Course guide
205127 - 205127 - Launch Vehicles and Trajectory Optimisation

Last modified: 11/04/2025

Unit in charge: Terrassa School of Industrial, Aerospace and Audiovisual Engineering
Teaching unit: 748 - FIS - Department of Physics.

Degree: MASTER'S DEGREE IN AERONAUTICAL ENGINEERING (Syllabus 2014). (Optional subject).
MASTER'S DEGREE IN SPACE AND AERONAUTICAL ENGINEERING (Syllabus 2016). (Optional subject).

Academic year: 2025 **ECTS Credits:** 3.0 **Languages:** English

LECTURER

Coordinating lecturer: Rovira Garcia, Adrià

Others: Betorz Martinez, Francesc

PRIOR SKILLS

This course is taught in English. Therefore, students need to have a sufficient level of English.
This course assumes that students have a solid knowledge in physics and mathematics, including proficiency in calculus, linear algebra, and differential equations, as well as a thorough understanding of classical mechanics.

TEACHING METHODOLOGY

Through presential classes and proposed exercises and assignments, students will learn the specifics of vehicle launcher design and trajectory optimization.

LEARNING OBJECTIVES OF THE SUBJECT

Launch vehicles play a crucial role in space exploration and satellite deployment and are distinct from other space vehicles due to their specific characteristics and operational requirements. This course addresses the main aspects of launch vehicle design, with special emphasis on the Guidance, Navigation, and Control (GNC) subsystem. Students will also be introduced to the principles of optimal control theory and its applications in trajectory optimization.

STUDY LOAD

Type	Hours	Percentage
Self study	48,0	64.00
Hours large group	27,0	36.00

Total learning time: 75 h

CONTENTS

Module 1: Introduction to Launch Vehicles

Description:
History of space launch vehicles. Typical launch vehicle mission profile. Launch vehicle subsystems overview.

Full-or-part-time: 4h
Theory classes: 2h
Self study : 2h

Module 2: Missions, Orbits and Flight Dynamics

Description:
Mathematics review tailored to the launch: spherical trigonometry, quaternions, constrained optimization. Launch vehicle dynamics: translational and rotational equations of motion. Energy requirements for injection into orbit.

Full-or-part-time: 13h
Theory classes: 5h
Self study : 8h

Module 3: Trajectory Analysis

Description:
Launch vehicle trajectories: ascent, coasting, and insertion phases. Gravity, aerodynamic and steering losses. Multistage concept: performance and optimal staging. Gravity turn trajectories. Launch sites, launch windows and azimuth angles. Integrated trajectory design.

Full-or-part-time: 14h
Theory classes: 5h
Self study : 9h

Module 4: Launch Vehicle Design

Description:
System requirements for Launch Vehicles. Integrated design guidelines. Propulsion and vehicle sizing. Vehicle aerodynamics and operating environment. Structures and separation systems. Avionics and GNC.

Full-or-part-time: 14h
Theory classes: 5h
Self study : 9h

Module 5: Launch Vehicle Trajectory Optimization

Description:
Basics of optimization: definitions, terminology, and aerospace applications. Calculus of variations. Introduction to Optimal Control. Hamiltonian and Pontryagin's Minimum Principle. Direct and indirect Methods. Software for optimal control. Examples of launch vehicle trajectory optimization.

Full-or-part-time: 30h
Theory classes: 10h
Self study : 20h

GRADING SYSTEM

The evaluation will be carried out according to the following criteria:
- Final exam in the form of a written test: 50%
- Assignments and exercises: 50%

All those students who have failed the final exam, will have the option to recover it by taking a global test that will be held on the day set in the calendar of the final exam period for the renewal of optional subjects. The qualification
of this renewal test will be between 0 and 5 and will replace that of the written test in the final exam, as long as the new mark is higher.

EXAMINATION RULES.

Test-type exam with multiple answers

BIBLIOGRAPHY

Basic:
- Edberg, Donald L.; Costa, Guillermo. Design of rockets and space launch vehicles. 2nd ed. Reston, Virginia: American Institute of Aeronautics and Astronautics, 2022. ISBN 9781624106415.
- Suresh, B.N.; Sivan, K. Integrated design for space transportation system [on line]. New Delhi: Springer India, 2015 [Consultation: 24/04/2024]. Available on: https://link-springer-com.recursos.biblioteca.upc.edu/book/10.1007/978-81-322-2532-4. ISBN 9788132225324.
- Longuski, J.; Guzmán, J.J.; Prussing, J.E. Optimal control with aerospace applications [on line]. New York: Springer New York, 2014 [Consultation: 24/04/2024]. Available on: https://link-springer-com.recursos.biblioteca.upc.edu/book/10.1007/978-1-4614-8945-0. ISBN 1461489458.
- Betts, John T. Practical methods for optimal control using nonlinear programming. Philadelphia: Society for Industrial and Applied Mathematics, 2010. ISBN 9780898716887.