Mars Transit/Surface Habitat Commonality Studies

University of Maryland
Final Progress Review

Exploration Habitat (X-Hab) 2018
Academic Innovation Challenge

May 31, 2018

University of Maryland Personnel

- Dr. David L. Akin - Faculty Mentor
- Lemuel Carpenter - Graduate Mentor
- Charlie Hanner - Undergraduate Mentor
- ENAE 100 Design Team
  - 6 students (first-year): Nicolas Bolatto, Sean Fowlet, Thanushree Manjunath, Thomas Skinner, Benjamin Brotzman, Rohil Bahri
  - Focused experimentation
- ENAE 483/484 Capstone Design Course
  - 24 students (seniors) in habitat design team
  - Systems analysis, detailed design, and design/build/test/evaluate (DBTE) component

Problem Statement

- Human exploration missions to Mars will require habitats for both transit and surface exploration
  - Extended transit durations may require artificial gravity
  - Human exploration of the moon may precede Mars
  - Development of multiple independent habitats will be prohibitively expensive
- Achievable exploration goals are optimized by achieving maximum commonality between habitats
  - Need better understanding of the role of gravity in habitability design
  - Perform extended simulations of IVA operations in micro-G, lunar, Mars, and Earth gravity levels

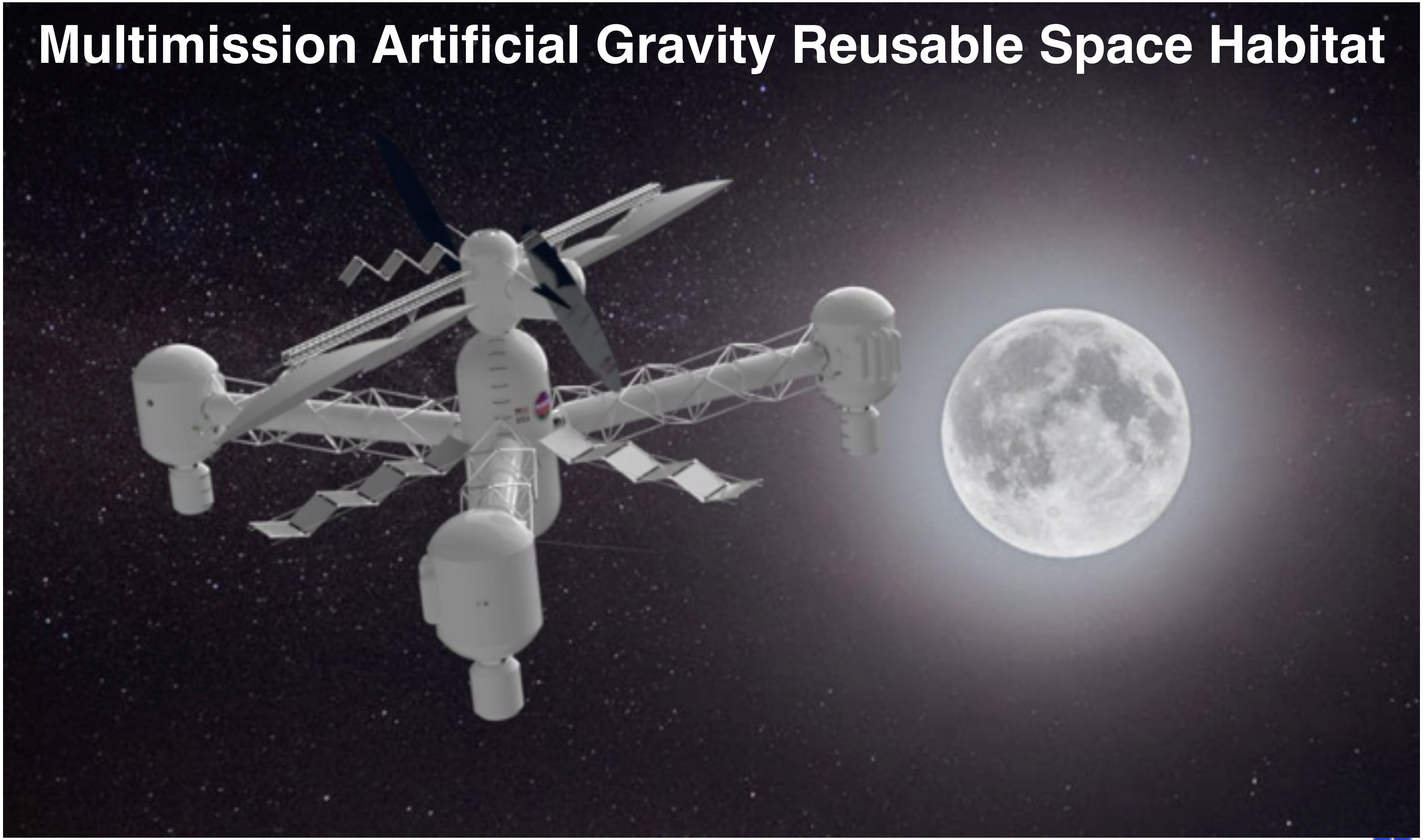
Program Rationale

- Serious limitations exist to studying microgravity or partial gravity habitability in Earth gravity
- Body segment parameter ballasting in underwater environment provides one of the most realistic partial gravity simulations available on Earth
- Underwater test durations are limited, so not practical to perform extensive "habitat" simulations
- Design test set-ups to take advantage of environment, avoid limitations
- Top priority: test subject safety

Program Objectives

- Perform fundamental research into biomechanics and human performance at variable gravities using the unique capabilities of underwater simulation
  - Microgravity
  - Lunar
  - Mars
- Create limited habitat simulation with various task simulators which can be adapted across different gravities
- Tie into detailed design of variable gravity habitat by leveraging senior capstone course

MARSH Final Design



MARSH Habitat Design Products

- Critical Design Review
  - 23 April 2018
  - 351 slides
  - 4 hours
- Final Report
  - 18 May 2018
  - 298 pages

MARSH

Space Systems Laboratory
University of Maryland

Critical Design Review
23 April 2018

MARSH: Multi-mission Artificial-gravity Reusable
Space Habitat

MARSH

ENAE484 Senior Capstone Design Final Report

Team

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Skylar Trythall
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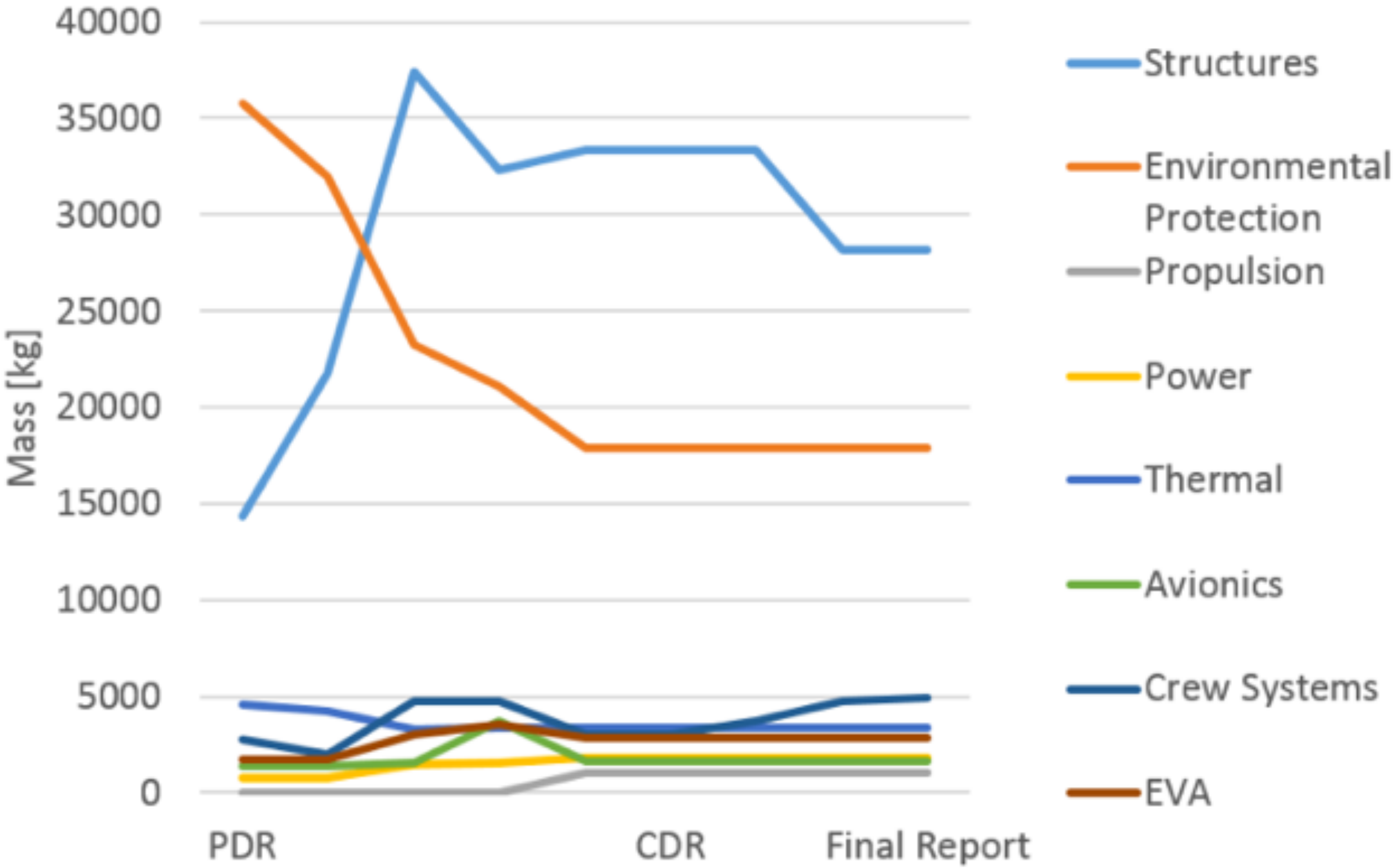
Jacob Zembower

