The Shuttle Mission:
Enabling Science and Exploration
Life Sciences

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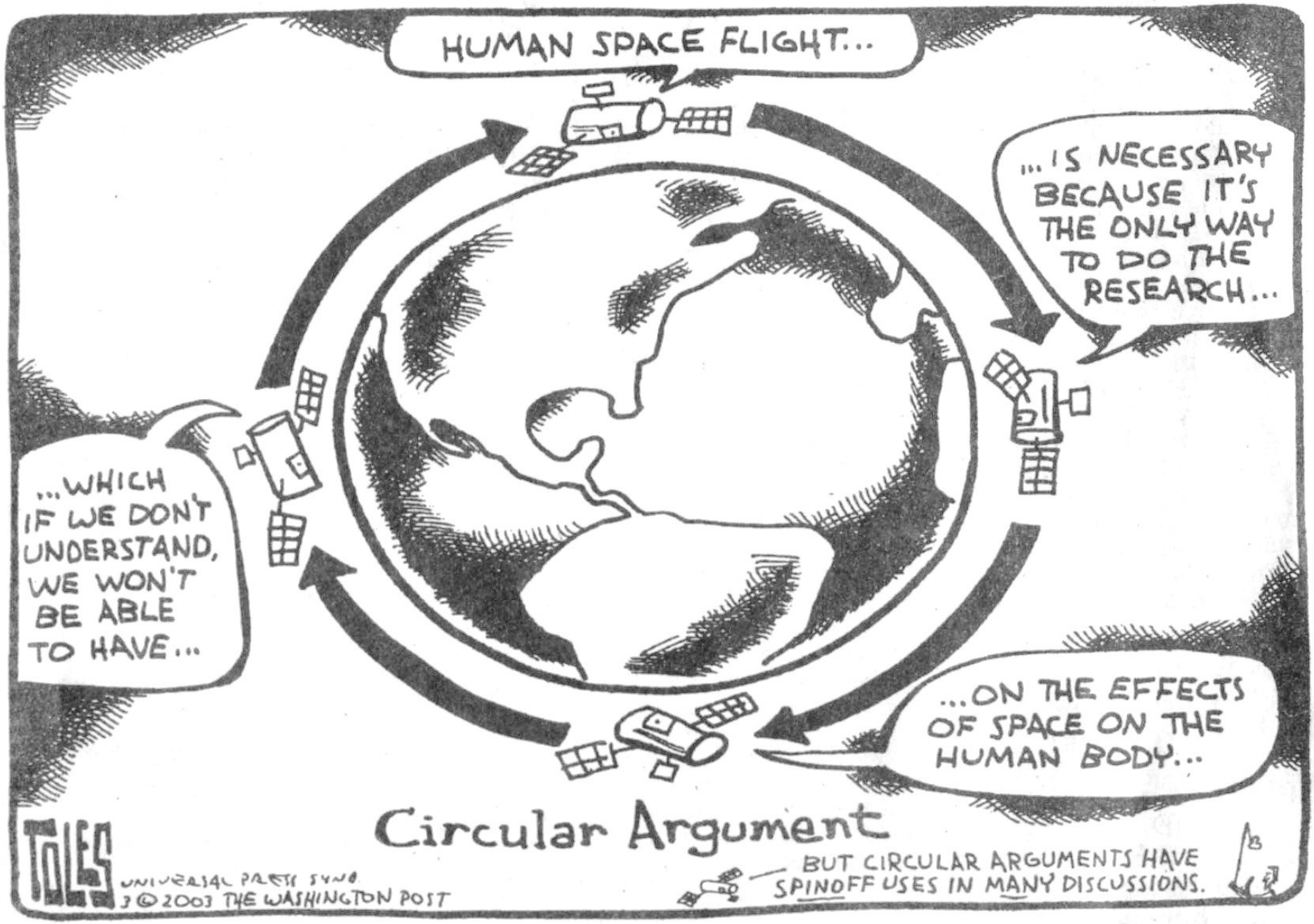
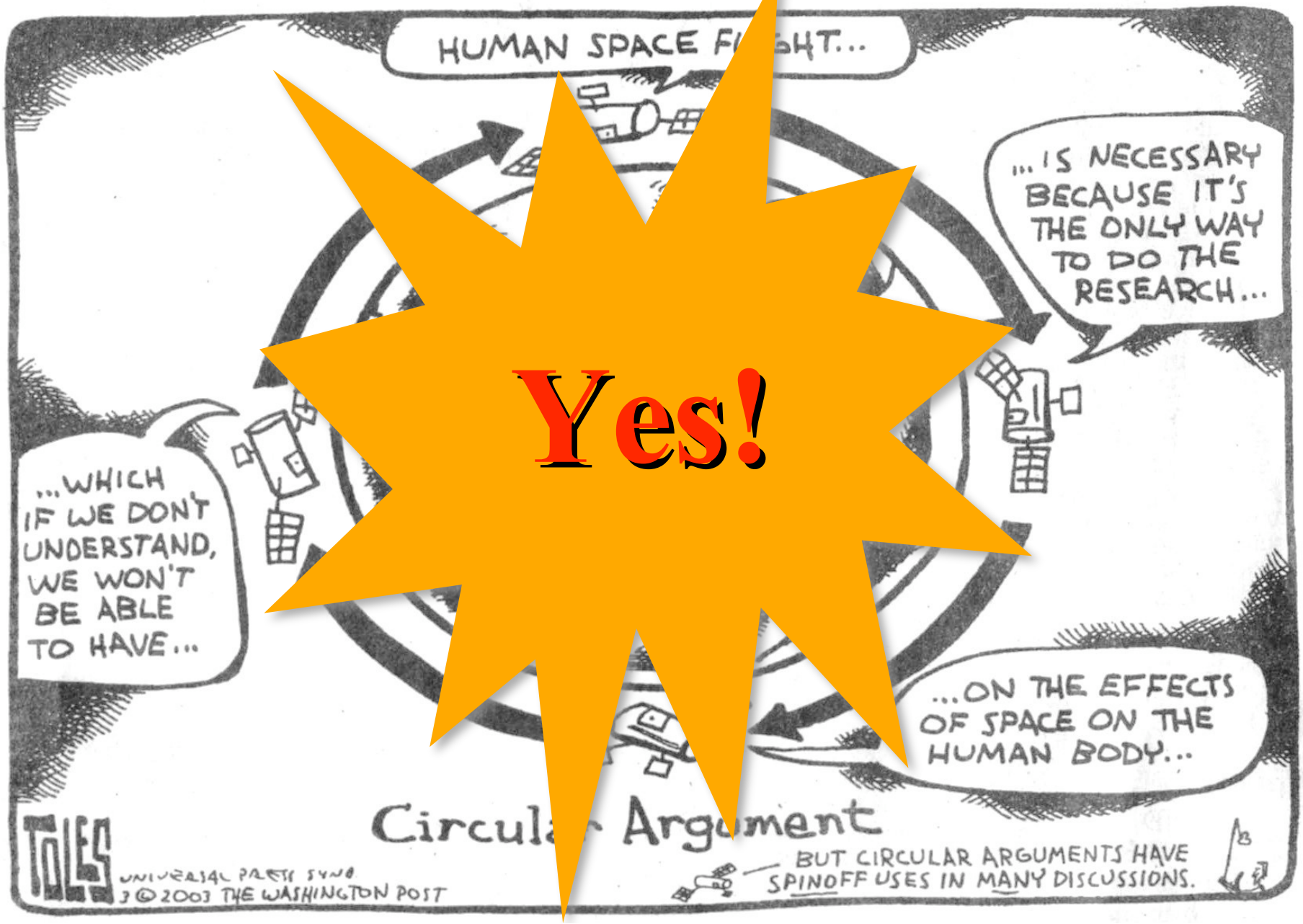
“Burning holes in the sky?”
“Going around in circles?”



