Course Syllabus/Design Project

- Lecture #01 – August 29, 2023
- Course Syllabus
  - Goals
  - Web-based Content
  - Schedule
  - Policies
- 2023/24 Design Projects

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Goals of ENAE 483/484 (and 788D)

- Learn the basic tools and techniques of systems analysis and space vehicle design
- Develop individual skills in computer-aided design and engineering communications
- Understand the open-ended and iterative nature of the design process
- Simulate the cooperative group engineering environment of the aerospace profession
- Develop experience and skill sets for working in teams
- Perform and document professional-quality systems design of focused space missions concepts

Outline of Space Systems

- ENAE 483/788D (Fall)
  - Lecture style, problem sets and quizzes
  - Design as a discipline
  - Disciplinary subjects not contained in curriculum
  - Engineering graphics
  - Small design teams and projects
- ENAE 484 (Spring)
  - Five independent group design projects (separate sections)
  - Externally imposed matrix organization
  - Engineering presentations
  - Group dynamics
  - Peer evaluations

New Features of the Class

- Emphasize project content
  - Start 484 project during 483
  - Build teams for spring term by the end of September
  - Devote time in most classes for group design activities
  - Hold first 484 design reviews by end of 483
- Changes to the content
  - Emphasize design elements throughout all subjects
  - Move review subjects (e.g., orbital mechanics) to optional lectures
  - Provide project-specific lectures asynchronously

New Features of the Class

- "Design/Build/Test/Evaluate"
  - Space equivalent to "design/build/fly" for aero side
  - Parallels mission-level design activities
  - Major system(s) relevant to national programs

Web-based Course Content

- Data web site at http://spacecraft.ssl.umd.edu
  - Syllabus and course information
  - Lecture notes
  - Problems and solutions
- Course site on ELMS
  - Used for submitting homework and other assignments
- ENAE 483 Microsoft Teams site
  - Use for team communications, collaborative design activities, remote classes if necessary
- Akin's Laws of Spacecraft Design at http://spacecraft.ssl.umd.edu/akins_laws.html

Akin's Laws of Spacecraft Design - #1

Engineering is done with numbers. Analysis without numbers is only an opinion.

http://spacecraft.ssl.umd.edu/akins_laws.html

Akin's Laws of Spacecraft Design - #12

There is never a single right solution. There are always multiple wrong ones, though.

Akin's Laws of Spacecraft Design - #3

Design is an iterative process. The necessary number of iterations is one more than the number you have currently done. This is true at any point in time.

Course Content Overview

- Fundamentals of Spacecraft Design
  - Principles and tools of Systems Engineering
  - Vehicle-level design
  - Systems-level estimation
- Component Detailed Design
  - Crew Systems
  - Loads, Structures, and Mechanisms
  - Power, Propulsion, and Thermal Analysis
  - Avionics and Software
- Team Projects

Content 1: Fundamentals of Space Systems

- Systems Analysis
- Systems Engineering
- Space Environment
- Engineering Graphics
- Engineering Economics
- Mission Operations
- Design Case Studies

Content 2: Vehicle/System-Level Design

- Rocket Performance
- Cost Estimation
- Reliability and Redundancy
- Confidence, Risk, and Resiliency
- Mass Estimating Relations
- Resource Budgeting

Content 3: Component-Level Design

- Crew Systems
  - Space Physiology
  - Human Factors and Habitability
  - Life Support Systems Design
  - Radiation Effects and Mitigation
- Loads, Structures, and Mechanisms
  - Loads Estimation
  - Structural Design and Analysis
  - Mechanisms Design

Content 4: Component-Level Design

- Propulsion, Power, and Thermal
  - Propulsion System Design
  - Power System Design
  - Thermal Design and Analysis
- Avionics Systems
  - Attitude Dynamics/Proximity Operations
  - Data Management Systems
  - Communications
  - Guidance, Navigation, and Control
- Special lectures for this year's projects

Problem Sets

- There is a problem set associated with each of the space systems lectures, and with each of the disciplinary sections
- These problem sets will form the knowledge basis for the midterm and final exams
- The material in the lectures will also be crucial for successful completion of the team projects
- There can be extra problems on some sets for students in ENAE788D
- Each problem set has a full solution set posted after the submission deadline