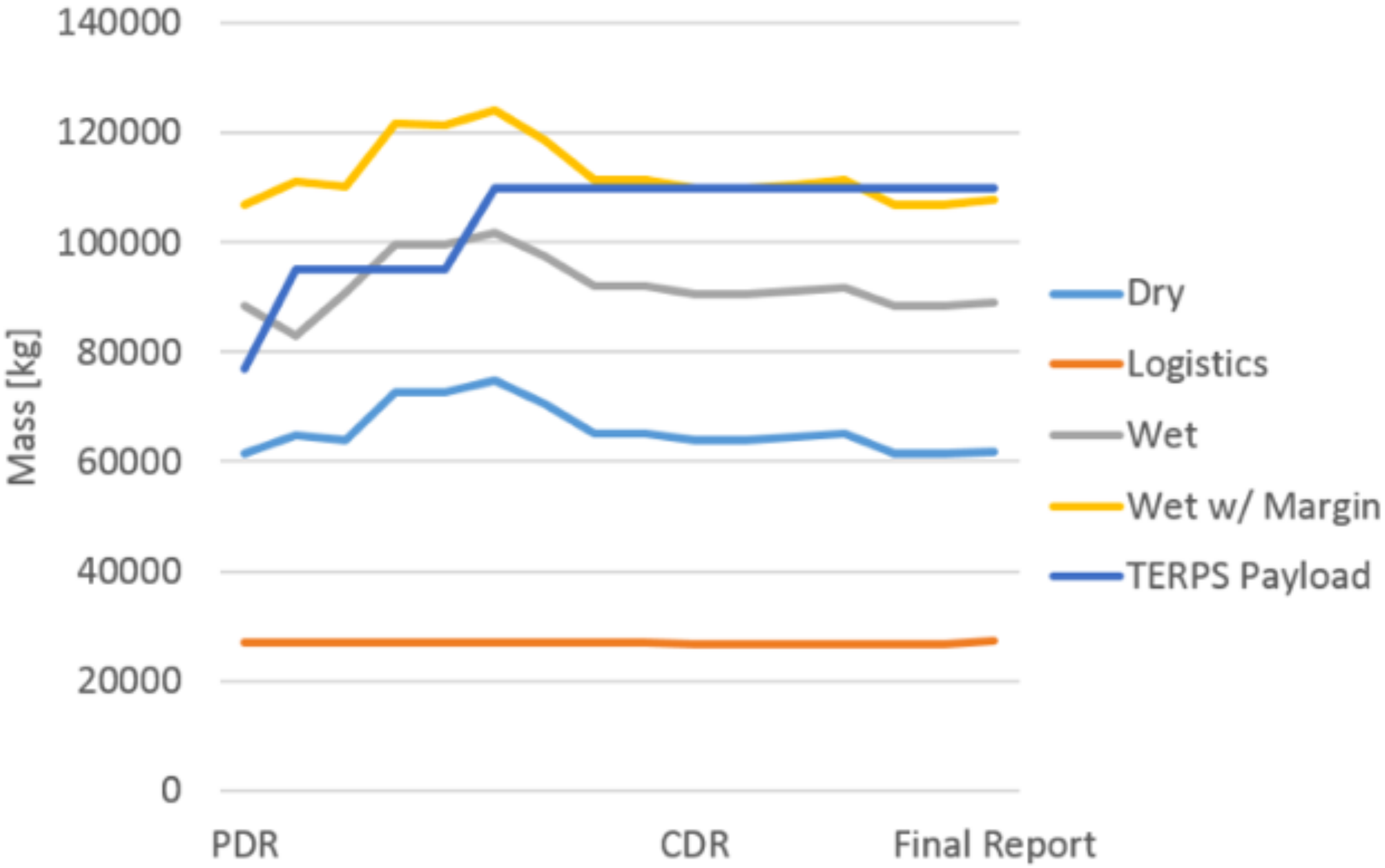
Faculty Advisors

Dr. Dave Akin Dr. Mary Bowden Dr. Andrew Becnel Dr. Jarred Young

MARSH Subsystem Mass Evolution



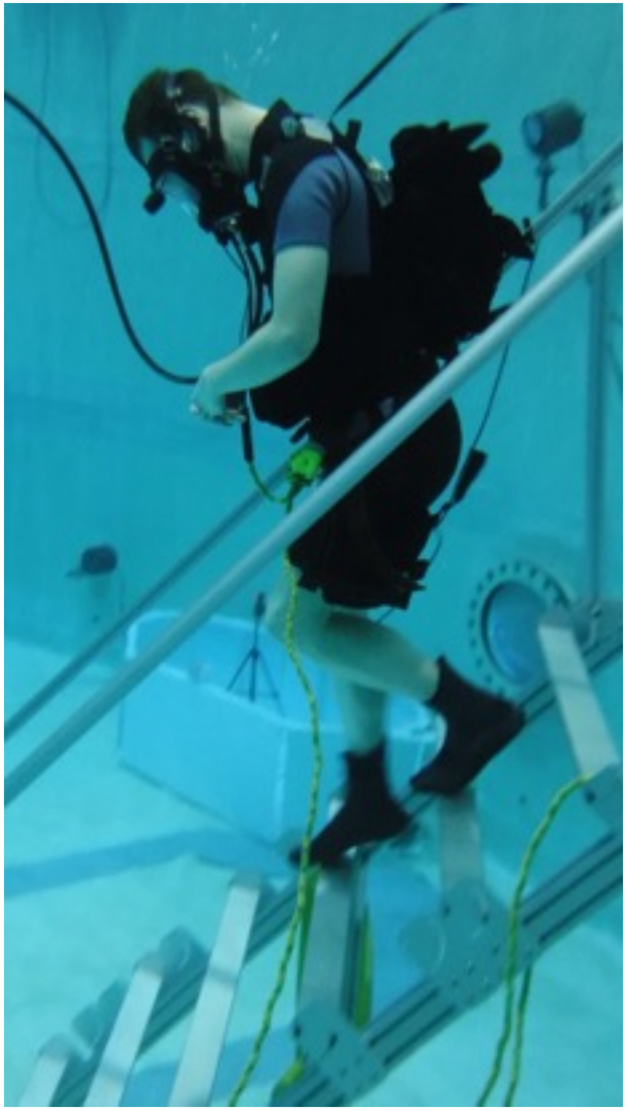
MARSH Total Mass Evolution



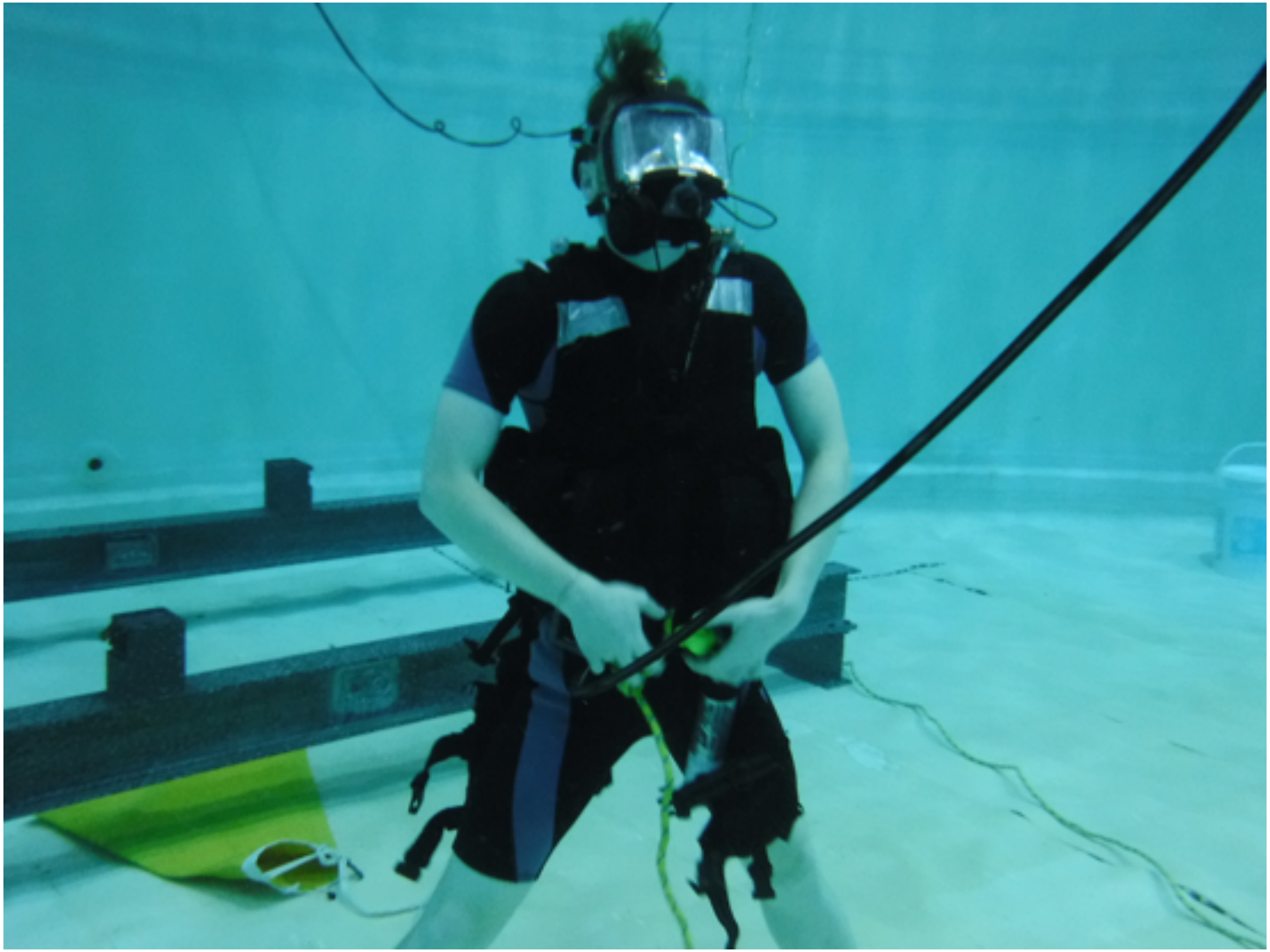
Artificial Gravity Habitat Challenges

- Rotating, low-friction, sealed bearings
- Radiation protection
- Providing sufficient despun real estate (e.g., docking, photovoltaics, radiators, communications…)
- Life support fluids management for both microgravity and significant gravity
- Redundant crew access/egress under gravity
- Systems and storage allocations between modules
- Fine details of spin (active?) stability