Human research in space flight?



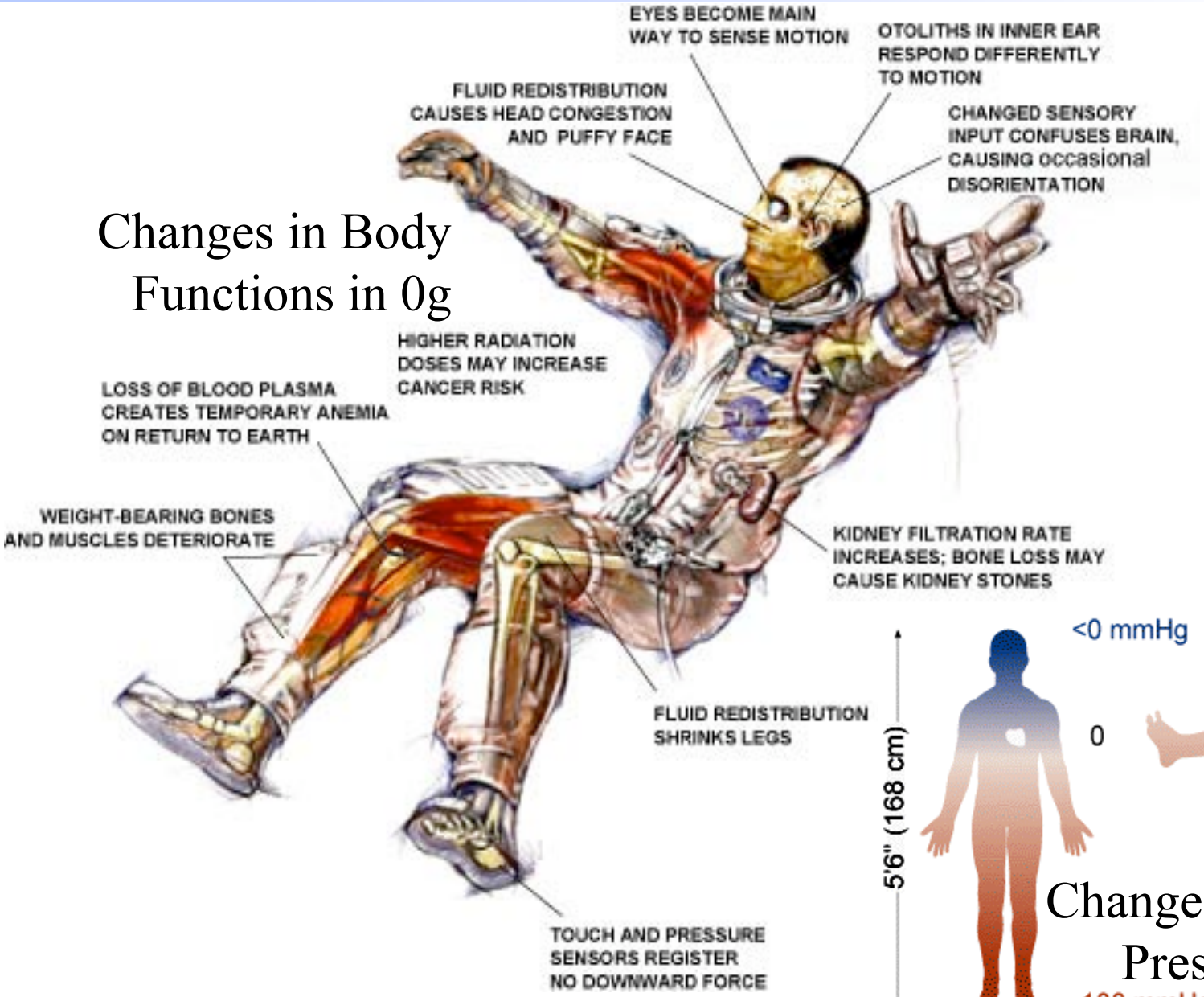
Assumptions

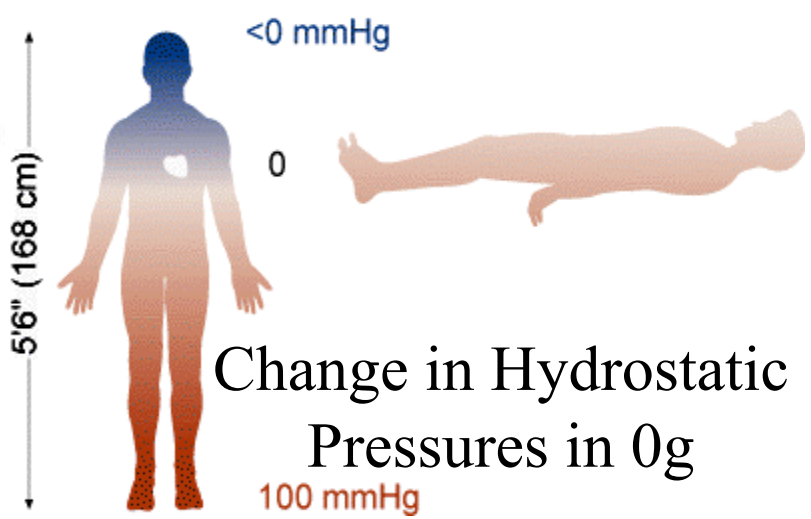
- No need to justify space exploration
- No need to justify human in situ space flight
- No need to justify applied human research in space flight
  - It may be the only natural constituency for human space flight!
  - Apologies to ARC colleagues: little mention of problems encountered in basic research involving non-human species