Fall-Term Team Design Exercises

- There will be two design projects over the course of the term
- The first will be performed by teams of 4-5 students - the team assignments will be given to you
- The second will be to start the 484 design process mid-term
- The results of the design exercise will be submitted as presentation slides (PowerPoint/Keynote/Open Office or equivalent, *and* PDF)
- Team grades will be assigned for each design exercise, including adherence to the principles of the engineering communications lecture

Course Schedule

- Maintained on web site (follow links or http://spacecraft.ssl.umd.edu/academics/483F23/483F23.index.html)
- Contains links to reference material, problem sets, solution sets, team project details, etc.
- Notes and announcements will also be posted at top of syllabus page as necessary

Grading Policies

- Grade Distribution
  - 20% Homework Problems
  - 20% Midterm Exam
  - 30% Team Design Exercises*
  - 30% Final Exam
- Late Policy
  - On time: Full credit
  - Before solutions: 70% credit
  - After solutions: 20% credit
- Homework/projects will be submitted via ELMS

* Team Grades

A Word about Homework Grading

- Homework is graded via a discrete filter
  - Homework problems which are essentially correct (10 pts)
  - Problems with significant issues (7 pts)
  - Problems with major issues (4 pts)
  - Problems demonstrating extra effort (12 pts)
  - 0 for missing problems
- A detailed solution document is posted for each problem after the due date, which you should review to ensure you understand the techniques used

Documentation

- In a group of 88 people, there are 3828 possible communication paths between two people
- Results and decisions you make will inevitably affect everyone else in the team
- The 484 final report should be a comprehensive documentation of everything all of you do on the project over this academic year
- Document! Use archival electronic media (forums and postings online) rather than informal (chat rooms, texts, e-mails)
- ***If we can't see it, you don't get credit for it***

Akin's Laws of Spacecraft Design - #22

When in doubt, document. (Documentation requirements will reach a maximum shortly after the termination of a program.)

A Word about CAD

- Computer-aided design is an important tool for all engineering, and an essential tool for a designer - You need to know CAD for your career!
- The best way to learn CAD is to use it - a lot!
- In a project team of this size everyone must use the same system - our preference is to use Siemens NX, but…
- For 483/484, we are going to suggest you use Fusion 360
  - Free (for students), works on PCs and Macs
  - Has better facilities for collaboration and image rendering
- "Resistance is futile"

Some Thoughts on Teamwork

- Your entire career will be spent doing engineering in teams
- You have had team experiences before (e.g., ENAE 100, ENES 100)
- This is intended to be as close as possible to your professional experience, except for a flat organizational structure (i.e., you can't fire anyone)
- Nothing can guarantee the success of a team - but a lot of things will guarantee its failure

Some Thoughts on Professionalism

- In this class, like life, you won't like everyone you interact with
- Nevertheless, you owe *everybody* respect and support where necessary
- Hopefully it's not necessary to say it, but there will be *zero tolerance* for discrimination on the basis of gender/race/nationality/sexual orientation/etc.
- You also owe your team(s) your best effort and dedication to the project(s)

Closing Comments

- Focus on numerical analysis and systems engineering → **this is not "hardware-bashing"**
- Look for your own design solutions → **this is also not "catalog shopping"**
- Approach everything rigorously with numbers → **this is also also not "adjective engineering"**
- Manage scope and risk along with cost, mass, and other design parameters
- Be innovative, while remaining real
- ***What you get out of the process is directly proportional to what you put in***

Selection of Class Projects

- Criteria - needs to be
  - a significant engineering challenge
  - of relevance to the current or future space programs
  - requiring the use of tools from 483 and prior classes
  - and of appropriate scope for this class.
- Preferable to be appropriate for entry into design competitions
  - External sets of requirements and deadlines
  - Fidelity to experience in your careers
  - Competition as motivation

ENAE 483/484 Projects

- ENAE 484 will be split into 4 (5?) sections, working on separate design topics
- Plan to start some 484 design activities in October, leading to Systems Concept Reviews for each team at the end of this term
- ENAE 484 will incorporate formal Preliminary Design Review (PDR) and Critical Design Review (CDR) with inputs from professionals in the field
- ENAE 788D students will form a single team to perform a systems design activity this term

2024 Possible Project Themes

- Long-Duration Mars Simulation at the Moon (RASC-AL)
- Sustained Lunar Evolution (RASC-AL)
- AI-Powered Self Replicating Probes (RASC-AL)
- Large-Scale Lunar Crater Prospector (RASCAL)
- Collaborative Robotic Lunar Rovers (GSFC)
- Space Utility Vehicle
- Robotic Servicing of Habitats
- Others?

