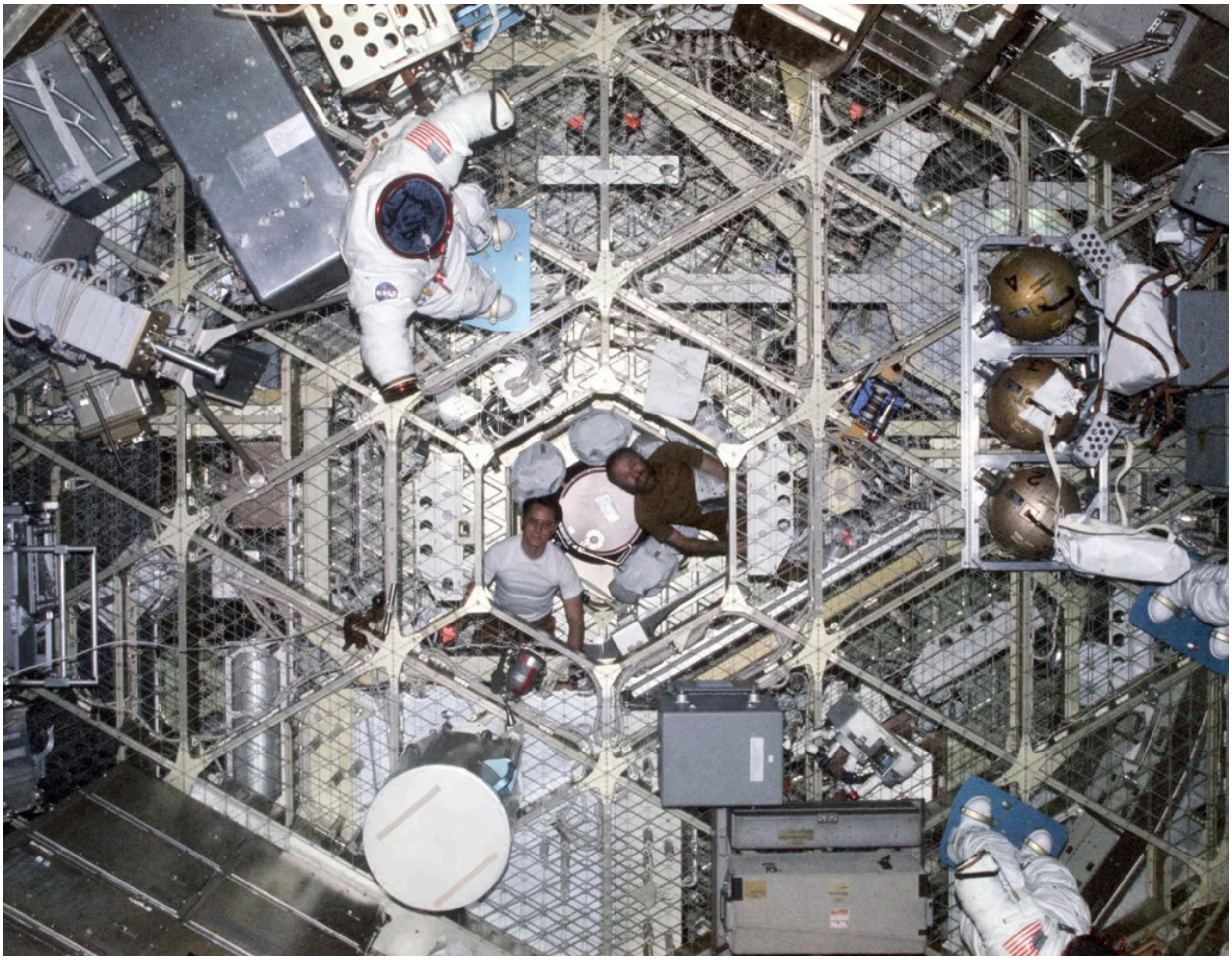
MIT Architecture + Aeronautics & Astronautics + Media Lab
4.154/ 16.S898/ MAS.S66 Space Architectures
Instructors: Skylar Tibbits, Nicholas de Monchaux, Jeffrey Hoffman, Cody Paige, Dava Newman
TAs: Oliver Moldow, Sean Auffinger
Tues/Thurs 1-4pm, Rm. 3-415



Vision:

With the proposed de-orbiting of the International Space Station in 2030 and the coinciding rise in commercial space flight operations, it is clear that human habitation of Low Earth Orbit (LEO) will dramatically increase, stimulating the design of human environments beyond earth. With NASA's Artemis program, the surface of the Moon will once again harbor human activities, over fifty years after the final Apollo mission. It is imperative that we design the future of space architecture with not only the best technology and functional performance but also with a primary focus on the human dimension: social, cultural, ecological, and aesthetic values. Up to now, very little of the environments of space exploration have been designed primarily for human experience; rather, they are focused purely on performance and safety. Yet how, and even why we live in space is now a question open to the design, engineering and other fields.

