Prototyping our Sci-Fi Space Future:
Designing & Deploying Projects for Zero Gravity Flights

Syllabus for Graduate Course MAS.S66

Class period: Wed 10am - 12pm

Recitations: Wed 12pm - 1pm [optional/as required, see below]

12 units [2 hrs class time; 1 hr recitation time; 9 hrs out of class homework]

Course website: https://zero-gravity.pubpub.org/

Contact: zerogravity@media.mit.edu

Course Description:

Welcome to the MIT Media Lab's course on project development, prototyping, and deployment readiness for parabolic flights. This course supports an annually chartered research flight. Admitted student teams will be offered project-deployment slots on the Media Lab Space Exploration Initiative's Spring 2021 parabolic flight. This course will cover three main topic areas:

- rapid prototyping and engineering skills to prepare projects for operation in microgravity
- logistics, training, and safety pre-approval steps to meet flight readiness requirements and pass a Technical Readiness Review (TRR)
- creative and technical lenses for the future of space exploration, exploring the MIT Media Lab Space Exploration Initiative's design and prototyping approach, MIT parabolic flight research examples across Science, Engineering, Art, and Design, and across departments.

Weekly sessions will rotate between providing direct preparatory steps for the parabolic flight, building skills towards project development and testing, and providing background knowledge and relevant real-world examples via guest lectures. Recitations will be offered throughout the course, to support prototyping and project development outside of class hours. Students are expected to attend recitations, but can opt-out if they can demonstrate prior mastery of the skill in question. Short problem sets will be assigned, associated with the Mechanical Design, Sensing & Electrical Design, and Manufacturing lecture content. Limited readings will be required, with short reading responses and project page documentation submitted via the PubPub course website.

By the end of the class, we expect student projects to be ready to pass an internal Critical Design Review (CDR) with an accompanying, mature prototype. Students will be expected to use the intervening time over IAP to finalize a flight model and submit final paperwork to the parabolic flight provider, with MIT Media Lab Space Exploration Initiative guidance.

This class is not intended to teach the fundamentals of mechanical design, embedded programming & circuits, and rapid prototyping from scratch. On most topics, we will assume prior knowledge. If you are new to these skills, we recommend taking "How to Make (Almost) Anything" in parallel.

mit media lab space exploration

Admission to the Course:

Admission to the course will be done by a "project team" consisting of one or more members. Interested graduate students apply via an online webform (link below) and share details on their proposed concept and team members. Depending on interest level and the number of applicants, we may have to cap team size to 3 or 4 people per project, actually admitted into the class. We do NOT require that all members of a team take the class, just a minimum of one representative for the project.

Admitted teams will be invited to take the class together and the associated single, coordinated project will be granted a **tentative** "project deployment slot" and one **tentative** "flyer slot" for a member of the project team to accompany and carry-out the research on the Spring 2021 flight (see definitions below). This means that several students may take the class together to work on a collaborative project, but we can only reserve one flyer seat per project. We will not choose who the ultimate flyer/operator is out of the team members -- this is up to the team and their research advisors.

Final determination of **confirmed** project deployment slots and **confirmed** flyer slots will be decided upon completion of a rigorous, novel prototype and thorough documentation that can demonstrate nearly-complete readiness to fly by the CDR at the end of the class. Course instructors will make the final determination on what flies. We do *not* intend to admit more projects into the class than we would have space for in the flight, so the course is therefore not a competition between teams. The reserved slots are there, but must be earned by high quality project completion.

Due to the physical constraints of the parabolic flight, we will only be able to admit a small total number of projects (and the final count depends on the physical dimensions of each proposed entry). Please see the course website for full details on admission criteria. The application will be open through Friday, **September 4th**, with final selections announced by **Sept 7th**, in preparation for the 2nd full class on **September 9th**. We strongly suggest applying as early as possible to give more time for review of your application, and because slots will be filled on a rolling basis. All applicants should attend the first class on **September 2nd**.

Interested in deploying a research project, with no need to personally accompany it? Great! These types of projects are easier to admit into the class, as they don't require an additional reserved "flyer" spot, which are in short supply. Projects applying in this category should be primarily passive (e.g. physiological sensors worn by participants or similar), and not require extensive efforts from other onboard flyers.

Not sure if you want to apply but are still interested and want to learn more? Please fill out this form so we can share the link to our first class. We may also host an info session prior to the first class: https://forms.gle/iXKXXWDqh3Ew1Xi19

How to apply:

Fill out this webform (linked to via course website as well):
https://forms.gle/2UESbASNbxkJgA6u7

Terms:

Project team: Consists of one or more collaborators on the same project.

Project deployment slot: A reserved opportunity to deploy a single research experiment or project on the parabolic flight. Presumes a certain amount of floor layout space for hardware, room to operate, and floating space in the cabin.

Flyer slot: A reserved opportunity for one human to accompany and carry-out a research experiment or project on the parabolic flight as an operator.