Long-Duration Mars Simulation at the Moon

- Develop an architecture for a long-duration simulation of a Mars mission conducted at the Moon, e.g.
  - 12-month microgravity stay in cislunar space with artificial comm delays representing a Mars transit hub starting NLT 2035
  - Land on the Moon and perform a 30-day exploration mission
  - Return to cislunar habitat and stay for 12 months before return to Earth
- Focus on habitats and transit vehicles to maximize fidelity of the Mars mission simulation; safety systems and abort options

Sustained Lunar Exploration Infrastructure

- Develop an architecture for evolving human presence on the Moon to expand available services and commodities
  - Service architecture should provide logistics (propellant and crew consumables), power, comm, navigation, and cargo transport
  - Initially for south polar region but expandable to rest of Moon
  - Design systems and operations as commercial endeavor, including costs charged to users to make it economically viable
  - South polar services available NLT 2035, provide growth plans to global support capabilities

AI-Powered Self-Replicating Probes

- Develop a concept for an autonomous spacecraft that enhances itself via resources it gathers as it visits multiple low-gravity bodies in the solar system
  - Launch to an initial body in the asteroid belt, use local resources to increase its capabilities without input from Earth
  - Concept of operations including initial configuration and accommodations for augmentations from local resources
  - Description of the AI/autonomy approach
  - Growth options to fully self-replicating spacecraft

Large-Scale Lunar Prospector

- Develop a concept for a prospecting rover that can operate for long durations in craters at the lunar south pole
  - Should be capable of determining location, composition, and accessibility of water ice and other volatiles in permanently shadowed regions
  - Capable of operating within the crater for up to a year with extended sorties into PSRs – focus on designing for extreme cold and darkness
  - Describe concept of operations, configuration and subsystems, integration into rovers and transports
  - Ready for initial operations NLT 2033

