MIT Architecture + Aeronautics & Astronautics + Media Lab
4.154/ 16.89/ MAS.S66 Space Architectures
Instructors: Skylar Tibbits, Nicholas de Monchaux, Jeffrey Hoffman, Ed Crawley, Cody Paige, Dava Newman
Tues/Thurs 2-5pm, Rm. 3-415

NASA

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 fields in collaboration with engineering and others.

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

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Class Overview:
This studio will bring together students and faculty from Architecture, Aeronautics & Astronautics and the Media Lab to imagine, design and create the future of habitats beyond the Earth - starting this semester with a prototype for the Earth's moon. 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 the lunar environment. Students will gain hands-on experience, working in teams, to design a lunar habitat to address strategic objectives associated with NASA's Artemis program, aiming to enable near-term sustainable settlements on the lunar surface. Lectures will explore varying mission goals and operating environment constraints, from launch, to orbiters, landers, rovers, and habitats. Guest lectures will include prominent engineers, scientists, designers, industry players and policymakers, with direct experience in lunar mission design and development.

This studio will explore the design and testing of lunar habitats through three 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 three main areas of skills development where students will:
- Area #1. Develop a mission concept that will address one (or more) of the key challenges associated with NASA's Artemis and its successors;to return humans to the lunar surface in the 2020s and unlock the possibility of permanent dwelling.

- Area #2. Actively contribute to the design and construction of a lunar 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.
- Area #3. Gain a comprehensive understanding of the state of lunar stakeholder activity and the emerging cis-lunar economy by engaging with policy makers, roadmapping tools, and via participation in MIT LOA (Lunar Open Architecture) database.

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 the MIT To the Moon To Stay flight opportunities. Our students should be the future designers, engineers and operators of space architecture.

Group projects should design/engineer/test for many of the following capabilities:
-Manufacturing/sourcing/transportation on earth
-Transportation - payload size/weight and other constraints
-Deployability/packability
-Construction in the lunar environment - human, machine, environmental constraints
-Manufacturing/fabrication on the moon
-Adaptation/performance in the lunar environment - multi-functional, multiple needs, changing environments
-Material performance - thermal, radiation, weight, strength etc.
-Life Support systems
-Science/research on the moon
-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 a lunar 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 lunar habitat. This research should then become the basis for a design proposal highlighting how the habitat will be produced (on earth or on the moon), 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 lunar habitats. Each group's habitat design may serve different needs and have unique functions/requirements - i.e. permanent habitats, or emergency shelters, bivouac shelters 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
-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 larger lunar 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
-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 lunar 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***
- 2/6 Studio Preview Presentation
- 2/8 Class Introduction / Exercise 1 Intro

Week 2
- 2/13 Lecture + Studio
- 2/15 Lecture + Studio

Week 3
- 2/20 No Class
- 2/22 Lecture + Studio

Week 4
- 2/27 Lecture + Studio
- 2/29 **Phase 1 Review**

Phase 2: (5 Weeks) Material Prototyping, Fabrication, Modeling

Week 5
- 3/5 **Phase 2 Intro**
- 3/7 Lecture + Studio

Week 6
- 3/12 Lecture + Studio
- 3/14 Lecture + Studio

Week 7
- 3/19 Lecture + Studio
- 3/21 Lecture + Studio

Week 8
- 3/26 No Class Spring Break
- 3/28 No Class Spring Break

Week 9 (MIT Space Week / Beyond the Cradle)
- 4/2 Lecture + Studio
- 4/4 **Phase 2 - Mid Review**

Phase 3: (6 Weeks) Final Prototype/Construction/Testing/Documentation

Week 10
- 4/9 **Phase 3 Kickoff**
- 4/11 Studio

Week 11
- 4/16 Lecture + Studio
- 4/18 Studio

Week 12
- 4/23 Lecture + Studio
- 4/25 Studio

Week 13
- 4/30 Lecture + Studio
- 5/2 Studio

Week 14
- 5/7 Lecture + Studio
- 5/9 Studio

Week 15 ***Presentation***
- 5/13 **Studio Final Review**