Course Syllabus/Design Project

- Lecture #01 – August 26, 2024
- Course Syllabus
  - Goals
  - Web-based Content
  - Schedule
  - Policies
- 2024/25 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 - https://go.umd.edu/483F24Teams
- 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
- Mil Specs, Standards, Requirements
- Engineering Economics
- Mission Operations
- Design Case Studies

Content 2: Vehicle/System-Level Design

- Vehicle 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 most of 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/483F24/483F24.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

About this Room…

- The “6-round” classrooms are designed to enhance collaboration
- In responce to past years’ feedback, we plan to have more 484 design activity during 483
- The goal is to have ~20 minutes of team design activity at the end of every class
  - Sections of lectures may be prerecorded and posted to free up time
  - You are responsible for *all* of the material from each lecture

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 85 people, there are 3570 possible communication paths between two people
- Results and decisions you make will inevitably affect everyone else in the team
- Looking ahead, 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

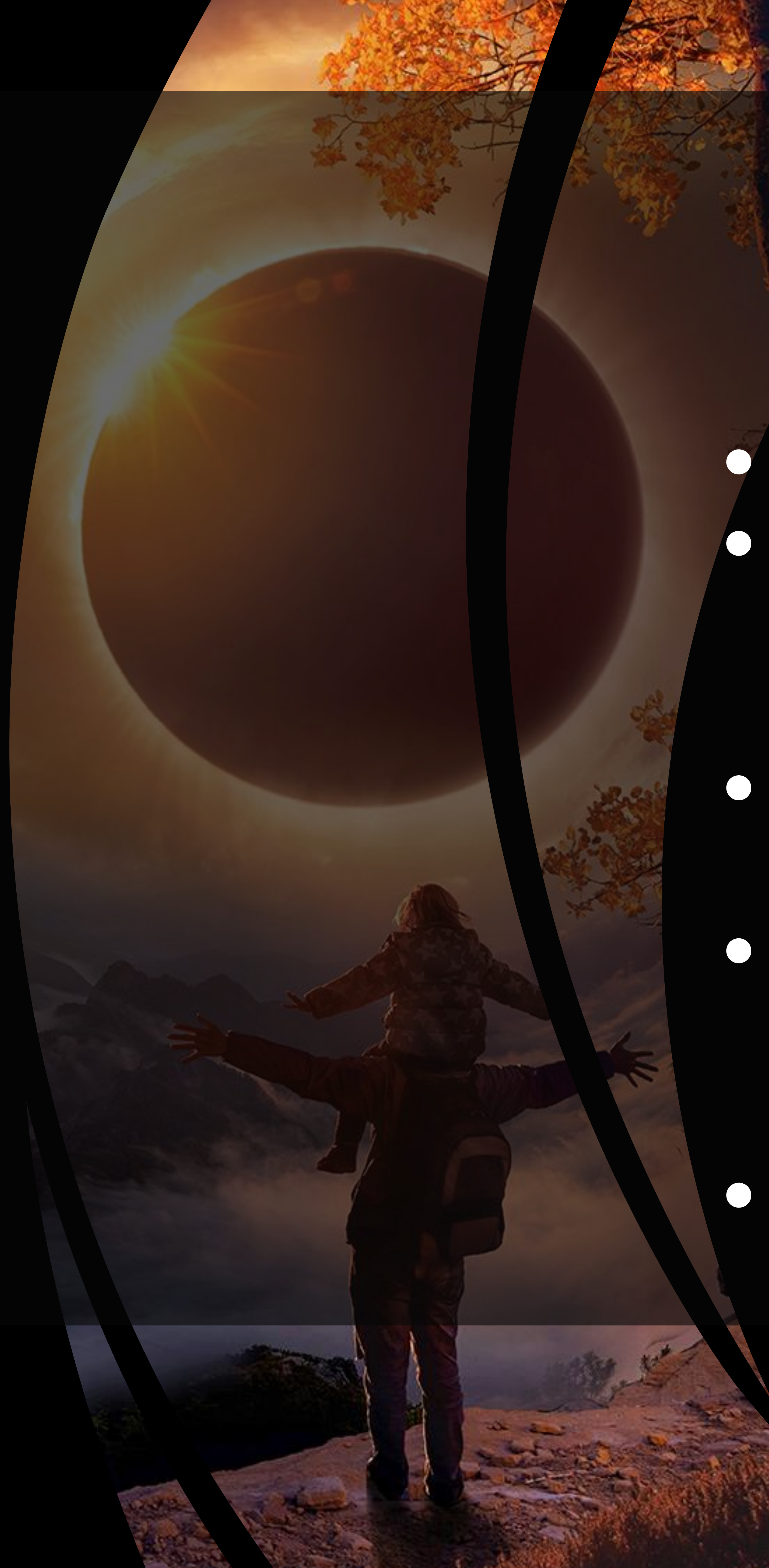
- Computer-aided design is an important tool for all engineering, and an essential tool for a designer - you need to know CAD for your career!
- The best way to learn CAD is to use it - a lot!
- In any project team everyone **must** use the same system - our preference is to use Siemens NX, but…
- For 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
- Use the software you like, but remember, "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