RASC-AL Competition

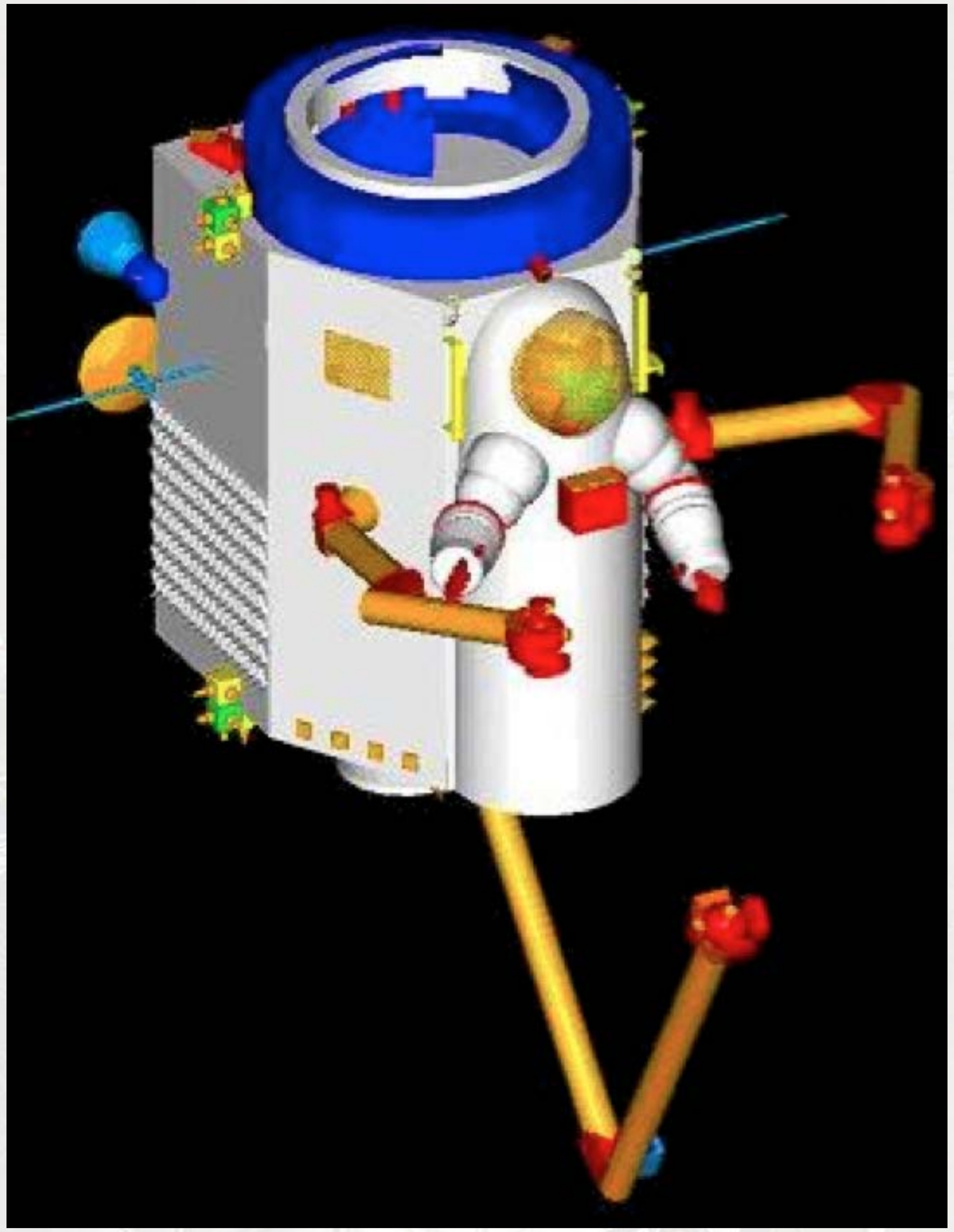
- Revolutionary Aerospace Systems Concept – Academic Linkage (http://rascal.nianet.org)
- Sponsored by advanced programs office at NASA Langley Research Center
- Up to 14 universities performing systems analysis on topics selected by NASA
- Competition in Cocoa Beach, FL in June selects best projects - awards trips to AIAA conferences
- Past competition has included MIT, Ga Tech, Michigan, Va Tech, USC, Penn State, WVU…
- UMd record in 20 years:
  11 Best in Theme, 7 Second Place Overall, 8 First Place Overall

Collaborative Lunar Exploration Rovers (GSFC)

- Exploration of lunar permanently shadowed regions by a network of cooperative instruments
  - Interactive design process with NASA Goddard scientists advising on science goals and instrument details
  - Spatial and temporal measurements of volatiles in PSRs
  - Measurement of regolith properties to understand weathering in PSRs
  - Option for astronaut involvement in operations
  - Hardware demonstrations using smaller hobby-level robotic hardware?