MIT has been home to innovation and a leader in human space flight since the 1960s; its graduates have provided over 15% of US astronauts, and its labs and workshops have constructed key technologies from the Apollo era to the present day. At the intersection of this experience and MIT's current values lies essential work on how we will live in the future – in space and on earth.

It is at the edges of the possible where we find important lessons for what we need to do here on earth. - Nicholas de Monchaux

Class Overview:

This Spring we will embark on the second iteration of MIT's interdisciplinary course on design for space habitats, which is a studio that brings together students and faculty from Architecture, Aeronautics & Astronautics and the Media Lab to imagine, design and create the future of habitats beyond the Earth, including but not limited to: rescue pods, science pods, spacesuits, capsule hotels and various others. This studio will be taught as a collaboration between three groups including shared lectures, assignments, group projects and presentations. The aim of the collaboration is to bring together students across the institute as well as faculty, and invited guest experts, to help conceptualize and materialize a future of human experience, architecture and construction. This semester's collaborative studio will prompt students to imagine, design, model, prototype and test their unique proposals. Projects may focus on novel approaches to: construction/assembly, deployability, transportation/logistics, human experience, In-Situ Resource Utilization (ISRU), material performance, or the many components of living and dwelling transformed on another world.

The semester will involve a detailed exploration of the design and engineering challenges posed by operating in LEO. Students will gain hands-on experience, working in teams, to design individual habitats for the space environment. Lectures will explore varying mission goals and operating environment constraints, from launch, to orbit. Guest lectures will include prominent engineers, scientists, designers, industry players and policymakers, with direct experience in mission design and development.

This studio will explore the design and testing of individual habitats for LEO through 3 phases:
1. Research & Concept Development,
2. Material Prototyping, Fabrication, Modeling
3. Final Prototype/Construction/Testing/Documentation

Course Structure:

- Lectures (BiWeekly) Topics by invited experts: scientists, engineers, artists & designers
- Individual/Group Desk Crits (Weekly) Discussions and feedback from faculty
- Internal Presentations (Monthly) Informal presentations with feedback from the faculty/class
- Mid Review (Mid semester) Formal presentation with feedback from invited critics & faculty
- Final Review (End of semester) Formal presentation with feedback from invited critics & faculty

The course will cover two main areas of skills development where students will:

- Area #1. Develop a mission concept for the space habitat
- Area #2. Actively contribute to the design and construction of an individual LEO habitat that can be tested through modeling, prototyping, 1:1 components or full-scale mock-ups. Students will be matched in teams made up of all three groups Arch, Aero/Astro, ML.

This course focuses on giving students near-term, practical knowledge and empowering direct development of realistic mission concepts and payload technical progress. A central goal is to expose students from diverse academic backgrounds to each other's ways of thinking and approaching problems. If successful, we should do more than simply educate exceptional students at MIT, the course should catalyze research activity on campus towards MIT's continued involvement in space. Our students should be the future designers, engineers and operators of space architecture.

Group projects should design/engineer/test some of the following capabilities:
-Manufacturing/sourcing/transportation on earth
-Transportation - payload size/weight and other constraints
-Deployability/packability
-Construction in the LEO environment - human, machine, environmental constraints
-Manufacturing/fabrication in LEO
-Adaptation/performance in the LEO environment - multi-functional, multiple needs, changing environments
-Material performance - thermal, radiation, weight, strength etc.
-Life Support systems
-Science/research in LEO
-Energy
-Food/agriculture
-Sustainability/waste/longevity/disassembly/recyclability
-Human experience, social, emotional, psychological, mental/physical health
-Design, aesthetics, color, material qualities, surface texture, comfort
-Ergonomics
-Planetary societal/ethical implications

Phase 1: Research & Concept Development

In the first phase of the project, students/teams will develop their initial concepts for an individual space habitat by conducting research on existing/emerging technologies, material properties, and fabrication/construction/environmental opportunities. Students should develop a concept around a proposed set of capabilities that can enable a new type of habitat. This research should then become the basis for a design proposal highlighting how the habitat will be produced (on earth or in space), how it will be transported, how it will be assembled/constructed/deployed, what it will be made from, what type of energy source it uses, how it responds or behaves, how it relates to the person and environment, how it may adapt over time as well as the end of life/sustainability aspects of the project. This phase of the project should combine both research and speculation towards the design proposal, yet students should focus on systems that they can physically build and test throughout the rest of the semester.