What follows is the view through my knothole

Human Responses to Weightlessness

Changes in Body Functions in 0g





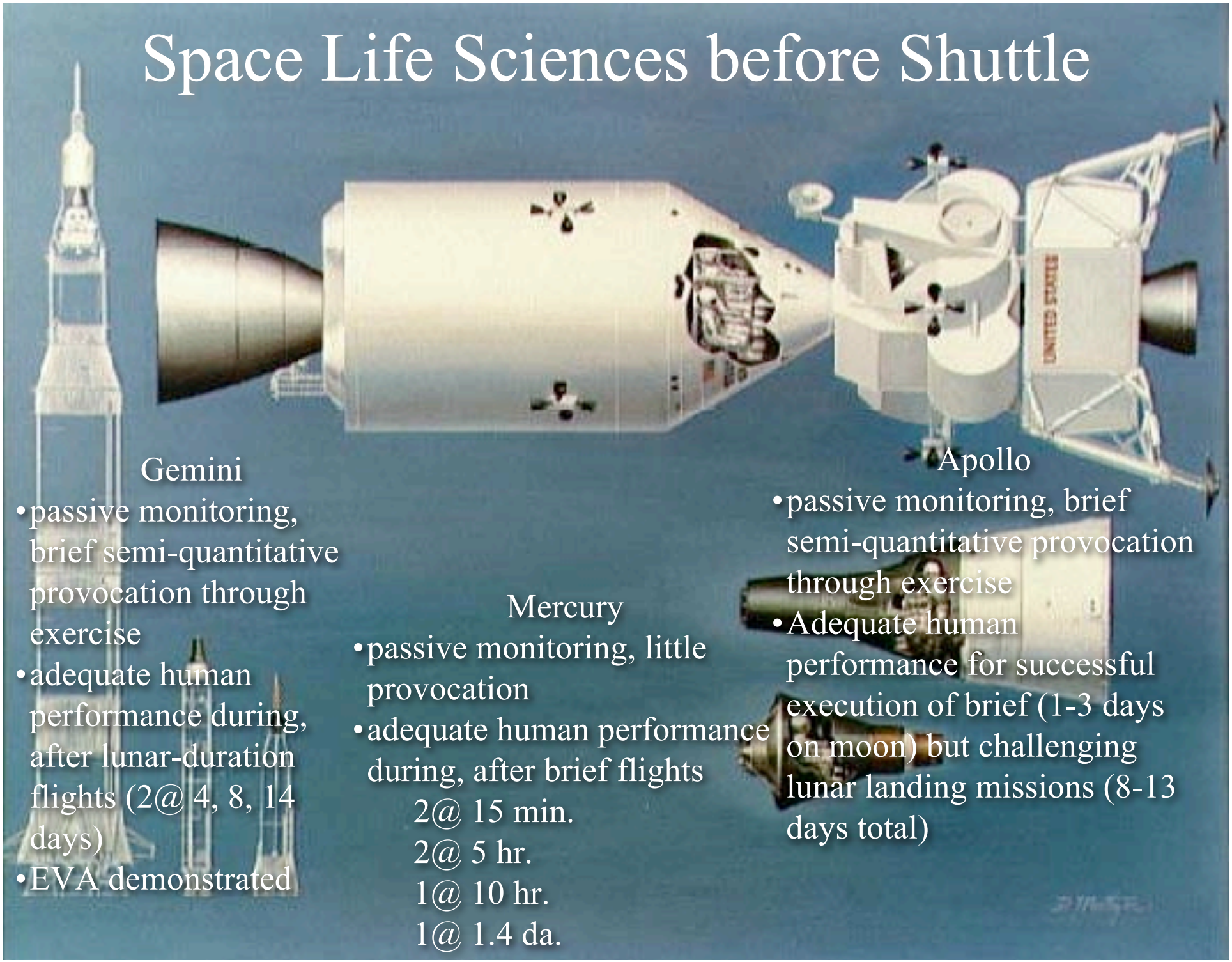
Change in Hydrostatic Pressures in 0g

Basic needs of life sciences research

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.