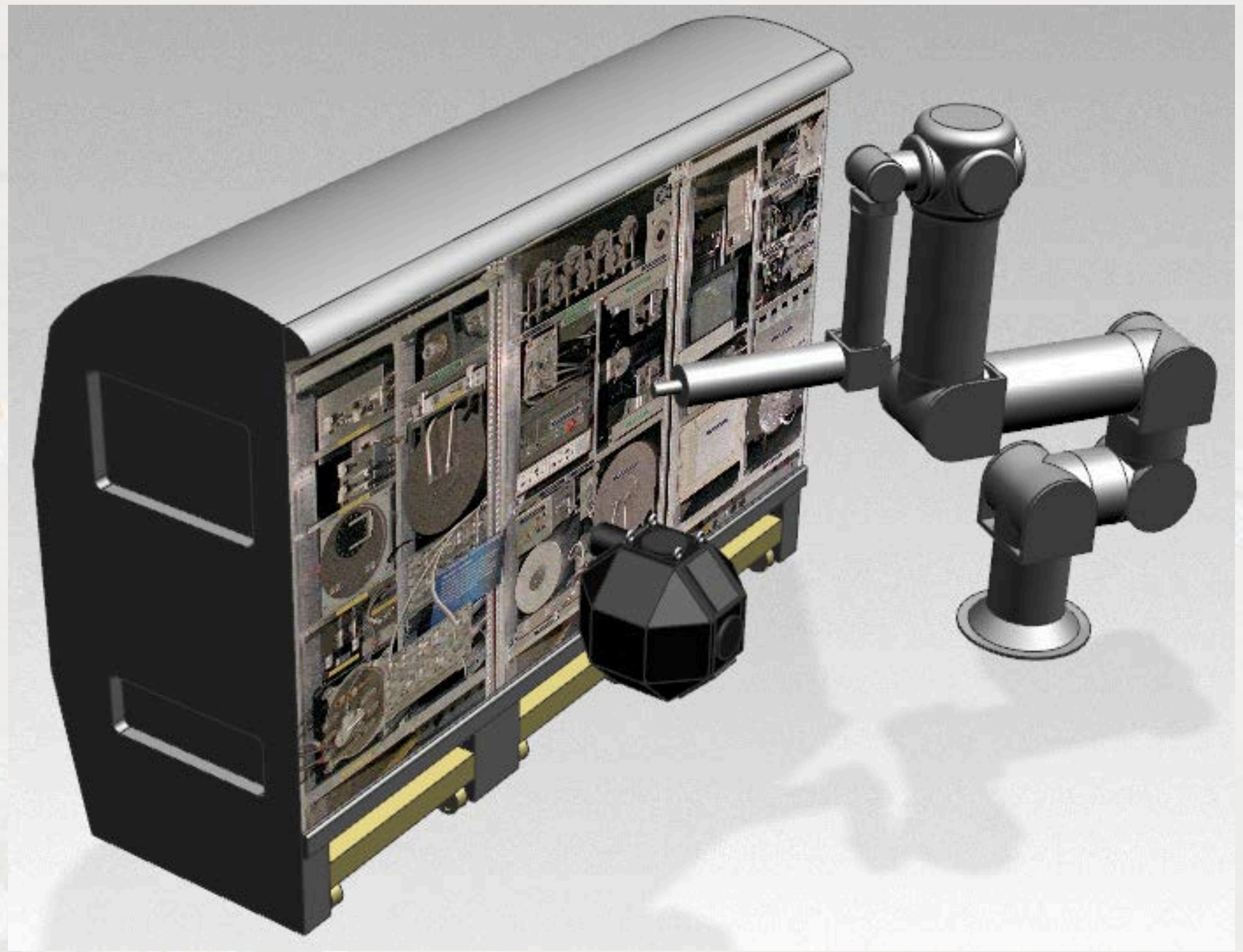
Space Utility Vehicle

- Concept: Single-person spacecraft with dexterous robotics for microgravity assembly and servicing
- Develop design reference mission(s) for SUV in Artemis (e.g., Gateway) and beyond (e.g., Phobos/Deimos exploration, asteroids)
- Perform detailed design of SUV(s) with adaptations to specific missions



Robotic Servicing of Habitats

- Future habitats (e.g., Gateway) will be unoccupied much of the time and will need robotic maintenance and resupply
- Design a habitat with dexterous robotics to allow operations without humans, or in collaboration with humans if present
- Focus could be on in-space or Moon/Mars habitats
- Use SSL robots for hardware testing



RASC-AL 2024 Emphasis on Prototypes

Teams selected as finalists for the 2024 RASC-AL Competition are ***highly encouraged*** to develop a prototype of part or all of their concept to demonstrate its key functions. Prototypes may vary based on each team's theme and proposed concept, but examples of a demonstration could include an advanced virtual reality simulation, a physical prototype of part or all of the concept, or a detailed model demonstrating the proposed architecture. The prototype's functions should be demonstrated within the team's final presentation and during the poster session at the RASC-AL Forum, either via video, virtual simulation, or by bringing the prototype/model to the Forum.

BONUS POINTS: Teams who develop and showcase a prototype during the 2024 RASC-AL Forum may be awarded ***up to 10 bonus points*** (added to their final score) for their prototype quality and capability demonstration.