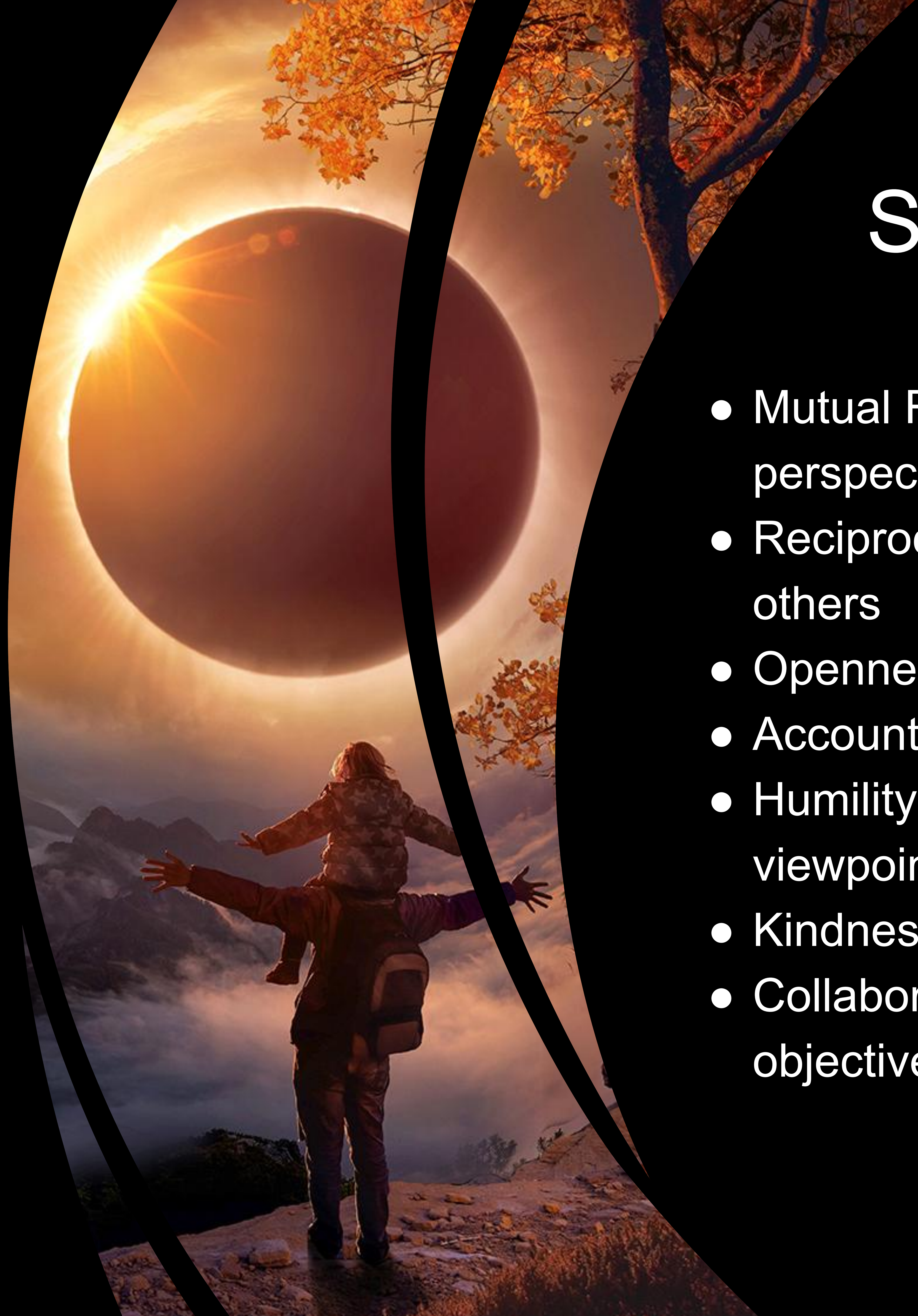
- In this class, like life, you won't like everyone you interact with
- Nevertheless, you owe *everybody* respect and support where necessary
- Hopefully it's not necessary to say it, but there will be *zero tolerance* for discrimination on the basis of gender/race/nationality/sexual orientation/etc.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