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

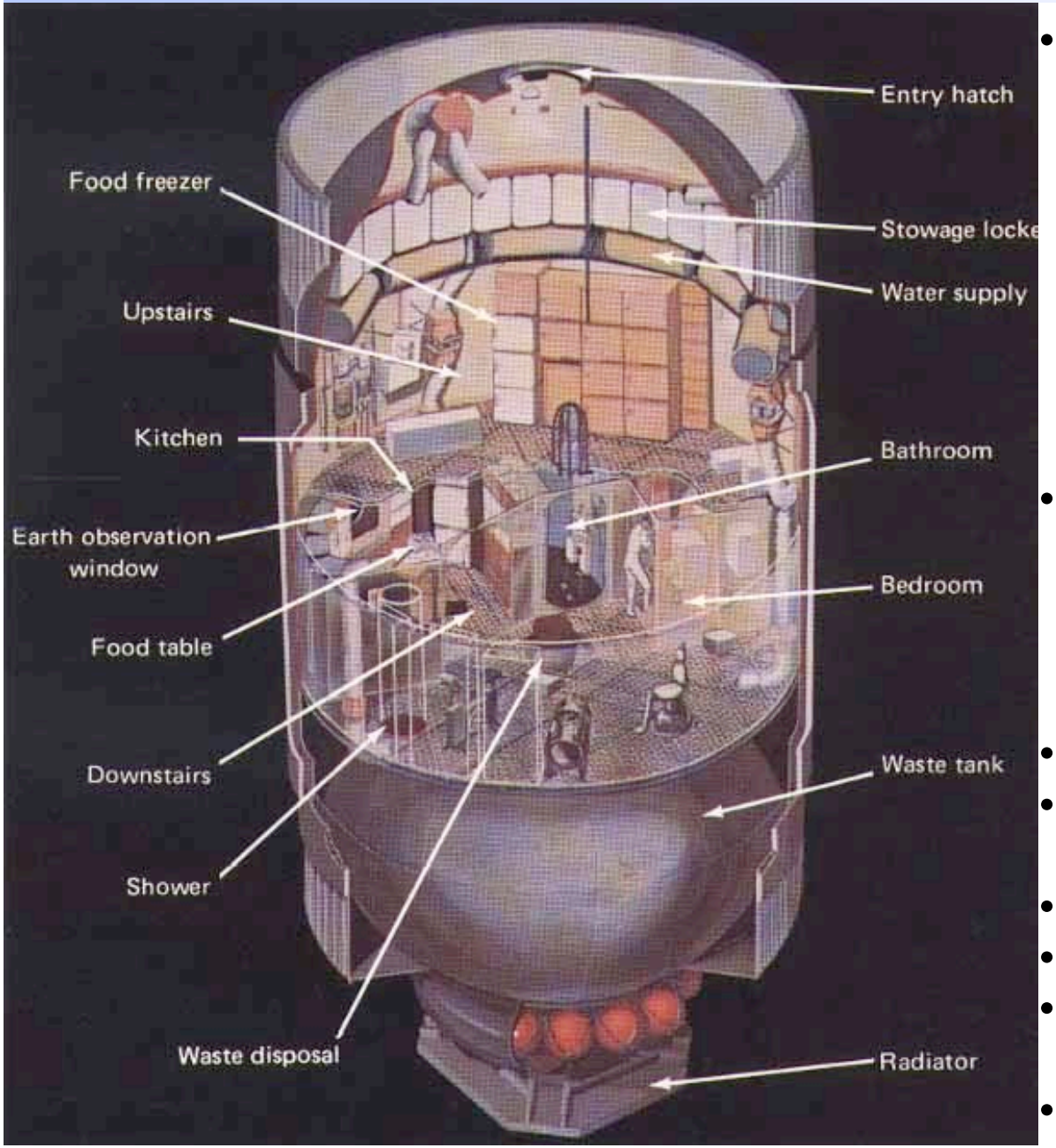
- passive monitoring, little provocation
- adequate human performance during, after brief flights
  - 2@ 15 min.
  - 2@ 5 hr.
  - 1@ 10 hr.
  - 1@ 1.4 da.