A Tale of Two Demonstration Systems

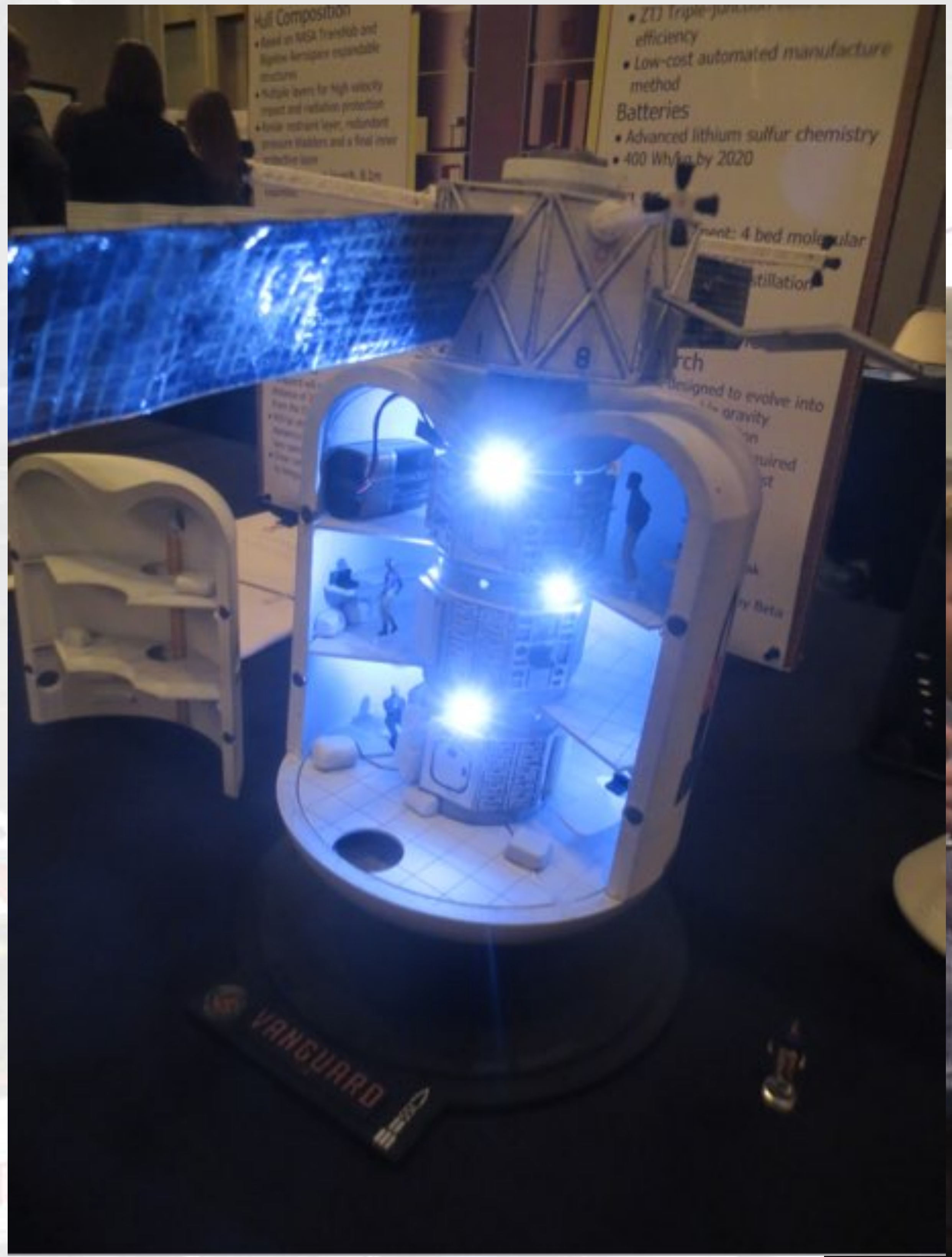
Design/Build/Test/Evaluate

- Hardware design, fabrication, and testing can be a valuable part of the 483/484 capstone projects
- A requirement for this term is to figure out exactly what you're building next term
- Choice is based on
  - Getting design data unobtainable by analysis (e.g., examine human mobility in low gravity)
  - Enabling meaningful mission simulations
  - Providing value for competitions
- Leverage the facilities and infrastructure of SSL

