

# Course guide 205127 - 205127 - Launch Vehicles and Trajectory Optimization

Last modified: 09/02/2024

Unit in charge: Teaching unit:	Terrassa School of Industr 748 - FIS - Department of	ial, Aerospace and Audiovisual Engineering 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: 2023	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**

Туре	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. American Institute of Aeronautics and Astronautics, 2022. ISBN 9781624106415.

- Suresh, B.N., Sivan, K. Integrated Design for Space Transportation System. Springer India, 2015. ISBN 9788132225324.

- Betts, J. T.. Practical methods for optimal control using nonlinear programming. Society for Industrial and Applied Mathematics, 2010. ISBN 9780898716887.

- J. M. Longuski, J. J. Guzmán, and J. E. Prussing.. Optimal Control with Aerospace Applications. Springer New York, 2014. ISBN 1461489458.