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)

Space Life Sciences before Shuttle

Skylab



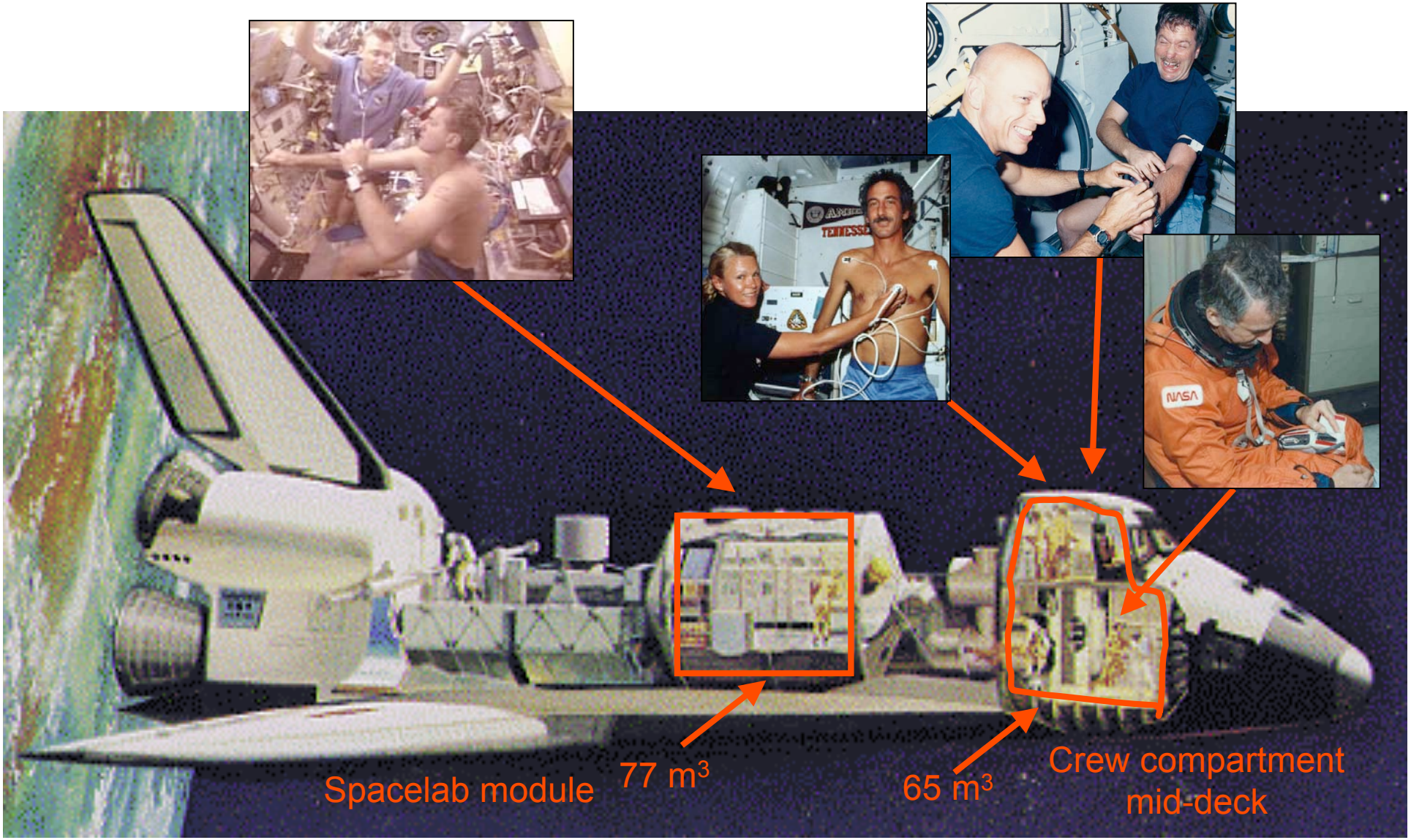
- Life sciences as top priority
  - Cardiovascular
    - Exercise
    - Simulated gravity
  - Metabolism and bone changes
  - Neuroendocrine
    - Hormones
    - Blood volume, red cell mass
  - Neurosensory (vestibular)
- Mostly extramural PIs who responded to solicitation
  - Intramural Project Coordinating 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
- Space motion sickness not insurmountable problem
- Meaningful work in EVA