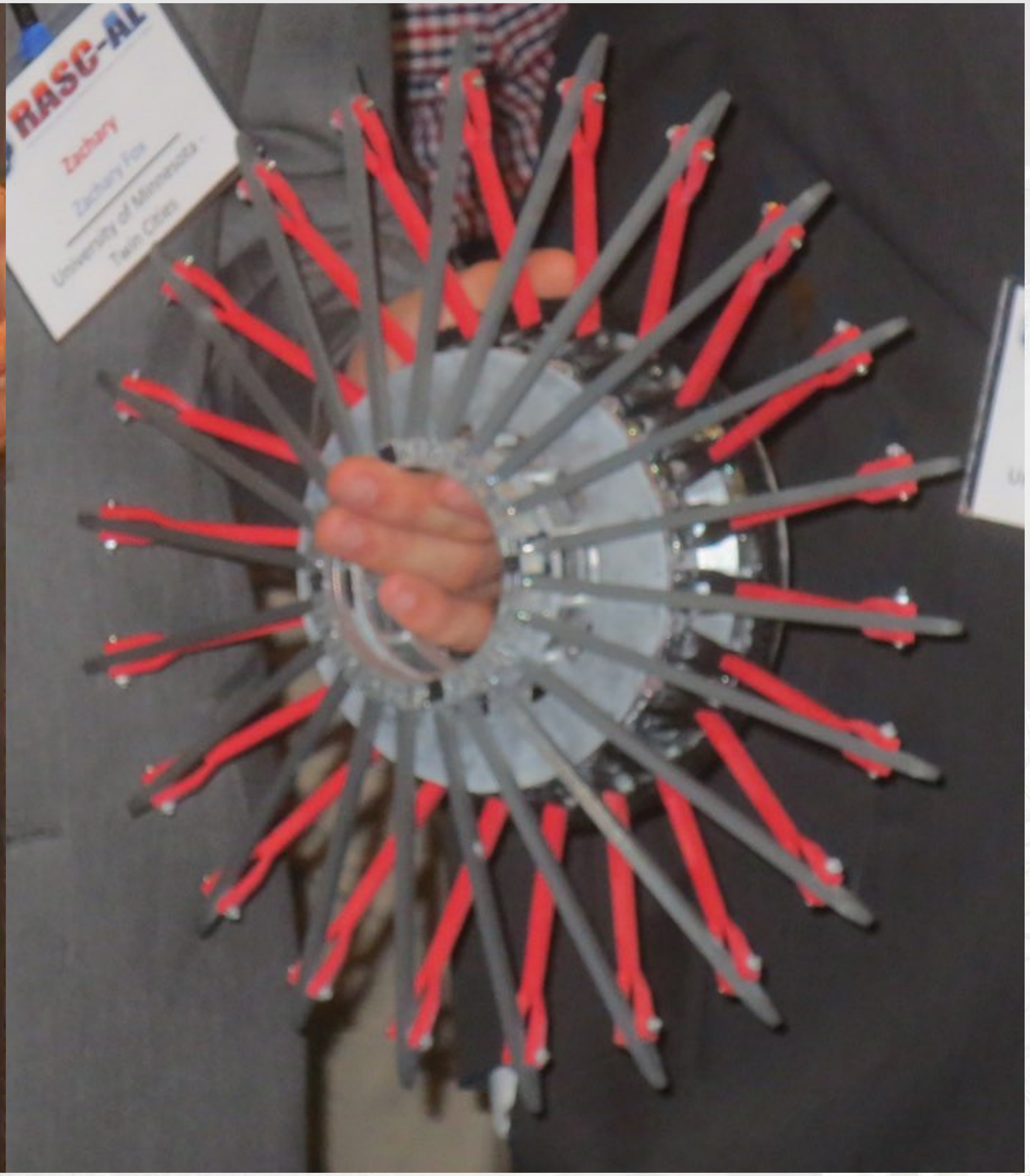
Experimental Studies in ENAE 483/4

- Traditionally, experimental studies are second-term (484) activities
- Would be ideal if experimental results were in time to affect 484 design efforts (before PDR in early March)
- Generally get results after CDR (late April)
- Intent to put significant effort into design and (potentially) construction of experimental hardware to ensure results are in time to improve 484 design

