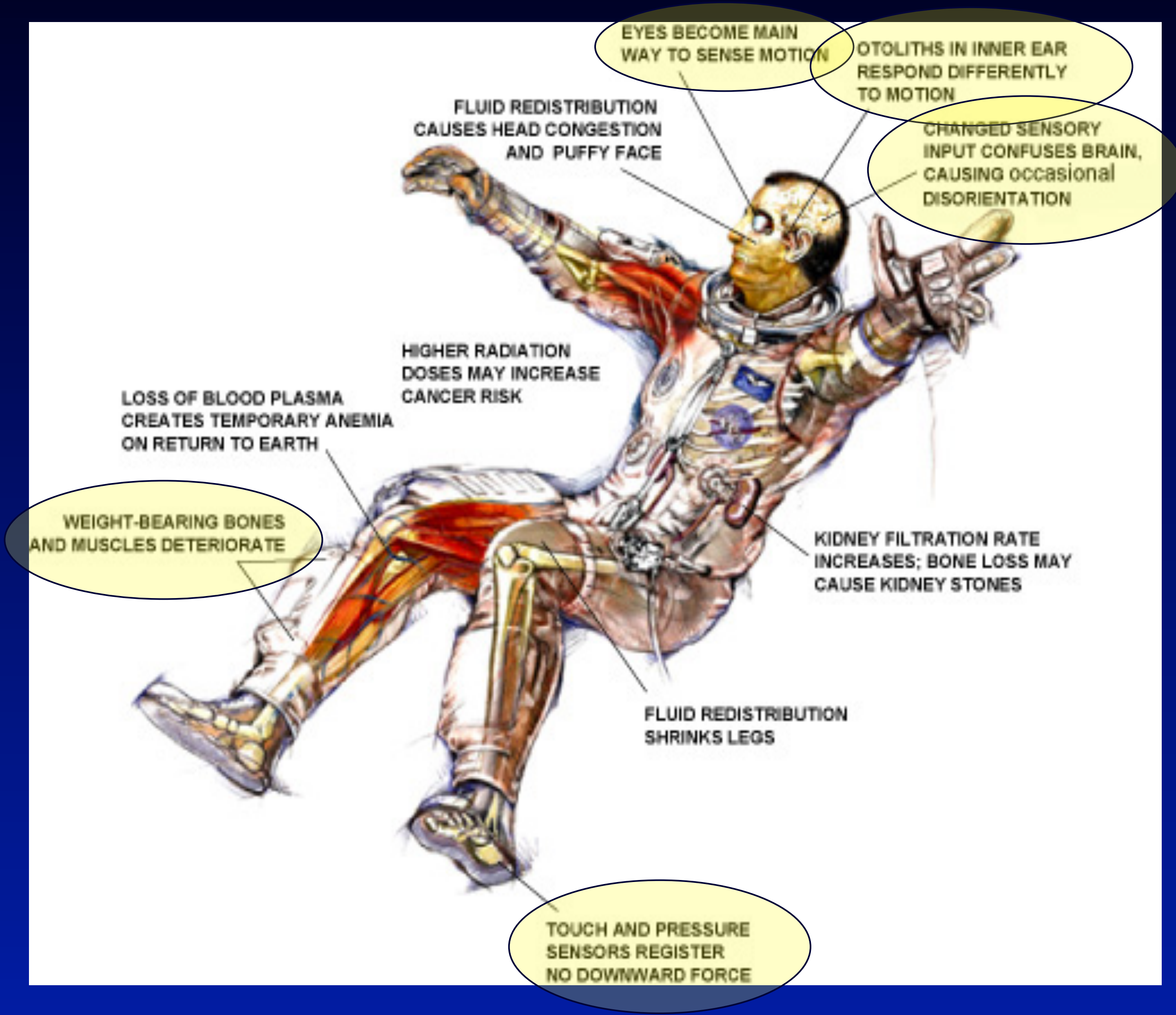
- Viewing Earth beneath your own feet during EVA can trigger sudden sense of height, fear of falling, and enhanced awareness of orbital motion.
- The natural compulsion to hang on can sometimes be disabling.
- Turning away from Earth and putting spacecraft “below” instead of Earth can resolve problem.