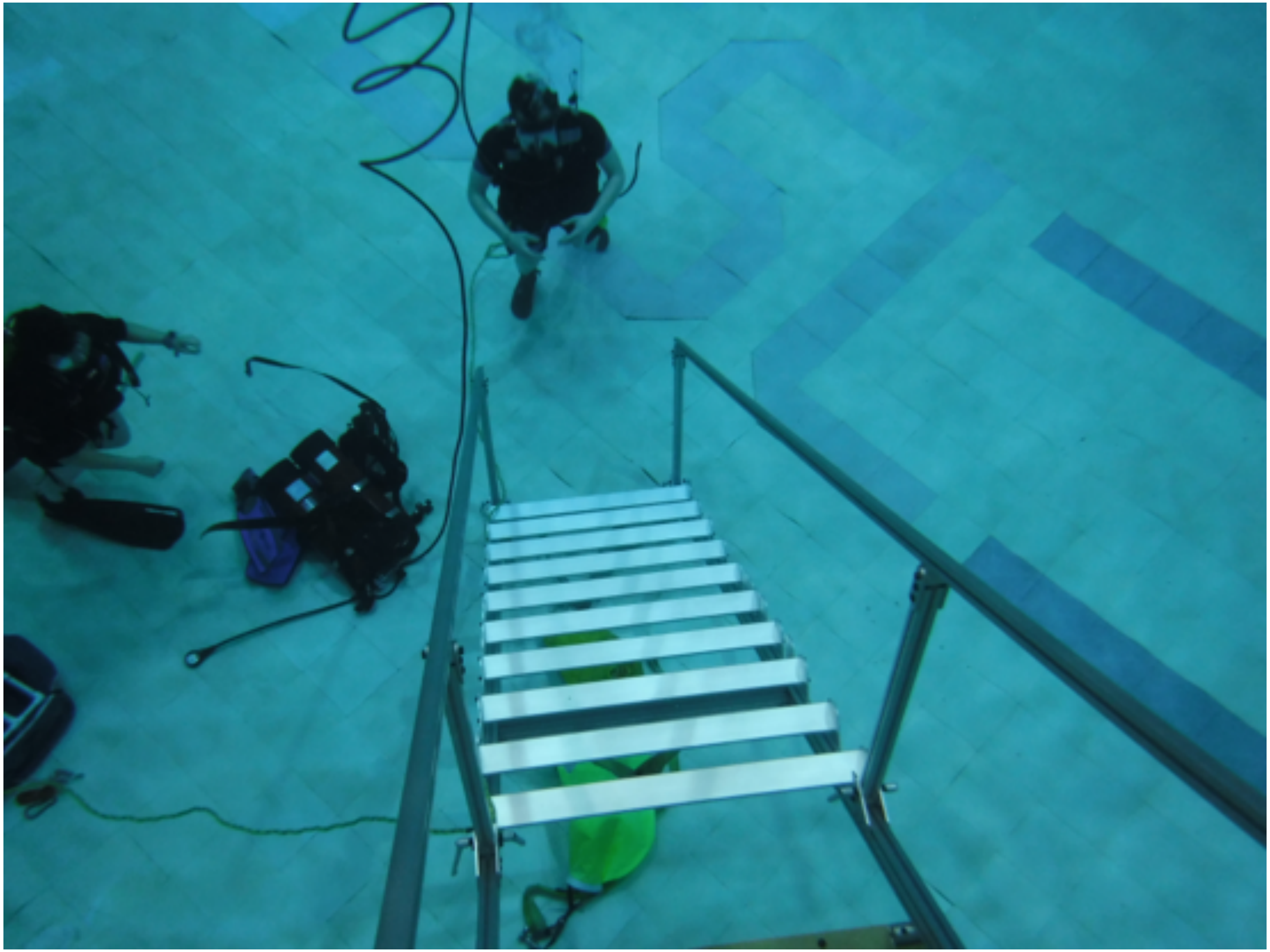
Inter-Deck Access Testing



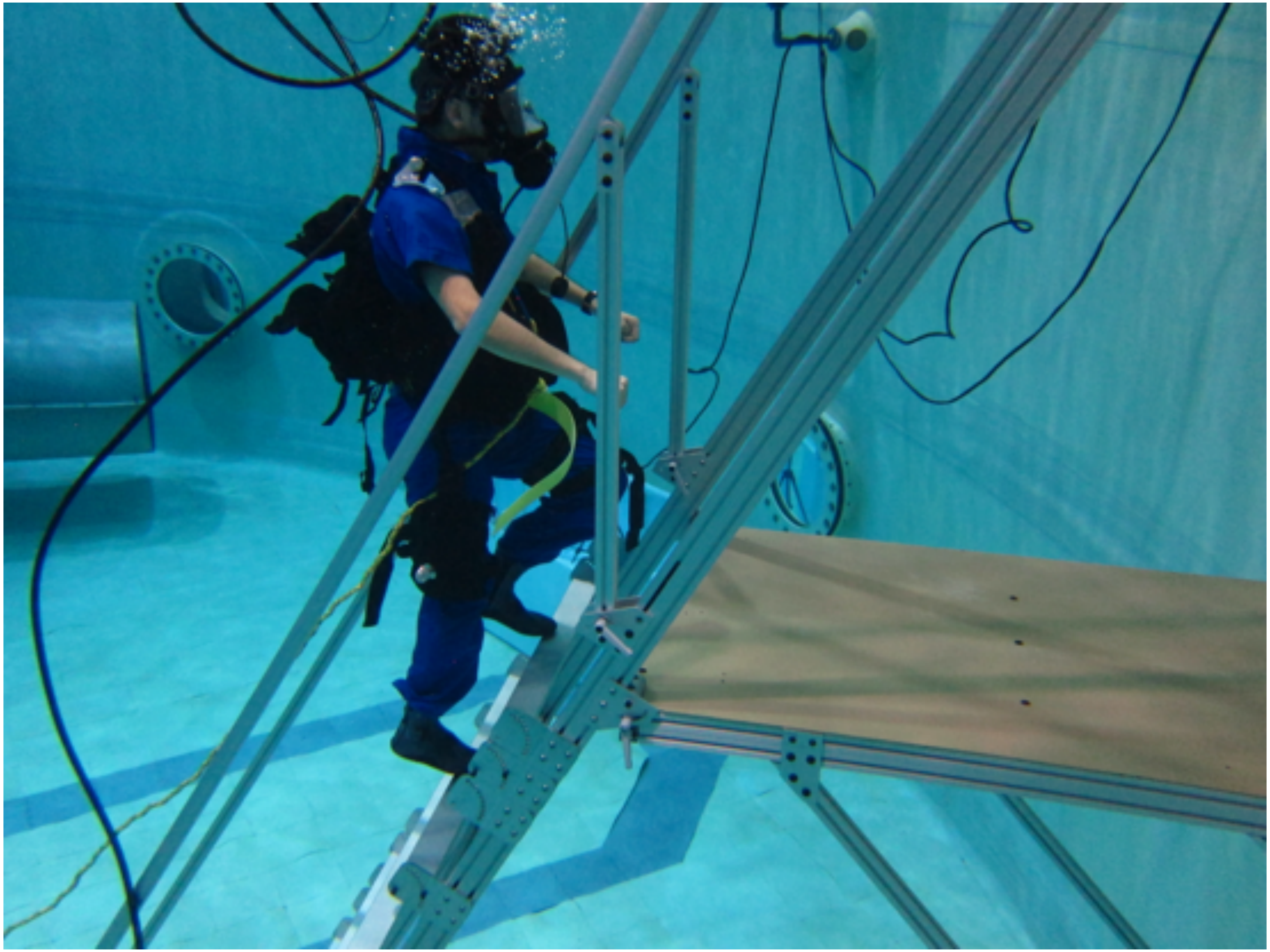