The hypothesis of this studio is that students will take advantage of existing technology to design, engineer and create their space habitats. Each group's habitat design may serve different needs and have unique functions/requirements - i.e. short term habitats, or emergency escape pods, capsule hotels etc. Most of the technologies likely already exist from a range of fields - materials science, aero/astro, engineering, synthetic biology, new fiber & textile technologies, new composites, embedded electronics, soft robotics/pneumatics, self-assembly, autonomous/robotic construction, large-scale printing etc.. The challenge set forth is to imagine what is possible and combine the relevant capabilities to enable its physical creation — and allow for all the social and cultural concerns associated with long-term dwelling in extreme environments.

Deliverables for Exercise 1:
-Research Documentation/Presentation
-Drawings/Diagrams/Photos/Videos to explain the concept
-Initial prototypes
-Final Concept Presentation

Phase 2: Material Prototyping, Fabrication, Modeling
In the second phase, students/teams will translate their research and design proposals into physical experiments. This phase of the project will require physical prototyping, testing, iteration, engineering/modeling, and continual refinement of the project narrative. The prototypes and physical/digital models should be formulated into material structures/systems with the desired performance. These prototypes should be seen as one step towards testing the individual habitat design/system.

Deliverables for Phase 2:
-Material prototypes
-Numerical modeling, simulation/calculation of systems
-Process iterations, continual testing
-System diagrams
-Revised concepts, procedures/systems
-Final Drawings/Photos/Videos

-1st large-scale mock-ups
-Mid Review Presentation

Phase 3: Final Prototype/Construction/Testing/Documentation
In the third and final phase of the project, students will build human-scale prototypes of their habitats. The final prototypes/testing may be focused one of the key aspects of the project that is useful to test at 1:1 - i.e. habitat interiors & human experience/design/aesthetics/function/materials, or construction/assembly/deployability, or habitat performance/adaptation/environments or any other aspects. These prototypes should embody the behaviors, functionality, design, engineering of the original concept but will likely not include the entire habitat or every aspect. These are aimed at being functional tests and will need to be designed specifically for the project/concept to get the most useful information out of the final functional prototype/s. This exercise offers the opportunity to test the human experience and system performance at a larger scale.

Deliverables for Exercise 3:
-Large-scale Functional Prototype/s
-Process prototypes/Iterations
-Final Drawings/Photos/Videos
-Modeling/calculations/testing
-Final Presentation

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Phase 1: (4 Weeks) Research & Concept Development
Week 1 ***Introduction***
2/4 Studio Preview Presentation
2/6 Class Introduction / Exercise 1 Intro
Week 2
2/11 Lecture + Studio
2/13 Lecture + Studio
Week 3
2/18 No Class
2/20 Lecture + Studio
Week 4
2/25 Lecture + Studio
2/27 **Phase 1 Review**
Phase 2: (5 Weeks) Material Prototyping, Fabrication, Modeling
Week 5
3/4 **Phase 2 Intro**
3/6 Lecture + Studio
Week 6
3/11 Lecture + Studio
3/13 Lecture + Studio
Week 7
3/18 Lecture + Studio
3/20 Lecture + Studio
Week 8
3/25 No Class Spring Break - Field Trip
3/27 No Class Spring Break - Field Trip
Week 9
4/1 Lecture + Studio
4/3 **Phase 2 - Mid Review (First large-scale mock-up)**
Phase 3: (6 Weeks) Final Prototype/Construction/Testing/Documentation
Week 10
4/8 **Phase 3 Kickoff**
4/10 Studio
Week 11
4/15 Studio
4/17 Studio
Week 12 (MIT/MA Space Week / Beyond the Cradle)
4/22 Studio
4/24 Studio
Week 13
4/29 Studio
5/1 Studio
Week 14
5/6 Studio
5/8 Studio
Week 15 ***Presentation***
5/13 **Studio Final Review**

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Learning Objectives:
The goal of this course is to develop an understanding of the design, development, challenges and opportunities for creating space habitats. Students will be exposed to different academic disciplines and new ways of thinking about designing space architecture. Throughout the courses students should be able to engage with an increasing level of design/engineering exploration through iterative studies and move fluidly between different modes and scales of operation. Students should be able to work collaboratively with their group to develop a complete project by the final review. Students will need to demonstrate design and engineering principles, the understanding of conventions, and an ability to sustain an increasing level of refinement of the project over the semester.

Statement of Required Work:
There are three main phases throughout the semester. Each phase is meant to build off of one another, helping students/teams to develop a complete project, step-by-step. There are three formal reviews scheduled throughout the semester that are milestones in the sequence of the three phases.