NASA Core Values
+ Science Activation Application

February 2024

- Safety/Health – We recognize this as NASA’s number one core value
- Excellence
    - Rigor – We use evidence and work toward audience-based solutions
    - Innovation – We look for novel ideas to improve our practices
- Integrity
    - Public Value – We seek to add value in all our activities
- Teamwork
    - Partnerships – We leverage connections including internal and external partnerships to amplify our impact
- Inclusion
    - Broadening Participation – We strive to share NASA science for the benefit of all



Science Activation Group Norms

March 2022 Update

- Mutual Respect – We respect each other and value each others' perspectives
- Reciprocity – We take care of ourselves so we can also care for others
- Openness – We listen first and assume positive intent from others
- Accountability – We take full responsibility for our words/actions
- Humility – We own our limitations of perspective and seek others' viewpoints
- Kindness – We are kind to each other, even when we disagree
- Collaboration – We work together to achieve common goals and objectives

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 sections, working on separate design topics
- Plan to start some 484 design activities immediately, 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 grad students will form a single team to perform a systems design activity within this term

2024 Possible Project Themes

- Sustained Lunar Evolution (RASC-AL)
- Science/Technology Demonstrators for Human-Mars Precursor Campaign (RASC-AL)
- Small Lunar Servicing and Maintenance Robot (RASCAL)
- Collaborative Robotic Lunar Rovers (GSFC)
- Standardized Habitat Rack Design and Testing (X-Hab)
- Others?

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:
  12 Best in Theme, 8 Second Place Overall, 8 First Place Overall

Sustained Lunar Evolution

- For Foundational Exploration (FE) segment of Artemis - 33-day surface stays with up to 4 crew
- Design/develop/demonstrate scalable lunar infrastructure and services architecture that leverages space logistics; in-space servicing, assembly, and manufacturing (ISAM); and in-situ resource utilization (ISRU)
- Availability of basic infrastructure at lunar south pole
- Demand for tens of (metric) tons of regolith/year for regolith extraction, metal production, and propellant production

Science/Technology Demos for Human-Mars

- Develop mission concepts for innovative science missions or technology demonstrators, focusing on reducing risks to future crewed Mars missions (e.g., geological studies, environmental monitoring, habitability investigations)
- Perform detailed design of the hardware for the mission payload, but include launch and transport systems to send payload to Mars
- Identify key technology areas critical for human Mars exploration that would be validated by your mission concept

Small Lunar Servicing and Maintenance Robot

- Develop a concept for a robot that can accomplish ISAM tasks on the lunar surface
- Capable of manipulating and transporting small payloads, attaching power/data/fluid umbilicals, inspecting and repairing surface systems, monitoring the environment
- Capable of operating autonomously or teleoperated, either locally or remotely from Earth
- Build, test, and demonstrate an Earth prototype (<500 kg)

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?