Space Shuttle: 1981-2010

Accommodations for Humans



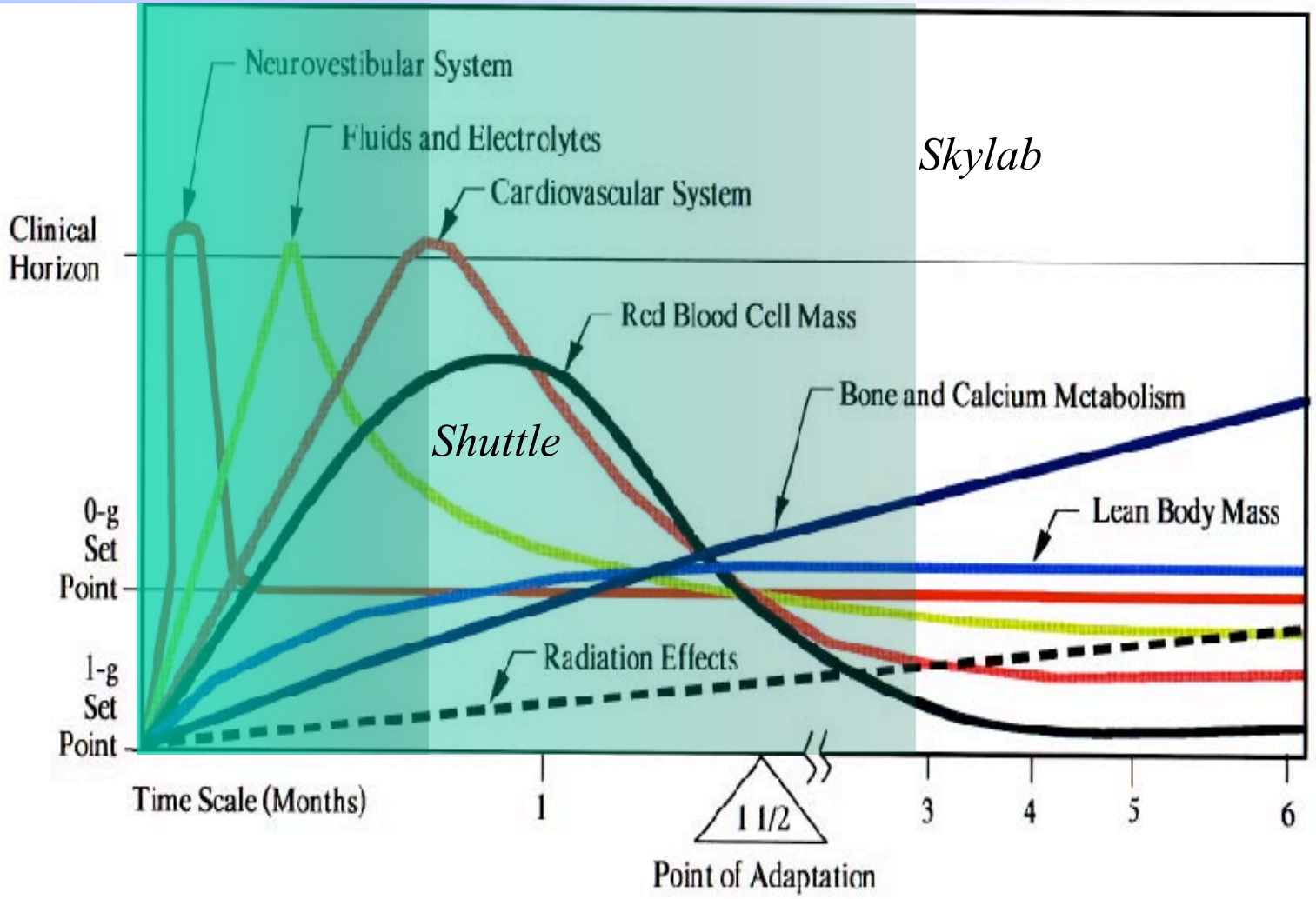
Shuttle Life Sciences Research on Spacelab

- Shuttle research was intended to continue Skylab approach
  - Initially (pre-1978), Spacelab missions were intended to accommodate solicited proposals
    - Mostly extramural researchers
    - Research intensive as primary payloads
      - Usually a large number (~dozen) per mission
      - Mutual interference required constrained timelining
    - "Hypothesis-driven" as "good science"
    - Relatively rare missions
      - 5 dedicated life sciences missions
      - 12 mixed-manifest, shared between LS and μg or space science
    - Small subject populations ("n")

Shuttle Life Sciences Research on Routine Missions

- Later (starting in 1982), routine missions accommodated intramural directed research
  - Operationally-driven to address crew safety, health and performance issues
  - Space-available, non-interference as supplemental activities (medical DSOs)
    - Usually a small number per mission
  - Mostly intramural researchers
    - Bill Thornton established precedent
    - Others eagerly followed
  - Many dozens of missions
  - Potential for large cumulative n

Time Course of Physiological Changes in Weightlessness (notional)



Post-flight Baseline Data Collection

- "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

The mission is not over just because the wheels stop rolling

Pre-Shuttle Recovery Operations, Post-flight Health & BDC

Bad

Good

Mercury

Bad

Good

Gemini

Better

Good

Apollo, Skylab

Shuttle-era Recovery Operations, Post-flight Health & BDC

Shuttle

Bad

Very good

Oh, well…

Post-flight BDC

- Difficult to interpret post-flight data
  - Confounded by preceding activities (in reverse order)
    - Family and VIP visits
    - Walk-around
    - Egress from Orbiter
    - Initial ambulation after landing
    - Heat stress in crew cabin
    - ~High g load (1.8 g seated upright) during entry
    - Vestibular effects of g loads
    - Efficacy of g-suit
    - Efficacy of fluid loading countermeasure (salt tablets and water)
    - Late de-orbit activities—always rushed!
    - Cold-soaked crew compartment overnight
    - Cumulative effects of spaceflight physiological, psychological adjustments (including recovery from space motion sickness)

In-flight data collection

Boots on the ground

- Serial assessments of adjustments during spaceflight
- Unconfounded by post-landing events

- What is appropriate preflight baseline condition?
  - Supine? Head-down? For how long?
- Possibility of early in-flight measurements to document earliest physiological responses to weightlessness
  - Adaptation begins pre-flight
    - 2+ hr. semi-supine before launch

In-flight data collection

Passive

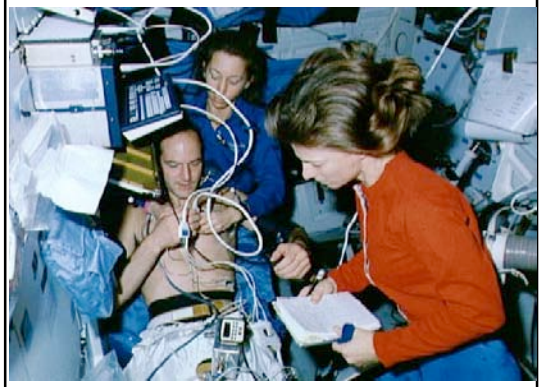
- Just being there (in-flight reports, post-flight measurements)
- ALL missions