2/27 - Phase 1 Review
4/03 - Phase 2 Review / Mid Review
5/13 - Phase 3 Review / Final Review

Completion Requirements:
Completion of each phase, rigor in process and clarity in presentation, as well as the overall progress of the semester (including attendance and collaboration with team members) will be fundamental to completing the course.

Evaluation Criteria and Grading:
The following criteria will be used for the evaluation of a student's work, both in terms of helping their progress and in final grading. (01) Concept: How clearly is the student/team articulating the conceptual intentions? (02) Translation of Concept: How well is the student/team using their concept to develop the project? (03) Representation/Testing Appropriateness: How well matched is their choice of representation/testing/prototyping to their project goals? (04) Representation/Testing/Prototyping Quality: How accomplished are their modes of representation for the project (drawings, images, videos, presentations) as well as the rigor of their testing/prototyping? To what degree does the work convey what is needed for the project goals? (05) Presentation: How clearly is the project presented - verbally, desk crits, in class discussion, final reviews?? (06) Participation in Discussions: How actively and how constructively are they involved in class discussions? (07) Response to Criticism: How effective are they at taking feedback from instructors, classmates and outside

jurors? (08) Auto-Critical Skills: To what extent are they able to critique their own work regularly and effectively and make progress towards their project goals? (09) Attendance – see below.

A: Excellent - Project surpasses expectations in terms of inventiveness, design/engineering rigor, appropriateness, verbal and visual representation, concept, craft, and personal/team development. Student/team develops concepts and techniques above and beyond what is discussed in class.
B: Above Average - Project is thorough, well researched, diligently pursued, and successfully completed. Student/team pursues ideas and suggestions presented in class and puts in effort to resolve the requirements. Project is complete on all levels and demonstrates potential.
C: Average - Project meets the minimum requirements. Suggestions made in class are not pursued with dedication or rigor. Project is incomplete in one or more areas.
D: Poor - Project is incomplete. Some basic aspects of the project are not complete. Student/team does not demonstrate the required project development.
F: Failure - Project is unresolved. Minimum objectives are not met. Performance is not acceptable. This grade will also be assigned when you have excessive unexcused absences.

Studio Culture:
Work in the design studio will build sequentially. Therefore, your commitment to continual development on a daily basis is important. It is important to emphasize the importance of your peers and team as a source of support, inspiration, and feedback. Magnification of your development is made possible by the collective nature of the class. Teamwork and group collaboration are important, as each of you has something to gain from your colleagues. Our studio is a place for all, and it necessitates careful attention to the needs of everyone in it.

Attendance:
Attendance for the full duration of each class is mandatory. The studio is an exceptional learning environment that requires your presence as well as your input. You are allowed two excused absences for the semester. An excused absence is defined as one that was discussed with and approved by the professor at least 24 hours prior to the date of absence, or a family or medical emergency that is confirmed by your physician or a dean in GradSupport. Absences beyond the two allotted will result in a decrease in your final grade. If you miss six or more studio classes, you will be asked to drop the subject or receive a failing grade.

Student Support:
If you are dealing with a personal or medical issue that is impacting your ability to attend class or complete work, students should contact Grad Support. These offices are here to help you. The deans will verify your situation, provide you with support, and help you work with your professor to determine next steps. In most circumstances, students will not be excused from

coursework without verification from a dean. Please visit the Grad Support website for contact information and more ways that they can provide support.

Academic Integrity and Honesty

Personal Conduct: Instructors, TAs, and students in this course are expected to act responsibly, ethically, and with respect for the dignity of all others, both within and outside the classroom. Issues relating to personal conduct, including discrimination and harassment, will be taken extremely seriously. Students should take the time to become familiar with MIT's major policies on personal conduct, which can be found here - https://conduct.mit.edu/. MIT students are here because of their demonstrated intellectual ability and because of their potential to make a significant contribution to human thought and knowledge. At MIT, students will be given unusual opportunities to do research and undertake scholarship that will advance knowledge in different fields of study. Students will also face many challenges. It is important for MIT students to become familiar with the Institute's policies regarding academic integrity, which can be found here: https://integrity.mit.edu/.

Disability Accommodation and Access Services:

MIT is committed to the principle of equal access and an inclusionary environment. Students who need any form of accommodation are encouraged to speak with the instructor as early as possible. Students who need disability accommodations are encouraged to speak with Disability and Access Services (studentlife.mit.edu/das), prior to or early in the semester so that accommodation requests can be evaluated and addressed in a timely fashion. If you have a disability and are not planning to use accommodations, it is still recommended that you meet with DAS staff to familiarize yourself with their services and resources. Contact Disability and Access Services with any questions at 617-253-1674 or via email das-student@mit.edu.