Standardized Habitat Rack Design and Testing

Standardized Habitat Rack Design and Testing

- Equipment interfaces on ISS are made modular by use of international standard payload racks (ISPRs)
- Major upgrades can be accomplished by crew rack replacement (made possible by microgravity)
- NASA wants a design for a new standard rack that is compatible with any gravity environment
- Requirements include designing, fabricating, and testing a standard rack including internal components, with 1g and partial gravity (underwater) testing

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

RASC-AL 2024 Emphasis on Prototypes

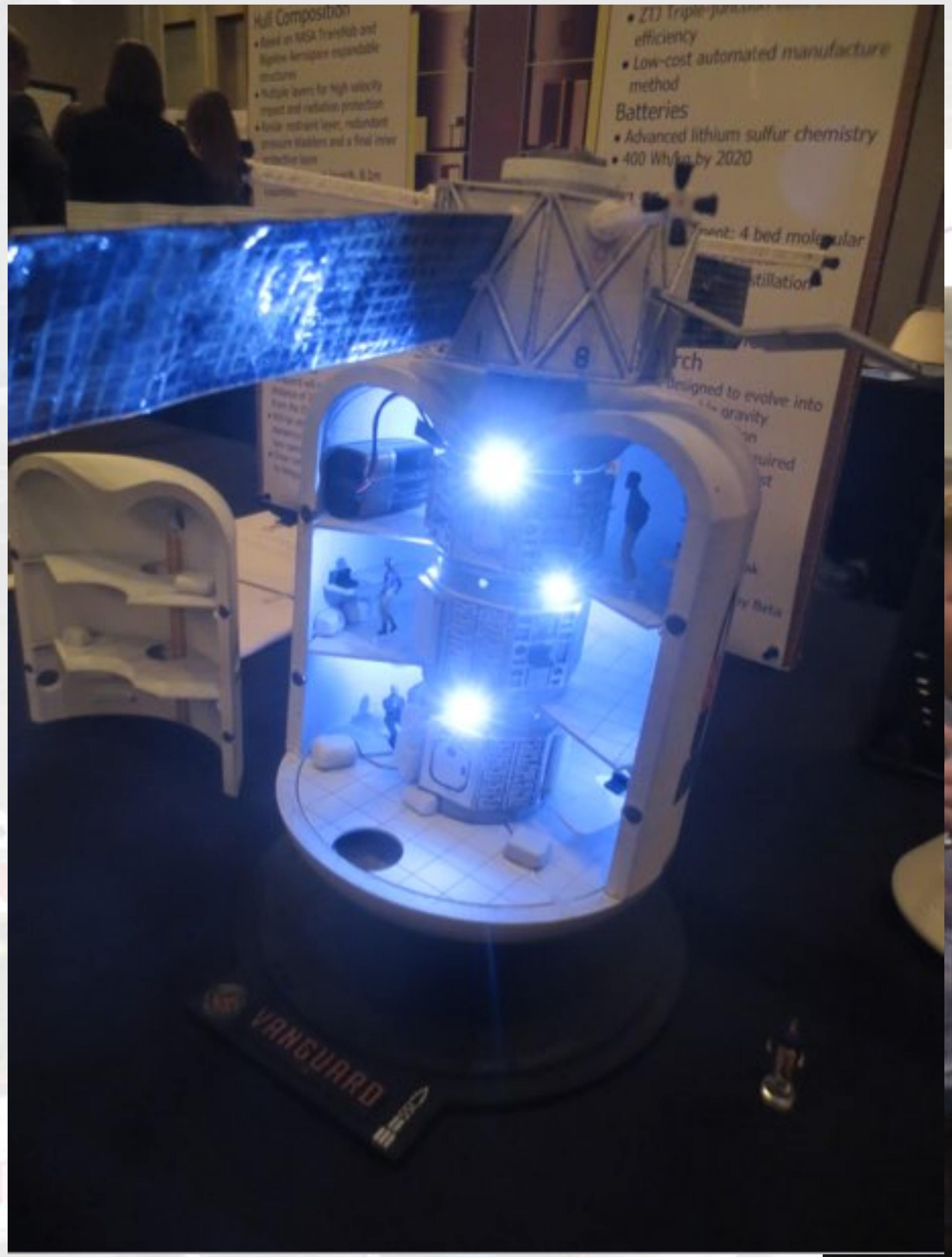
Teams selected as finalists for the 2024 RASC-AL Competition are ***highly encouraged*** to develop a prototype of part or all of their concept to demonstrate its key functions. Prototypes may vary based on each team's theme and proposed concept, but examples of a demonstration could include an advanced 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.