Test Subject Ballasted to Lunar Gravity



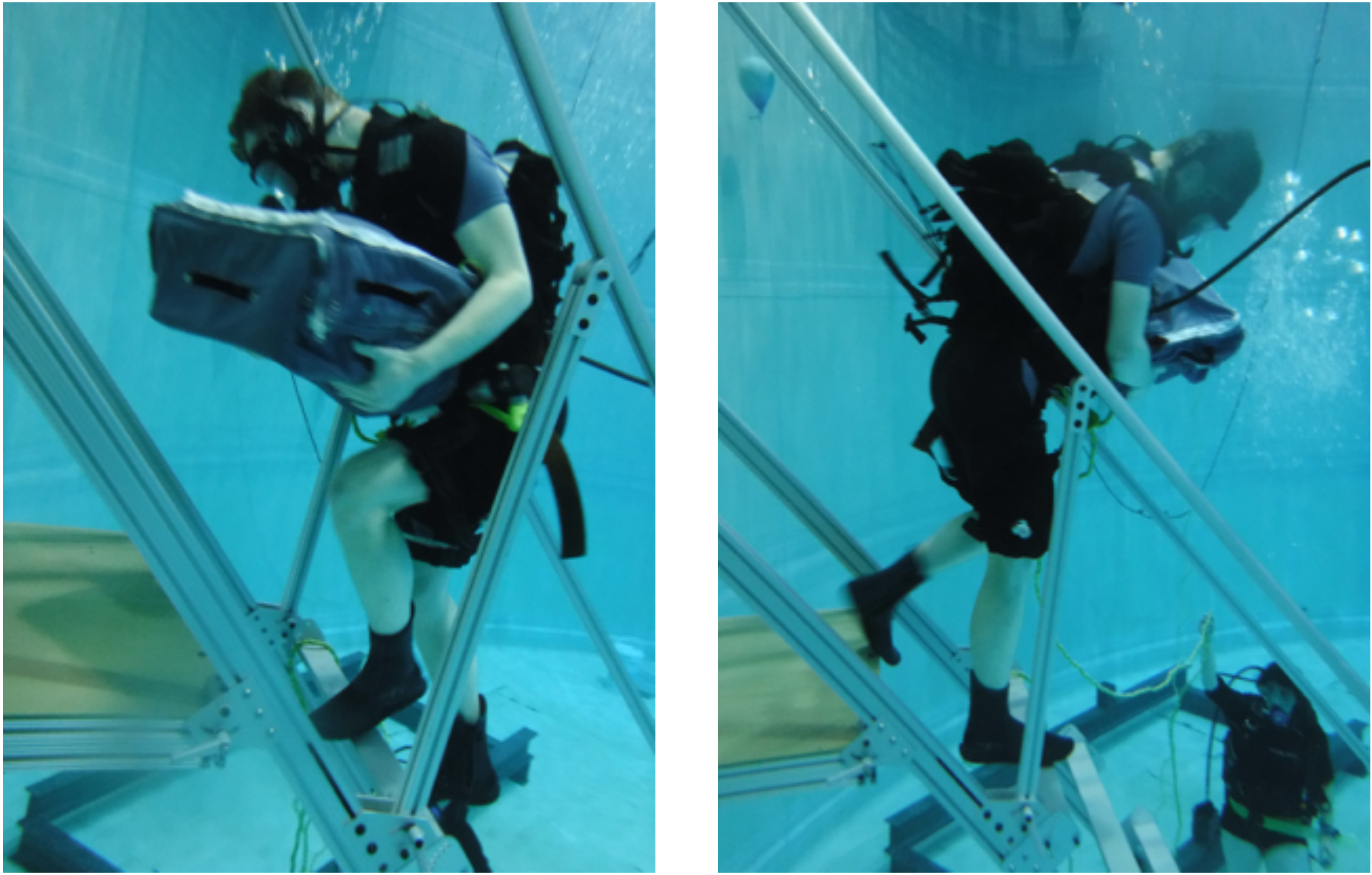
Staircase in Place (Top View)



Unencumbered Ascent (Lunar G)



