

Indian Institute of Technology, Kanpur

Proposal for a New Course

1. **Course No:** AE XXX
2. **Course Title:** Space Exploration Mission Formulation
3. **Per Week** Lectures:3(L), Tutorial: 0(T), Laboratory: 0(P), Additional Hours[0-2]: 0(A)
4. **Credits** ($3*L+2*T+P+A$): 9
5. **Duration of Course:** Full Semester
6. **Proposing Department:** Aerospace Engineering
Other Departments/IDPs which may be interested in the proposed course: SPASE
7. **Proposing Instructor(s):** Rachana Agrawal (AE)
Faculty members interested in teaching the proposed course: Dipak Kumar Giri (AE)
8. **Course Description:**

A space exploration mission is a high-risk high-cost endeavor with little margin for errors. It is also a multi-disciplinary affair and requires various systems to work together. The mission architecture is often arrived at through an iterative design and testing process. If you are eager to learn how a space mission is born and designed, this course is for you! Welcome!

In this course, you will learn about the lifecycle of a typical space mission and the design process of constituent systems. By the end of this course, you will be able to design a preliminary concept of a space mission given its objectives and constraints. You will work in teams on a **semester-long project** to design a mission concept to a planetary destination. The lecture sessions are designed to guide you through the process and will require active participation in class. The teams will be able to receive feedback on their design through regular presentations, finally culminating in a formal Mission Concept Review presentation. The course is meant to provide a holistic understanding of space mission engineering and develop critical design skills.

A. Objectives:

By the end of this course, students will be able to...

- Design a space mission architecture concept for given science objectives through trade study of critical mission parameters.
- Generate feasible conceptual designs of the major subsystems based on a feasibility criteria defined at the beginning of the course.
- Identify interdependencies between subsystems and iterate the mission design toward a coherent mission concept by working with other subsystem teams.
- Practice presentation skills and justify the design as a team to a panel, following a standard Mission Concept Review format used in the space industry.

B. Contents:

The course is divided into three units:

1. Mission formulation (~4 weeks)
2. Concept development (~7 weeks)
3. Mission and space system operations (~3 weeks)

Sub-Units	Topics	Intended Learning Outcome (Students will be able to ...)	Lectures (Total 39)
<i>Unit 1: Mission Formulation</i>			
Mission/Project Lifecycle	Flight Project lifecycle; Introduction to the mission formulation and objectives; Concept maturity levels; formulation within constraints;	1. Describe a typical mission lifecycle and identify key milestones 2. Describe the iterative mission formulation and development process.	2
Science/Mission Requirements Definition	Science objectives and instrument; Science Traceability Matrix; System requirements definition; requirement statements	1. Identify key elements of a science traceability matrix 2. Design a STM based on the given science objectives 3. Identify key stakeholders and generate level 1 requirements	3
Mission trade space study	Mission architecture overview; morphological matrix; Key design trades; Design space exploration; pareto evaluation; point design selection; analysis of alternatives;	1. Identify key mission parameters and flight systems 2. Create a morphological matrix for a trade study 3. Develop a probabilistic model for comparison of the missions 4. Model a pareto optimization framework and shortlist candidate architectures	5
<i>Unit 2: Concept Development</i>			
Systems Engineering/Mission Architecture	Systems engineering principles; concept of operations; system development life cycle; sub-system interdependencies; concurrent engineering;	1. Recognize the key attributes of a major system development life cycle and the role of the systems engineer in each stage of the life cycle. 2. Work in a multi-disciplinary team to communicate system requirements and constraints 3. Apply fundamental methods of analysis and evaluation used in designing space systems and selection of the most appropriate system design.	4
Preliminary Sizing/Technical Budget	Contingency and margin; Mass budget; functional analysis and diagrams;	1. Create key system-level engineering products and diagrams used in the analysis and definition of space systems and subsystems	3