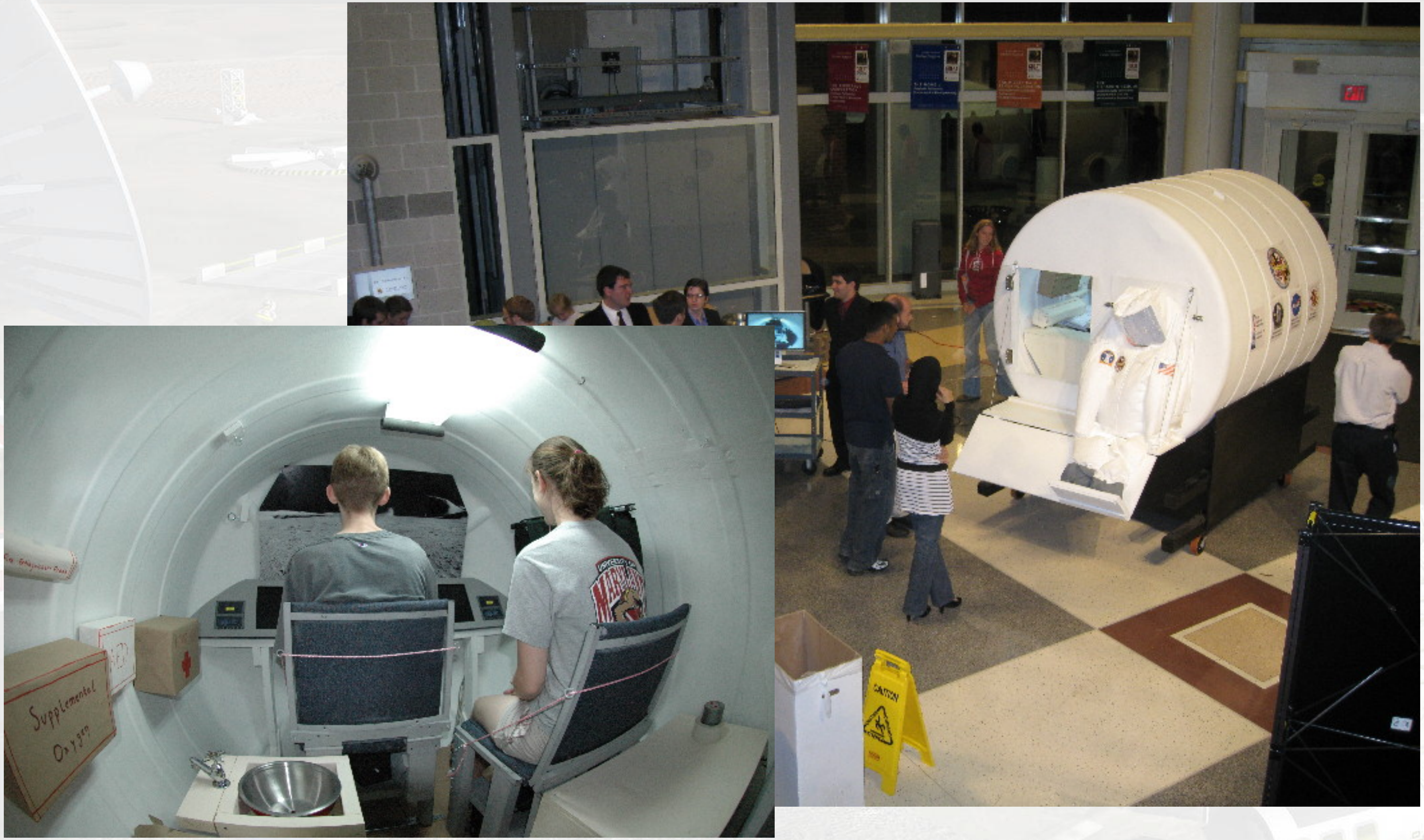
Sample Hardware – Display Models



Sample Hardware: Working Models



Sample Hardware: Full-Scale Mockups



Hardware Synergy: Space Systems Lab

Hardware Development - Spring 2019

X-Hab 2019 - Inflatable Airlock @ JSC

In-Class Prompt

- Divide up into ~12 groups and discuss projects
- Brainstorm other projects of similar scope that you would be interested in working on
- (Roughly) rank-order based on consensus, add comments
- One person in each group should volunteer as note-taker and summarize discussions
- Send an e-mail with the discussion notes to dakin@umd.edu at the end of class
- Do the assignment associated with Lecture 1 on course web site (https://spacecraft/ssl.umd.edu and follow links)

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