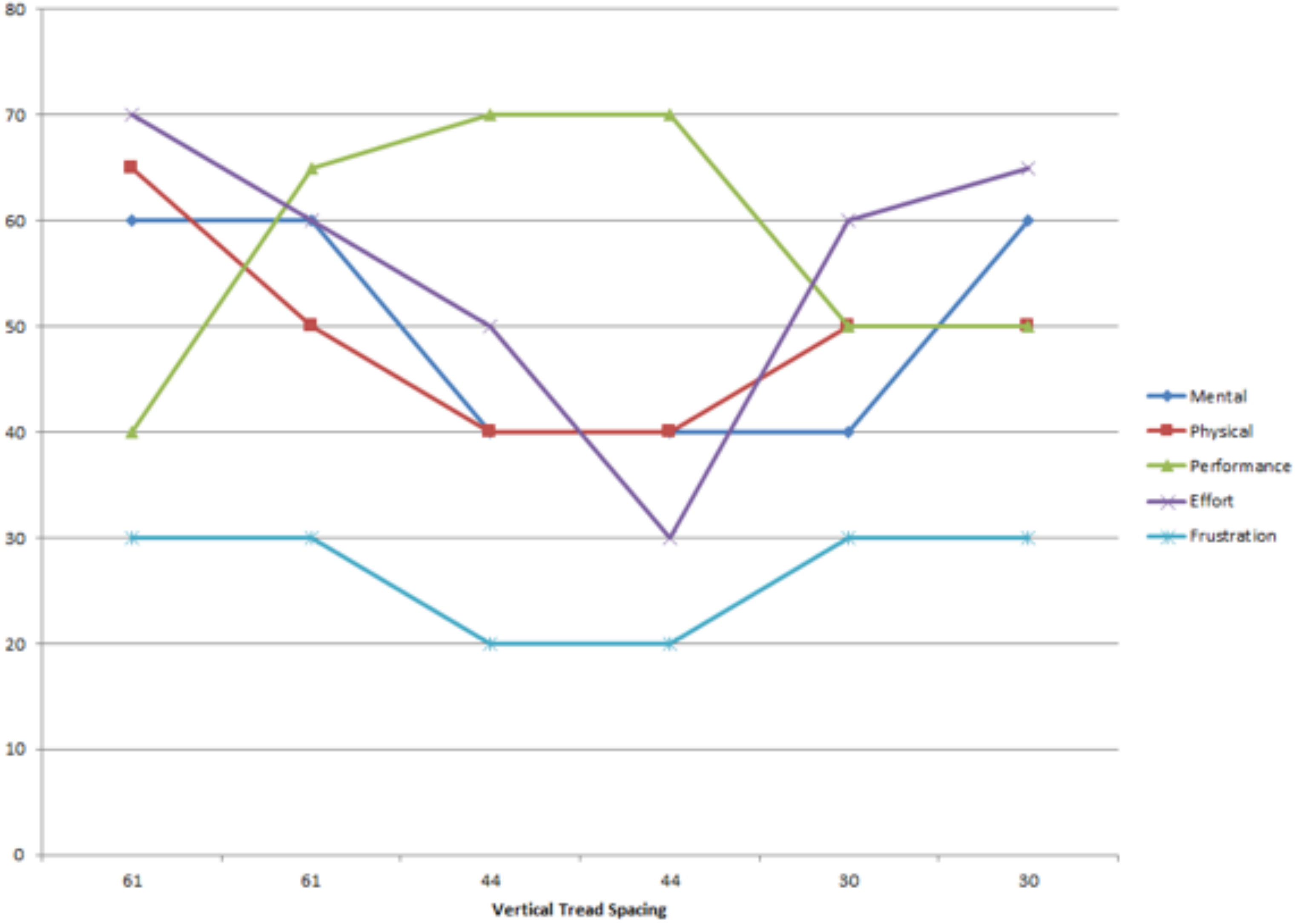
Test Subject Carrying Weighted CTB



Correlation Tests in Lab Environment

Navigating Stairs at 1G with CTB

NASA Task Load Index of Tread Spacing

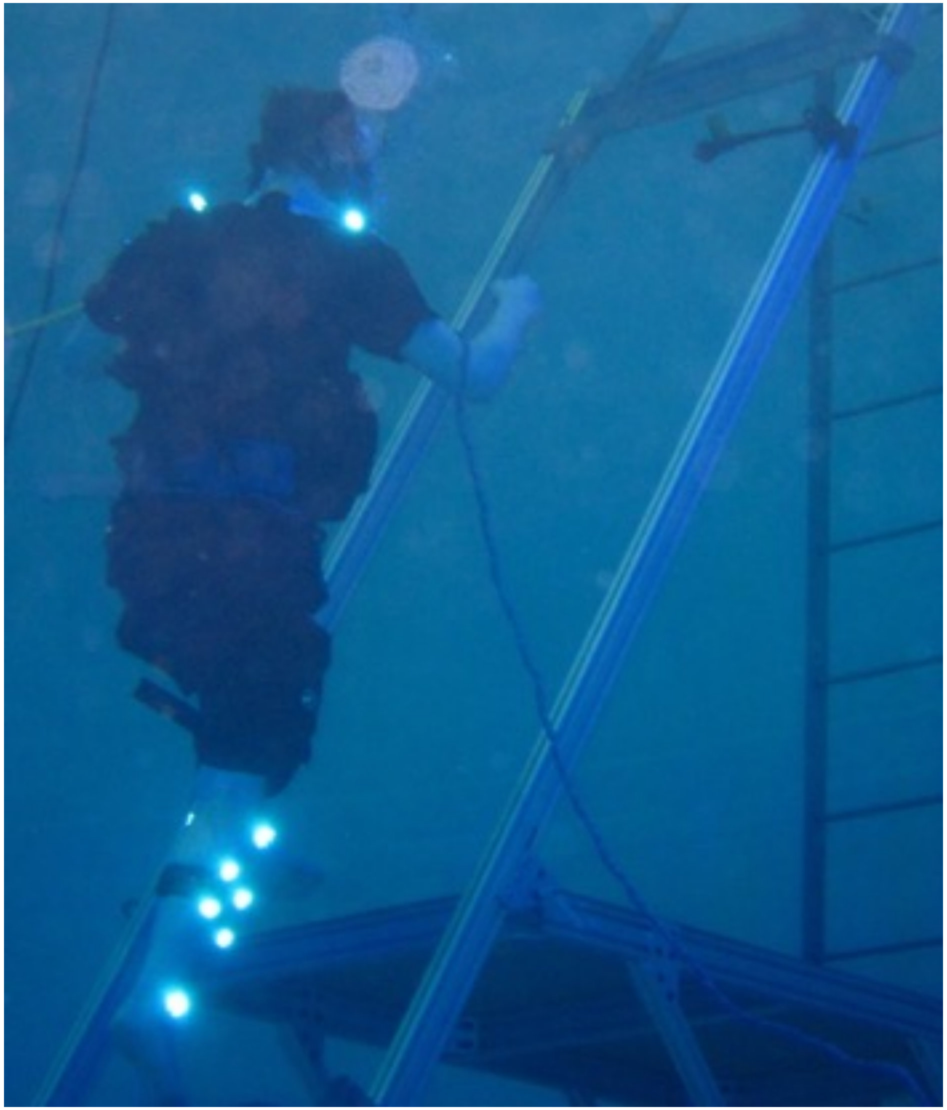


Transition Times for Test Cases

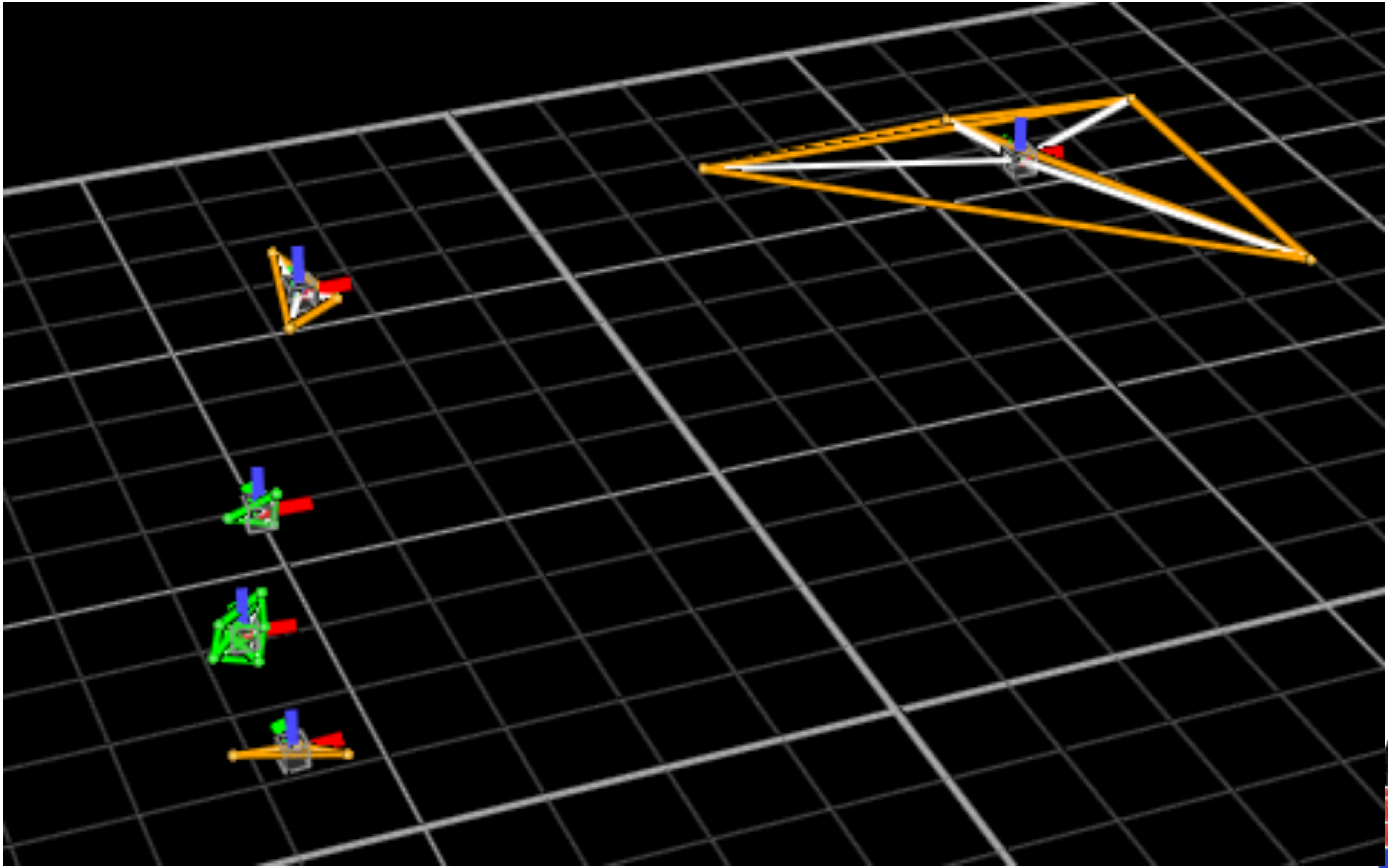
1G Dry		w/o CTB	w/ CTB
50 deg	Up	6.58	6.70
	Down	6.10	6.31
60 deg	Up	6.63	6.04
	Down	5.75	4.86