	technical budgets document;	and in the preparation of space mission concepts.	
Sub-system Sizing	DV and propellant budget; Telecommunications link budget; Data volume; GNC sub-system sizing; Power budget and power profiles; thermal modeling and thermal control; sub-system alternatives	<ol style="list-style-type: none"> 1. Identify critical subsystems 2. For each subsystem <ol style="list-style-type: none"> a. Design functional architecture b. Design a first-order system that meets the identified requirements and constraints c. Work with other subsystems in the team to identify gaps in requirements and revise the design 3. Generate mass, power, and data budget tables 	8
Risk and cost analysis	Cost estimation; earned value management; risk likelihood and consequence; risk matrix and mitigation; failure modes assessment;	<ol style="list-style-type: none"> 1. Generate a statistical mission cost estimation 2. Identify key risks and rank them based on likelihood and consequence; identify mitigation strategies 	3
Mission Concept Review I (MCR-I)	Team Design Review	<ol style="list-style-type: none"> 1. Present preliminary design in a Mission Concept Review format. Be able to explain the trades involved and design choices. 	3
Unit 3: Mission and system operations			
Baseline design iteration	Requirements satisfaction; critical gaps and feasibility assessment; technology readiness level	<ol style="list-style-type: none"> 1. Evaluate the quality of the mission concept based on satisfaction of requirements and constraints and feasibility 	2
End-to-end concept of operations and scheduling	Mission operations; launch window assessment; Critical events; Project schedule; test and validation planning;	<ol style="list-style-type: none"> 1. Generate a detailed concept of operations 2. Evaluate primary and backup launch windows 3. Create a project schedule along with test/validation plan 	3
Final Mission Concept Review (MCR-II)	Final project presentation by the student team(s)	<ol style="list-style-type: none"> 1. Synthesize the final design as a team and present to a panel. 2. Demonstrate action on feedback from MCR-I and improvement in design and presentation. 3. Create a design report following a given format typically used in space sector. 	3

C) Pre-requisites:

This course is for senior undergraduate students and post-graduate students.

At least two undergrad/grad courses in structures/thermodynamics/attitude dynamics/controls/flight mechanics/propulsion/space dynamics/communication systems/space systems/space environment.

D) Short summary for including in the Courses of Study Booklet:

This course equips students with practical experience in the formulation and engineering of planetary space missions. Through a semester-long, team-based project, students will conceptualize and design a mission to a planetary destination—starting from broad scientific goals and progressing through the full lifecycle of mission development. Students will gain a comprehensive understanding of mission architecture, including subsystem design, trade studies, and systems integration. Lectures are structured to guide students through each phase of the design process, with active in-class participation and collaborative problem-solving at the core. By the end of the semester, students will be able to develop a preliminary mission concept that meets defined objectives and constraints. This course intends to build a holistic grasp of space mission engineering while cultivating essential skills in teamwork, technical communication, and systems thinking.

9. Recommended books:

Wertz, J. R., Everett, D. F., & Puschell, J. J. (2011). *Space mission engineering: The new SMAD*. Microcosm Press.

NASA Systems Engineering Handbook. ([Systems Engineering Handbook - NASA](#))

10. Any other remarks:

What to expect in this course: This course will be highly interactive and critical engagement in class will be key for students to succeed in achieving the learning goals. Designing and implementing a space mission is a highly interactive endeavor, its success relying on great teamwork. Through these activities, you will not only build confidence in your individual learning, but also in voicing and presenting your ideas to your colleagues and carrying out productive group discussions. In addition, your participation in every class will provide feedback to us and to yourself about the status of your learning . We will also assess your class participation towards 10% of your total grade. Some of the planned activities include polling questions, open-ended questions, brainstorming, and interactive demonstration.

To prepare for participating in the class activities, we will provide relevant readings and prompts to think about before each class. We encourage you to make use of these resources for active engagement. Additionally, since this is a team based project course, students are expected to meet with their team members outside of the lecture hours to work together on the design problem. Weekly feedback and consultation sessions will be held between the teams and TAs, outside of the lecture hours. We encourage you to take advantage of these sessions, ask questions, engage in discussions, and obtain critical feedback.

Software: Some recommended software will be provided through course website. For some sub-system design problems, students are expected to determine the appropriate software tool, either provided by the university, available as open source, or developed on their own. Selection of the appropriate tools (including software) is an important part of the design process. Links to suggested tools will be provided. Students are expected to have access to and be familiar with the standard software used in engineering, including word processing, spreadsheets, presentation (e.g. PowerPoint) and computation (e.g. MATLAB). Students are free to choose the software and operating system that works best for their project team. Teams should set up a common cloud storage area (e.g. OneDrive or Google Drive) to share work among members.

Dated: __23/02/2026__ Proposer: __Rachana Agrawal__

Dated: _____ DUGC/DPGC Convener: _____

The course is approved / not approved

Chairman, SUGC/SPGC

Dated: _____