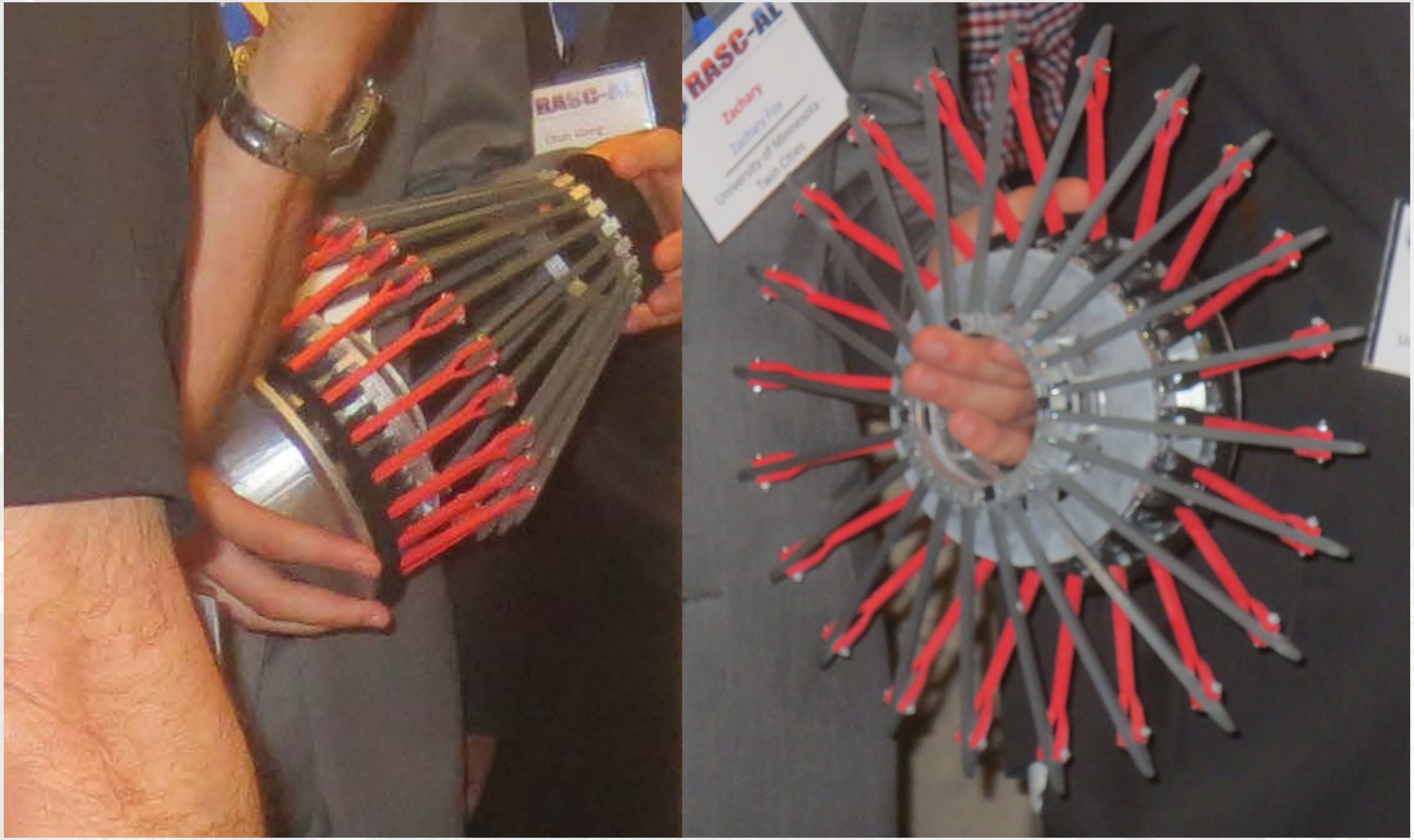
Experimental Studies in ENAE 483/4

- 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

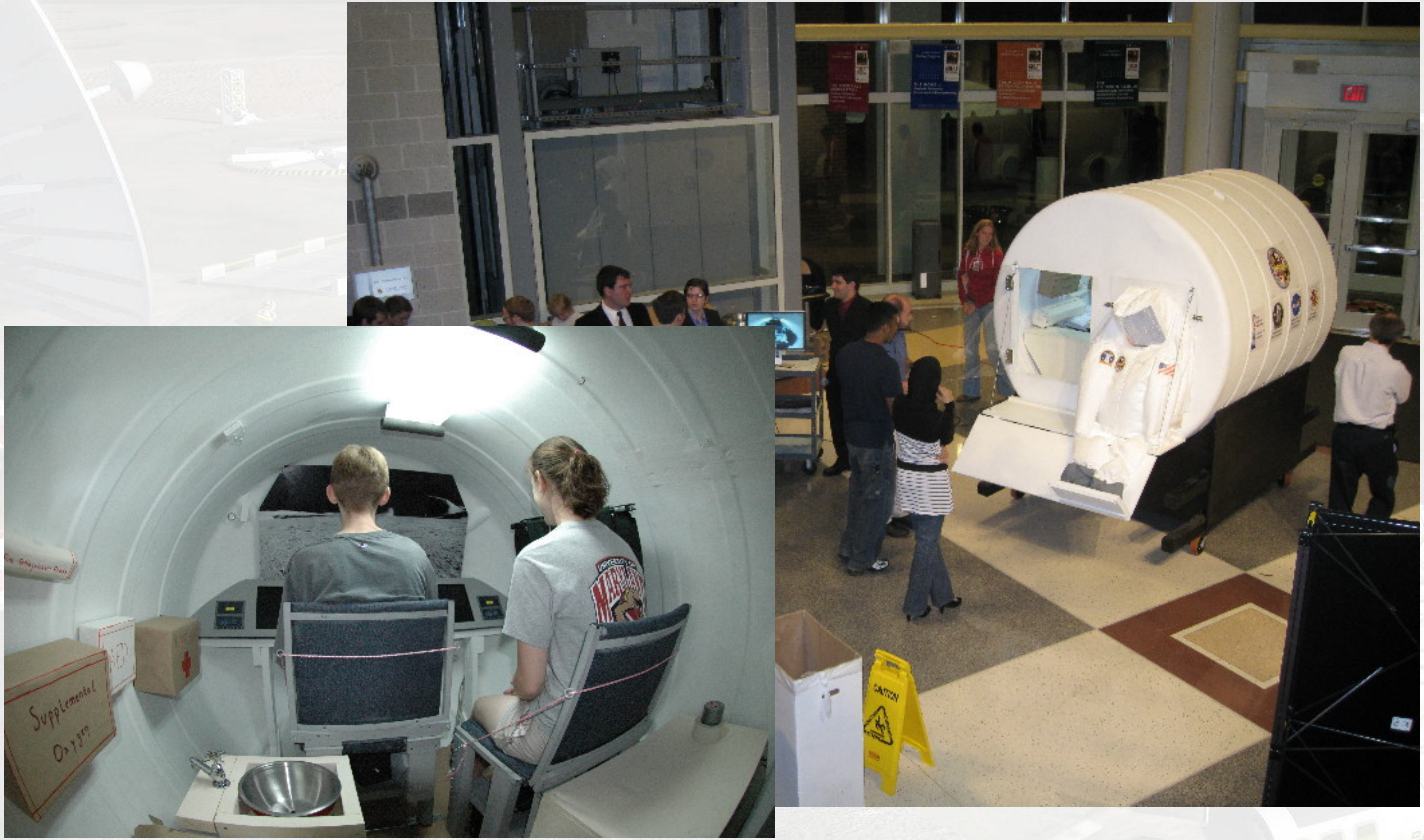
Sample Hardware – Display Models



Sample Hardware: Working Models



Sample Hardware: Full-Scale Mockups



Hardware Synergy: Space Systems Lab

A Tale of Two Demonstration Systems

Hardware Development - Spring 2019

X-Hab 2019 - Inflatable Airlock @ JSC

In-Class Prompt

- Divide up into groups of ~5 and discuss the listed 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 names of participants, discussion notes, and ranked project preferences to dakin@umd.edu at the end of class

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