Lunar UW		w/o CTB	w/ CTB
50 deg	Up	20.60	16.61
	Down	14.17	12.68
60 deg	Up	17.17	13.14
	Down	9.47	9.85

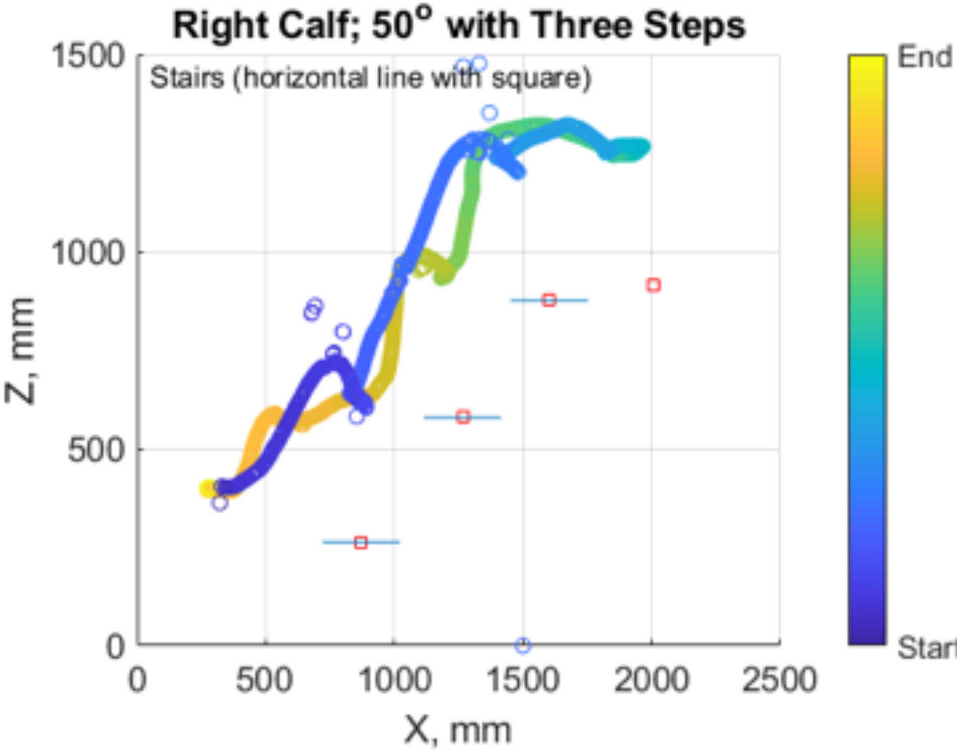
Motion Capture Data Collection

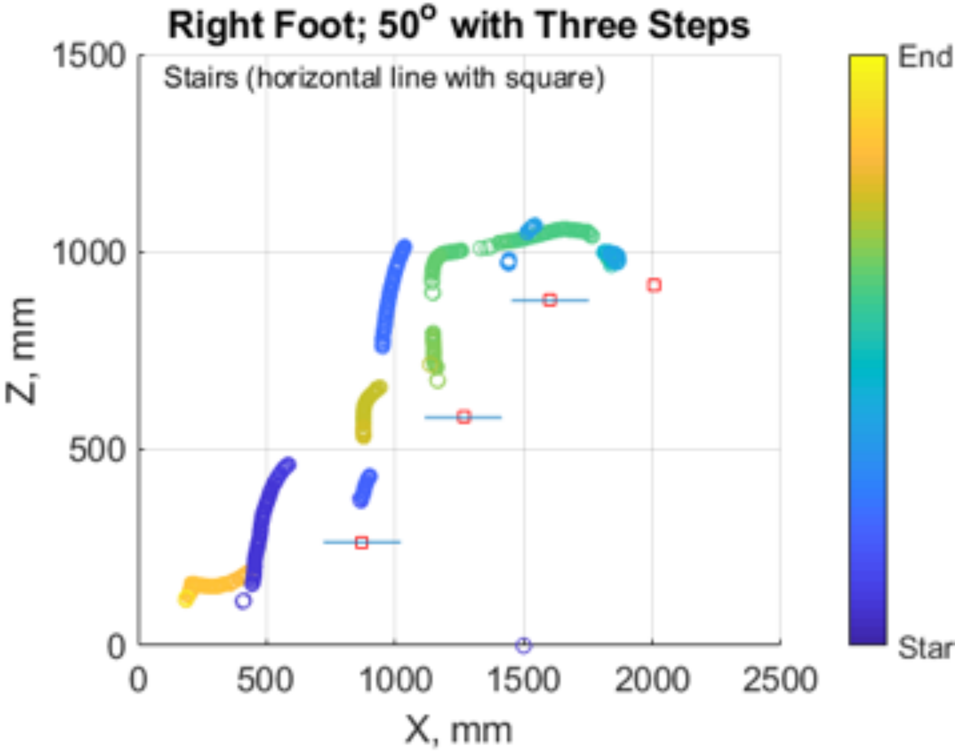


Motion Capture Data Example



Motion Capture Data (Laboratory)





Issues with Staircase Test Hardware

- Time required to reconfigure for different test case
  - Tread angle changes simplified by addition of thumb screws for diver adjustment
  - Tread spacing requires loosening eight bolts and sliding along 80/20 rail (best done between dives)
  - Changing angle requires “brute force” by divers
- Removal of handrails required due to interference with tread readjustment (addition of fall arrestor for safety)
- Need to paint/coat/cover metal components to reduce spurious signals in motion capture system

Interdeck Access Test Matrix (Ideal)

- Gravity levels
  - Microgravity
  - Lunar
  - Mars
  - (Earth)
- Stairway angle
  - 30°
  - 40°
  - 50°
  - 60°
  - 70°
  - 80°
  - 90°
- Gravity levels
  - Unencumbered
  - Carrying CTB
  - Carrying MO1
- Tread spacing
  - 10”
  - 12”
  - 15”
  - 18”
  - 24”
- Data collected via video, motion capture

Operations Lessons to Date: Timelines

- Test rig needs to be taken out of the water if inactive for more than a few days (corrosion)
  - Installation ~30 minutes
  - Removal ~20 minutes
- Reballasting for different gravity level ~10 min
- Reconfiguring between different angles ~20 min
- Reconfiguring between different tread spacing ~60 min (on surface)
- ~10 min per data point (single subject, 3 reps)
- 210 test cases (without μg or Earth gravity)
- 2450 min=~41 hrs per test subject (not including installation, removal, or stairway reconfiguration)

Neutral Buoyancy Test Personnel

- Test subject*
- Safety diver*
- Photo/video diver*
- Deck chief*
- Test conductor
- Motion capture operator
- (Support diver*)
- (Second test subject*)
- (Second safety diver*)
- (Deck support)

*must be UMd dive certified

Needed Modifications to Test Hardware

- Replacement of bolted 80/20 interfaces on risers with linear bearings including cam brakes (up to 40 places)
- Replacement of staircase attachments to platform with linear bearings including cam brakes (2 places)
- Fabrication of set of rungs to replace treads for vertical testing (20 items)
- Modifications to tube for vertical transfer tunnel studies