Course Requirements & Evaluation:

Assignment	Grade Percentage
Attendance, class participation, recitations	10%
Reading responses, project pages, and p-sets	20%
Mid-term Preliminary Design Review (PDR) + early prototype hardware review	20%
Final project - Project prototype for zero gravity flight must be nearly complete and team must pass a final internal review (CDR) - Project will be graded on novelty of the concept, execution & demo-ed operation, and thoroughness of technical paperwork completion in advance of Spring 2021 deployment	50%

Caveats on Joining the Class and Spring 2021 Parabolic Research Flight:

- Independent of approval from the course instructors, all students MUST have prior approval from their PI, or home department research advisors, before being guaranteed a project deployment slot and/or flyer slot. Prospective approval from advisors must be submitted in writing before students will be admitted to the course, and approval will again be solicited in January 2021 in advance of the flight, to reconfirm. Class applicants should arrange for their advisor to provide written approval, in the form of an email to zerogravity@media.mit.edu, before the end of day September 9th, 2020, when the class list will be finalized.
- Project teams and advisors will be required to sign an expectations document (to be provided the first week of classes), surrounding willingness to meet documentation deadlines and training requirements for integration with the parabolic flight provider, and agree to caveats described in this document.
- Students named by their teams as the "flyer" must be physically healthy and able to fly, per the guidelines of our chartered parabolic flight provider. Sample medical forms will be distributed on the first day of class.
- While the class is meant to prepare flyers and projects to pass the parabolic flight provider's initial paperwork and final on-site TRR, if your research does not pass the safety review or is otherwise not approved for flight by the parabolic flight provider, MIT Media Lab Space Exploration Initiative cannot guarantee a successful intervention on your behalf. It is ultimately the responsibility of each research team to prepare to pass the TRR.
- Projects that diverge materially from what was initially proposed and approved for entrance into the class will lose the Project Deployment Slot and Flyer Slot, unless prior approval for the change is received from the Course Instructors (this holds true in the post-class December - March period as well).
- Project teams and advisors must be prepared for the projects to be discussed publicly via MIT Media Lab and their home department (if different), MIT press, and outside press channels. This is not the venue for research that is still private and cannot be shared.
- Project team understands that raw materials, travel and lodging funding, and project shipping costs are NOT covered by this Space Exploration Initiative opportunity. The MIT Media Lab Space Exploration Initiative is covering the full cost of the zero gravity flight (flight ticket, ground presence and hangar rental space, on-site staff costs, etc.) but independent funding must be secured for the associated logistics costs to join the research campaign in Pease, NH in Spring 2021 (these costs are usually small).
- The flight scheduled for spring 2020 has yet to take place due to the COVID-19 pandemic. We hope to conduct that flight as soon as we are able. We are planning to conduct the flight associated with the upcoming class in spring 2021, however, circumstances outside of our control may postpone that flight into the summer or even beyond (i.e. after graduation). We generally honor flight spots even for subsequently graduated/alumni members of the MIT community, if they complete the course. Please take this into consideration and plan accordingly.

Course Schedule:

A recitation will follow most lectures. Students can be exempted from attending recitation if they submit, by the night prior, a past assignment or portfolio project that shows mastery of that week's topic. The recitation will provide an introduction to the skill that will be covered in the following week (paired with a pset).

The schedule is based on previous years, and may change to accommodate the many guest lecturers coming to speak to the class. An updated syllabus will be distributed after any major changes.

Date	Topic	Lecturer(s)	Reading + Recitation Topic
Sep 2nd	- Overview: review of syllabus, admission procedure, course expectations. - Parabolic flight basics (flight trajectories, parabola microgravity quality, airplane equipment and international venue options, etc.)	Joe Paradiso, PI for Responsive Environments group, MIT Media Lab Ariel Ekblaw, Founder & Lead, MIT Media Lab Space Exploration Initiative	Reading: Syllabus; admission criteria on course website; The Physical Behavior of Objects when Gravity is Missing; Weightlessness Recitation: Meet & Greet for teams; opportunity for collaboration/team forming
Sep 9th	Parabolic Flight Prep (120 min) - Mechanical design & buckling analysis; structural calculations for withstanding envelope of flight conditions; factor of safety limits - Examples from prior zero gravity flights (highlight of research missions across MIT & NASA's research program) - Designing for the deployment environment (constraints, restricted materials, unique operating affordances & considerations, etc.) - Overview of documentation requirements and safety review expectations	Matt Carney, MIT Media Lab PhD student, Biomechatronics group Ariel Ekblaw	Reading: - Parabolic flight provider's "Research Program Package" Recitation: CAD 3D modelling (OnShape). Sean Auffinger, SEI Mission Integrator
Sep 16th	Parabolic Flight Prep (120 min) - Research Program Package overview - PubPub pages	Ariel Ekblaw	Readings: - Karmali Parabolic Flight Dynamics paper - Welcome Kit BOM