Simple

- Sample collection (blood, urine, saliva, feces), processing, preservation

- Surface recording (ECG, EEG)
- Simple maneuvers (Valsalva, Muller)
- Simple interventions (exercise, baroreflex)
- Routine missions; some Spacelab, Spacehab

Complex



- Multi-session, multi-person, multi-hardware item activities
- Spacelab, Spacehab, some routine missions

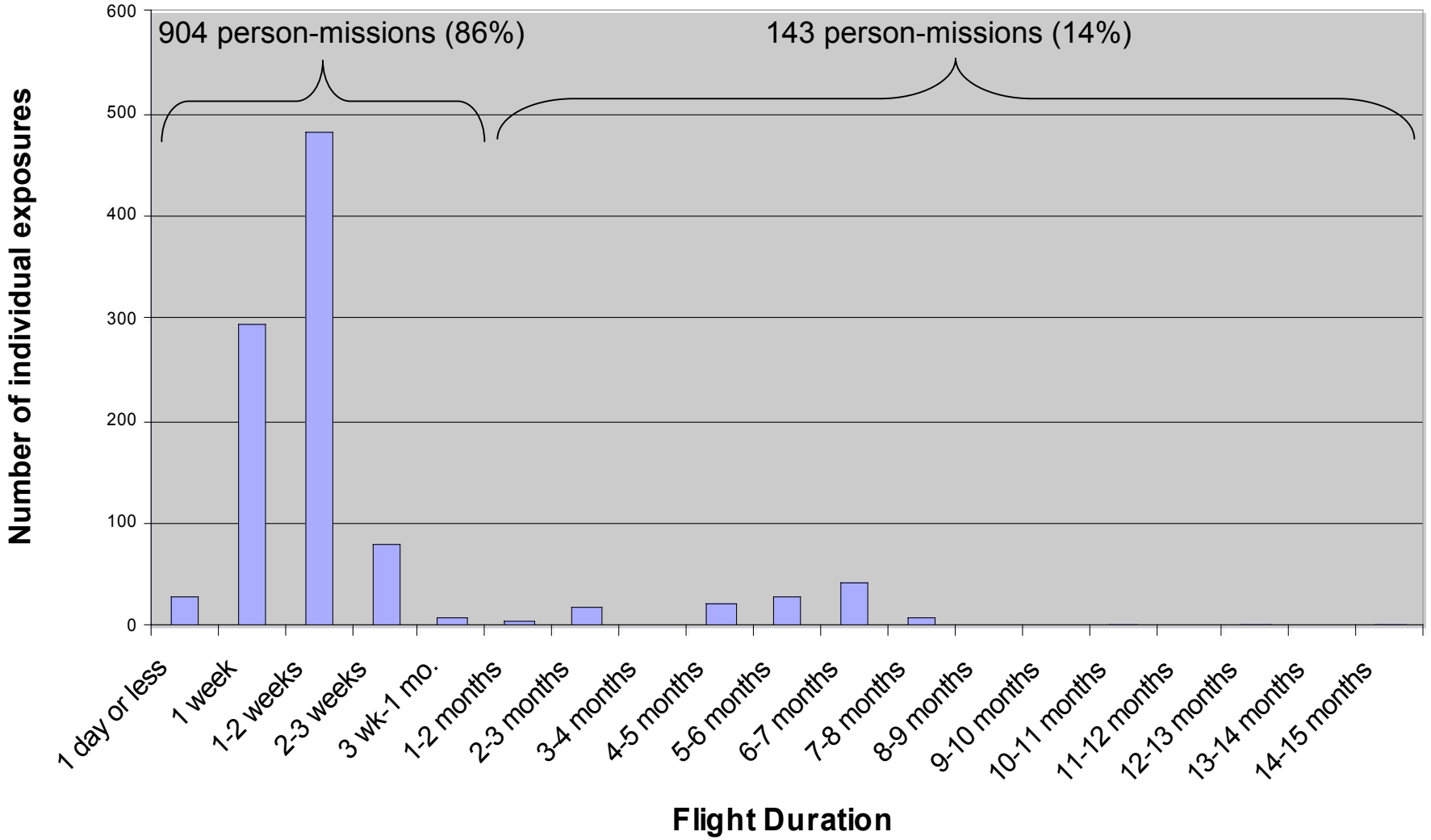
Preflight BDC

- Occurred at multiple occasions before flight
  - Allowed averaging to compensate for intrinsic biological variability
  - Possibly confounded by sequence of pre-flight phases associated with
    - Stages of intensive training (and fatigue)
    - Changes in psychological focus
    - Quarantine (and attendant relaxation)
  - Frequent launch delays
    - Necessary to document time (and pre-flight phase) before planned launch
      - Might be lost when expressed as time before actual launch
    - How much delay tolerable before data is considered “stale”
      - Some flights delayed across seasons