Planned Modifications to Test Protocols

- Dual test subjects (when available dive crew allows)
- Modifications to test hardware to facilitate more rapid reconfiguration
- Elimination of cargo transport except in specific cases
- Elimination of MO1 or other cargo bags except as test cases
- Will still require hundreds of hours of test time for statistically significant results

Vertical Ladder Testing

- Each MARSH crew module will be connected to central hub with inflated transfer tube
- Transit between central hub and modules will involve a 20+ meter vertical ladder
- Dynamics of rotational system are complex
  - Variation of appreciable gravity with radius (can be modeled with some development of hardware and procedures)
  - Coriolis force due to vertical velocity (not modeled)
- Test transfer of crew and cargo

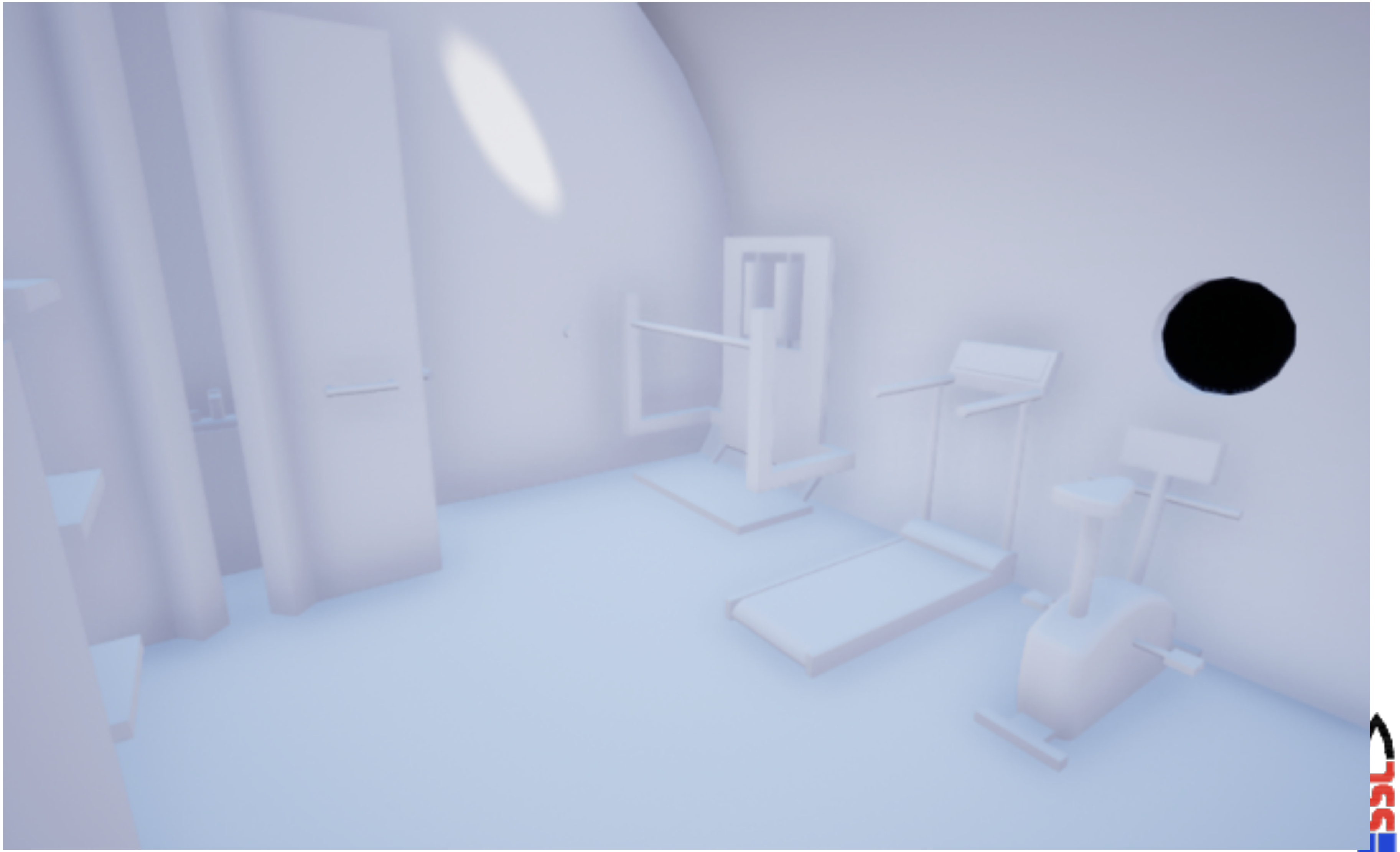
Vertical Transfer Tunnel Testing

- 60in diameter cylinder was designed and fabricated
- Installed on access ladder in NBRF water tank
- Preliminary testing performed on viability of this diameter and ladder placement
- Full test operations will require a redesign of stairway test rig

Virtual Reality Habitat Layout Assessment

- Import interior CAD images into Unity or Unreal Engine graphics environments
- Display three-dimensional models via Oculus
- Navigate through habitable spaces and evaluate layouts
- Hand controllers used for mobility, interaction with environment

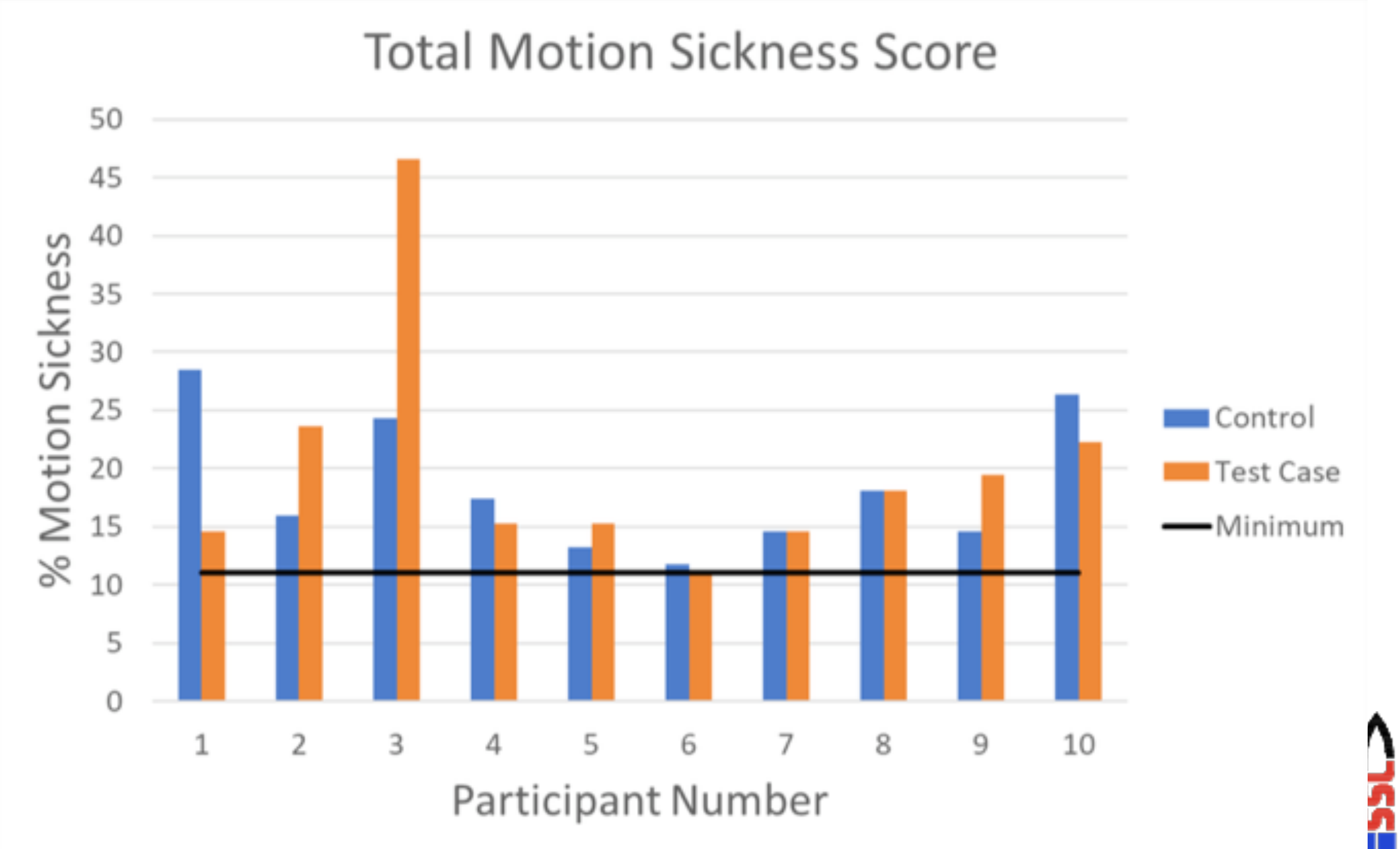
VR Interior Model with Solar Lighting



VR Testing Protocols

- Subjects were directed to navigate around modules with realistic solar lighting (sunbeam rotating around every 20 seconds)
- Qualitative assessment of layout, spaciousness
- Quantitative assessment of motion sensitivity using PSU Motion Sickness Assessment Questionnaire
  - Gastrointestinal (stomach awareness)
  - Central nervous system (dizziness or disorientation)
  - Peripheral (sweating or clamminess)
  - Sopite (mood or attitude changes)