Space Shuttle Accommodations for Humans

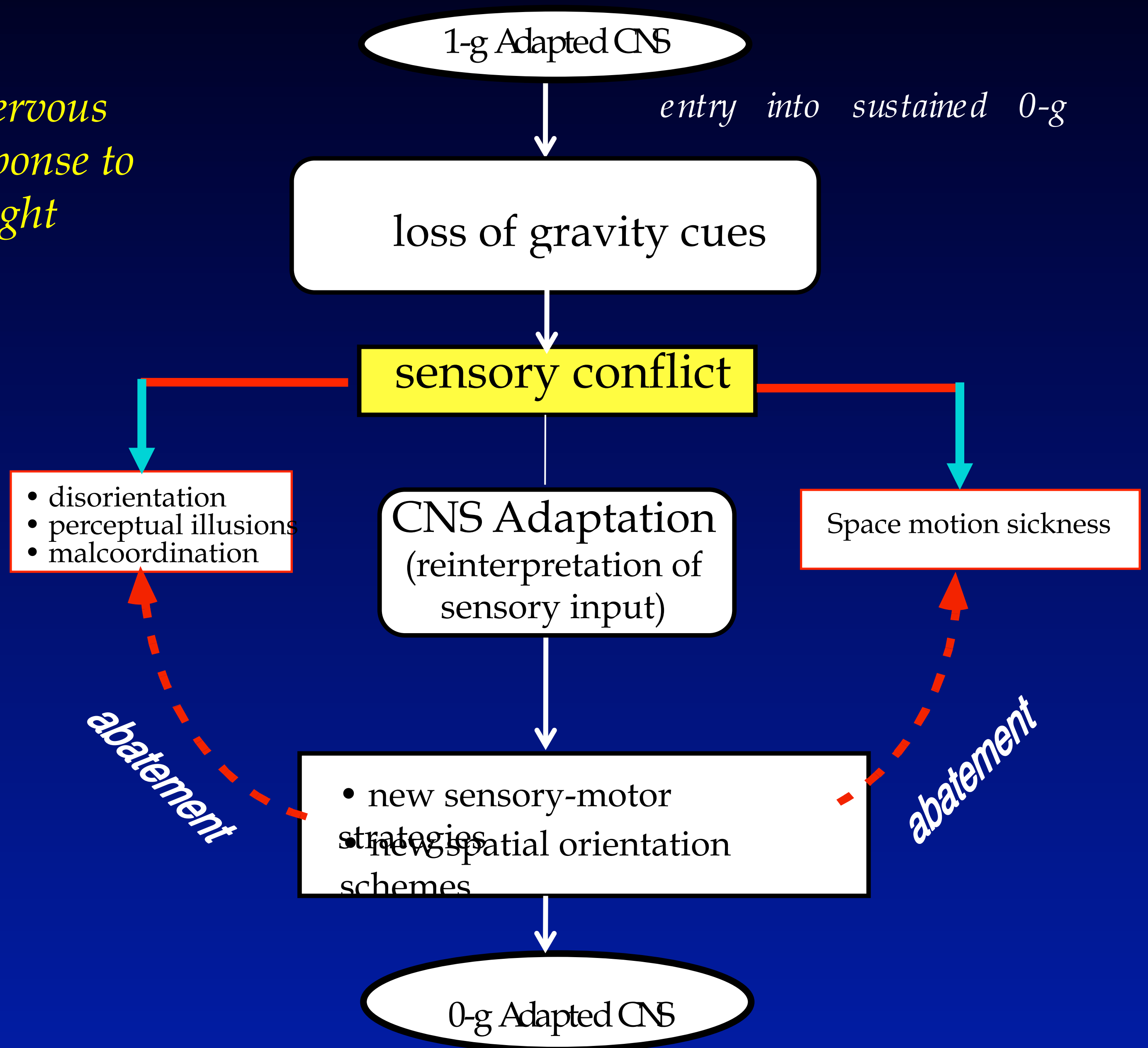




Human Responses to Microgravity



Central Nervous System Response to Spaceflight



Basic Assumptions Underlying Flight

- No need to justify space exploration
- No need to justify human in situ space flight
- No need to justify applied human research in space flight
- It may be the only natural constituency for human space flight!

What follows is the view through my knothole

Functional Mobility Test