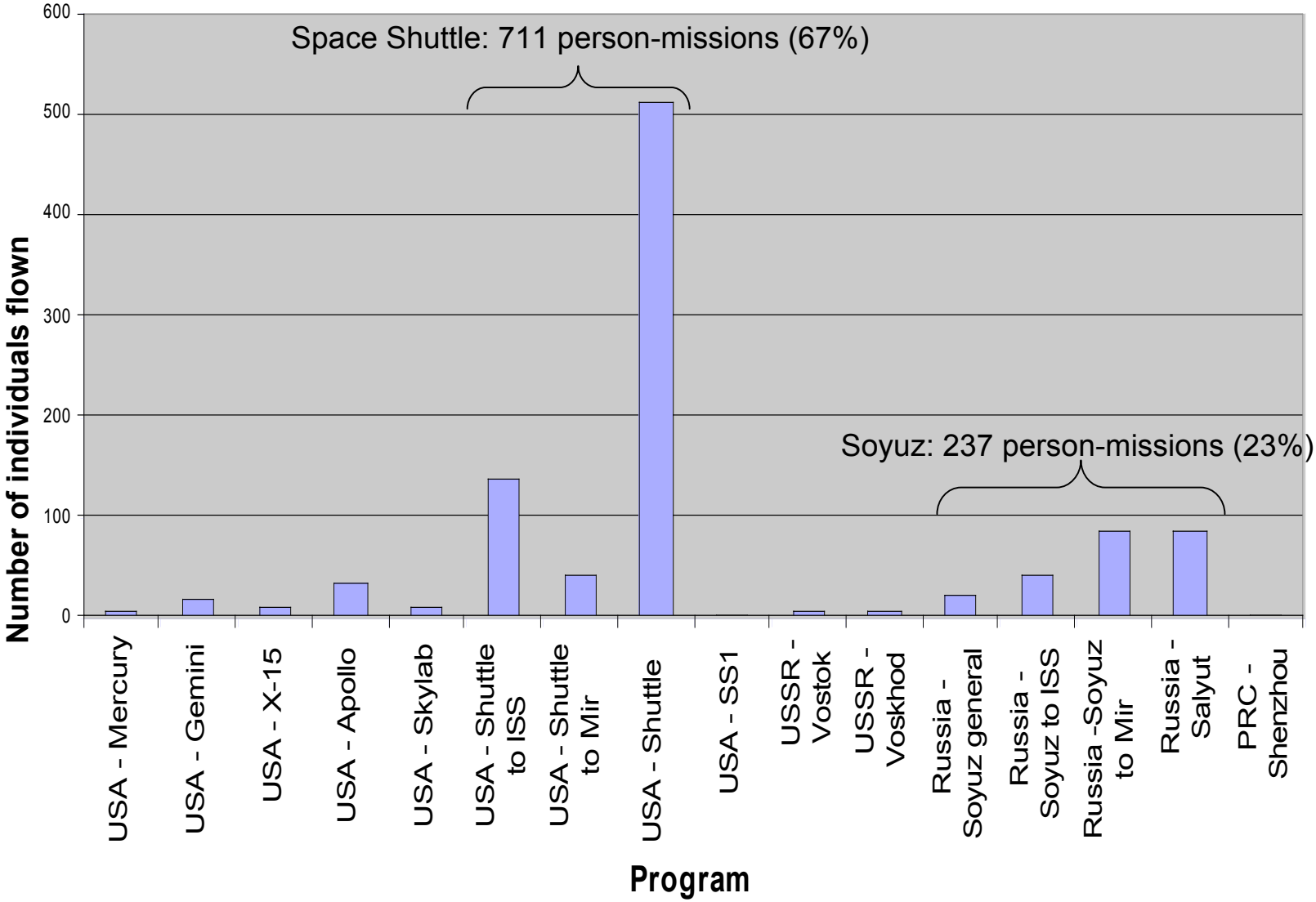
Life Sciences in Practice in Shuttle Era

- Flight surgeons closely aligned with demonstrated operational needs of astronauts and MOD
- Human-oriented researchers aligned with perceived operational needs, representing scientific community
- Basic researchers aligned with HQ and scientific community, not astronauts, MOD, flight surgeons, human-oriented researchers
- Subsequently modified with EDOMP, ESAS, etc.

Human Space Flight Experience



Human Space Flight Experience

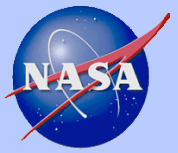


As of Feb. 6, 2008

Space Biomedical Research on Shuttle

"First Golden Age" 1983-1998

- Characterized by
  - Large habitable volume at ~Earth-like conditions
  - Large crew size and diversity for participant population
  - Frequent flight opportunities for data accumulation
  - Comparable flight durations (1-2+ weeks)
  - Early and late in-flight access
  - Broad involvement by extramural and intramural investigators
- Space Shuttle, especially Spacelab and SPACEHAB™ missions
  - Spacelab Long Module missions: 12 shared (1983-97), including 5 dedicated life sciences missions (1991, 1993, 1995, 1996, 1998)
  - SPACEHAB™ research missions: STS-95 (1998), STS-107 (2003)
  - Substantial opportunities on routine Shuttle missions, too
- Full potential not realized…
- Future golden ages…?
  - ISS, for long durations
  - Commercial: suborbital (very brief) and orbital (Shuttle-class)



Thank you.
Questions?

Communications and Coordination in *Early* Shuttle Life Sciences Research

Imperfect generalization…

Astronauts' and MOD preference:

CB → Flight surgeons ⟶ Researchers

Flight surgeons' preference:

CB ← **Flight surgeons** ⊘→ Researchers

Researchers' preference:

CB ← Flight surgeons ⟶ **Researchers**

…improved with experience

Human space flight requires human research

- Understanding effects of space flight—especially weightlessness—on humans is required for risk reduction
- Exposure of humans to weightlessness for prolonged periods is only way to validate results from analog studies and models, to acquire “ground truth” data. and truly understand effects of prolonged weightlessness on human health, safety and efficiency