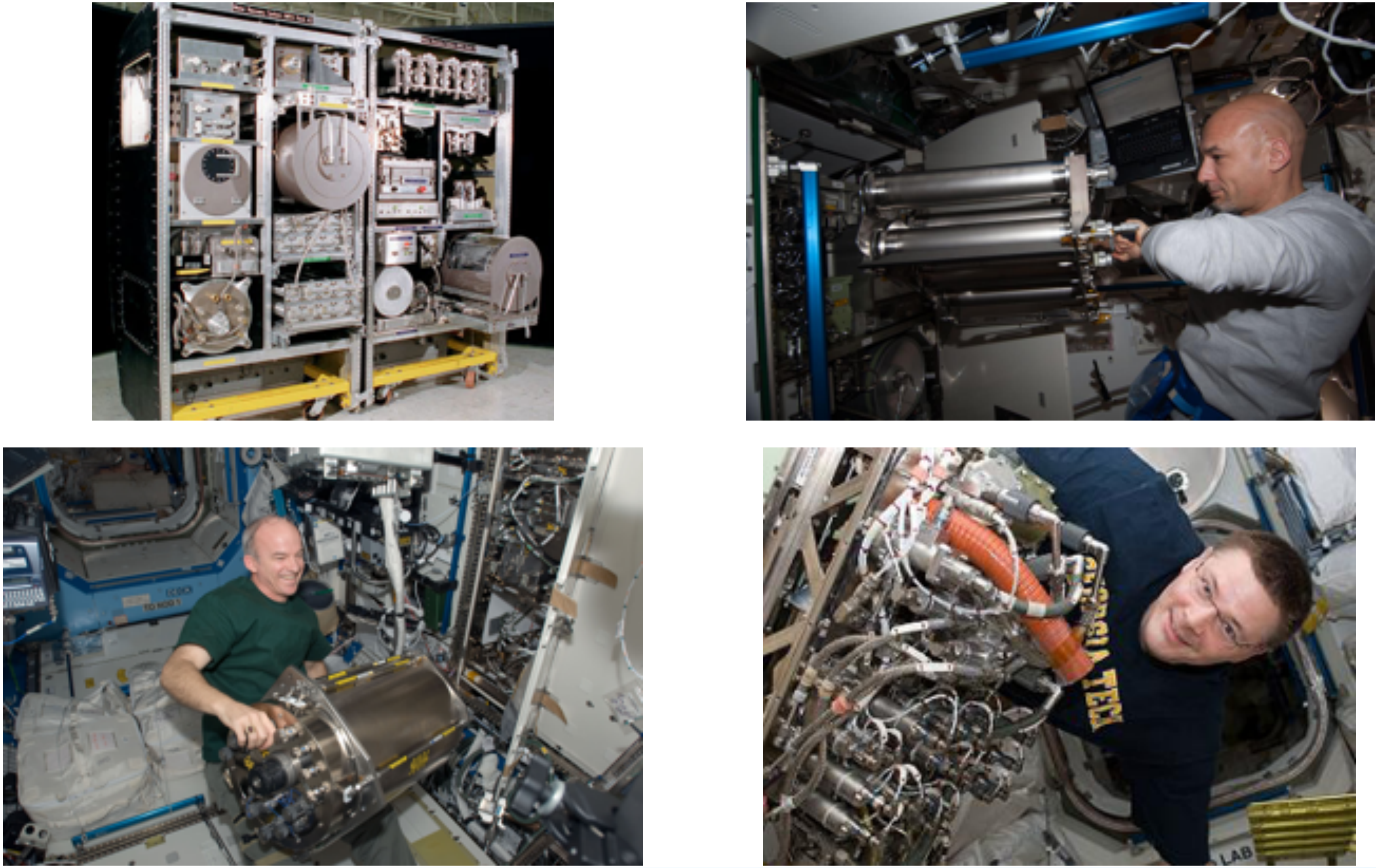
VR Testing Composite Sensitivities



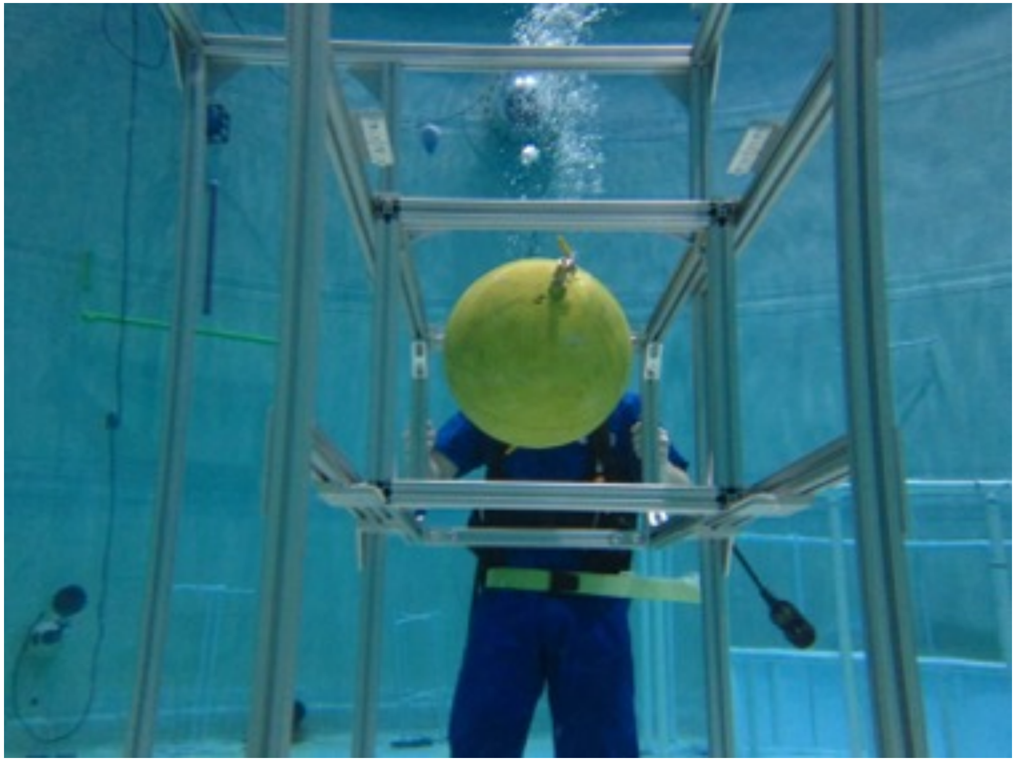
VR Testing Conclusions

- MSAQ showed apparent differences between test subjects, but analysis showed no statistical significance between test and control cases
- Subjects reported that there was sufficient room to move around inside each of the module layouts
- Expressed concern that windows would be stressful or evoke motion sensitivities; suggested curtains or covers
- Some subjects attributed motion symptoms to VR test environment rather than displayed scenes

Notional Test Task: ISS ECLSS



Multipurpose Reconfigurable Rack



Initial Neutral Buoyancy Testing

Rack Servicing Task Development

- Secure flotation sphere to removable rack
- Add appropriate simulation components (e.g., electrical connectors, hose connectors, insulation)
- Perform underwater testing at microgravity, lunar, and Mars gravity levels
- Perform control tests at Earth gravity in lab
- Use mockup for curved floor tests
- Add mockup details or additional rack elements with input from NASA
- Will be continued into 2019 X-Hab project

Publications from X-Hab 2018

- PDR slide package (473 slides - joint with TERPS)
- CDR slide package (351 slides)
- Final report (298 pages)
- “Experimental Investigation of Vertical Translation Design Commonality Across Differing Gravitation Levels” ICES-2018-244
- “Design Development of an Artificial-Gravity Mars Transit Habitat” accepted for AIAA Space 2018