	- Sensing, actuation, and circuit design for zero gravity projects - Best practices for safety, fault analysis, redundancy, and recovery - CAD pset due	Peter Dilworth & Jamie Milliken, MIT Media Lab, Space Exploration Initiative	Recitation: Non Standard Time: 12:30pm-1:30pm Embedded Programming, Circuit Design, Sensing. Patrick Chwalek
Sep 23rd	Space Exploration Lenses (120 min) - Brainstorming activity - Designing and developing space technologies to improve life on Earth & advance social justice - Ethnography in space research; research methods, cataloguing processes, social trends & themes - Art & Design approaches in zero gravity - Discussion of examples from ML 2019 flight; fine arts to performance art, mixed-media, and interaction design; from historical examples to contemporary - Circuit pset due (Sep 25)	Ariel Ekblaw Danielle Wood, PI for Space Enabled group, MIT Media Lab Xin Liu, Arts Curator, MIT Media Lab, Space Exploration Initiative Sands Fish, Staff Designer, MIT Media Lab, Space Exploration Initiative	Readings: Cosmos Aesthetics of Verticality The Reasons for a Symposium In Free Fall Mediated Perception Towards an Experience of Extreme Environments New Models for Democratic Engagement Optional: The Effect of Altered Gravity States Psychedelics can have the Same Overview Effect Operating Manual for Spaceship Earth We are all Aliens Planetarium chapter of the Geostories, Another Architecture for the Environment book Recitation: Design Aesthetics of Zero-G, Sands Fish
Sep 30th	Space Exploration Lenses (120 min) ***Astrobiology*** -Life Detection Instrumentation, Venus mission study, microgravity experiment prep -Biological experiments in microgravity	Chris Carr, Assistant Professor, Aerospace Engineering & Earth and Atmospheric Sciences, Georgia Tech Sunanda Sharma, SEI Staff Biologist	Reading: Nanopore Sequencing 3D Scanning and Printing CNC Machining Recitation: Machine Shop overview: Safety and common tools, processes, and capabilities. Sean Auffinger, SEI Mission Integrator

Oct 7th	Parabolic Flight Prep (60 min) - Panel of previous student flyers	Alexis Hope Maggie Coblentz Paula do Vale Pereira Valentina Sumini	Reading: SPHERES: SSL, NASA
	Space Exploration Lenses (60 min) - Engineering for zero gravity & the space environment	Rebecca Masterson & Alvar Saenz-Otero, MIT Space Systems Laboratory	Recitation: Completing the RPP - Sean Auffinger, SEI Mission Integrator
Oct 14th	Parabolic Flight Prep (120 min) - In-class PDRs: 10 presentations, 15 mins each (with overflow into recitation time)	Reviewers: Paradiso, Ekblaw, Auffinger +Course TAs	Reading: PDR Assignment Description Recitation: Overflow time for PDRs
Oct 21st	Space Exploration Lenses (120 min) ***Artifacts for life in space and robust engineering*** -Prototyping the artifacts of our Sci Fi Space Future - Designing for 10,000 years. Long Duration Development and Robustness. - Manufacturing as an Art and Design Practice	Danny Hillis, Inventor & Cofounder, Applied Invention Che-Wei Wang, Founder, CWandT machine shop, art & design practice, [asynchronous]	Readings: http://longnow.org/clock/ https://cwandt.com/ Recitation: Introduction to tools and suppliers for remote/virtual manufacturing, Levi DeLuke, Jamie Milliken
Oct 28th	Parabolic Flight Prep (120 min) - Guidance, Navigation, and Control - RPP examples - RPP Paperwork and safety review help-session.	Joe Paradiso Sean Auffinger SEI Staff	Readings: Recitation: Open office hours
Nov 4th	Parabolic Flight Prep (120 min) -Next steps for working with SEI (Suborbital, ISS, Lunar deployments) - Special Guest appearance - RPP Paperwork and safety review help-session.	Ariel Ekblaw TBD Charlie Bolden TBD SEI Staff	Readings: TBD Recitation: Open office hours
Nov 11th	NO CLASS. Veterans Day.		

Nov 18th	Parabolic Flight Prep (120 min) TBD -An Astronaut's Perspective on Microgravity -Science and fundamental research explorations in zero gravity; human spaceflight & bioastronautics	TBD Jeff Hoffman, Co-Director, Human Systems Lab, Ret. Astronaut TBD Larry Young, Apollo Program Professor Emeritus	Readings: TBD Recitation: Open office hours
Nov 25th	NO CLASS. Thanksgiving Break		
Dec 2nd	Parabolic Flight Prep (120 min) - In class CDRs - Day one	Reviewers: Paradiso, Ekblaw + others as invited	Readings: TBD Recitation: CDRs
Dec 9th	Parabolic Flight Prep (120 min) - In class CDRs - Day two	Reviewers: Paradiso, Ekblaw + others as invited	Readings: TBD Recitation: CDRs
Dec 9th 4-6p	Veteran Flyers Panel & Reception Note: outside of class time! - Astronauts training flights + ISS flight time	Reviewers: Paradiso, Ekblaw + others as invited TBD Ret. and Current Astronauts Cady Coleman, Jeff Hoffman, Nicole Stott, Tony Antonelli Nicholas de Monchaux, MIT Professor and Head of Architecture	