Course guide
300521 - CDIOII - Cdio II

Last modified: 14/01/2026

Unit in charge: Castelldefels School of Telecommunications and Aerospace Engineering
Teaching unit: 748 - FIS - Department of Physics.
710 - EEL - Department of Electronic Engineering.
739 - TSC - Department of Signal Theory and Communications.

Degree: BACHELOR'S DEGREE IN SATELLITE ENGINEERING (Syllabus 2024). (Compulsory subject).

Academic year: 2025 **ECTS Credits:** 5.0 **Languages:** Catalan, Spanish

LECTURER

Coordinating lecturer: Definit a la infoweb de l'assignatura.

Others: Definit a la infoweb de l'assignatura.

PRIOR SKILLS

Basic programming in C
Basic programming in Python
Basic programming in Matlab
Basic analog electronics

TEACHING METHODOLOGY

The course is organized around the development of a project in which a weather balloon equipped with a telemetry system will be launched in order to determine its location, orientation, environmental variables, and the geometric parameters of the balloon during the ascent phase. All measurements will be oriented toward a final objective, which will vary and be defined in each edition of the course.
Students will be organized into groups of twelve to form project teams. Each team must design, assemble, and implement a complete, functional, and independent probe from those developed by the other teams, and will compete to produce the best design, which will ultimately be launched at the end of the course.
The probe design is structured into six subsystems: power supply, heating, communications, atmospheric variable measurement, localization and orientation, and image capture and processing. Each subsystem will be assigned to a working group consisting of two students. Consequently, each project team will be composed of six working groups that must coordinate to ensure functional compatibility, mechanical and electronic integration, and compliance with the requirements of the complete system.
The course is organized into three blocks: basic training in the topics necessary for the development of the probe, training in electronic tools for microcontroller programming and PCB design, and project development. While the first two blocks will be carried out through lectures combined with practical demonstrations, project development will be conducted autonomously by the working groups in the laboratory, under the supervision of faculty members specialized in each of the subject areas.

Although each working group will develop different subsystems, all of them will be required to program a microcontroller as well as design and implement an electronic circuit using the professional tool Altium.

LEARNING OBJECTIVES OF THE SUBJECT

- Use professional tools for editing electronic system schematics and designing printed circuit boards (PCBs).
- Program and configure microcontrollers for their integration into electronic data acquisition systems.
- Describe and relate the layers of the atmosphere to their environmental conditions.
- Design a basic autonomous power supply system.
- To understand the physical phenomena that determine the temperature of a system in the upper layers of the atmosphere or beyond it, as well as the control and design methods required to maintain that temperature within the specified operating limits.
- Understand the main configuration parameters of a LoRa communication system.
- Analyze how extreme environmental conditions affect the operation of electronic systems.
- Determine the attitude of a terrestrial observation system using inertial and magnetic sensors.
- Apply basic sensor fusion techniques to optimize measurement accuracy.
- Work in a coordinated manner as part of a team, planning and structuring the project through division into functional subsystems.

STUDY LOAD

Type	Hours	Percentage
Hours large group	55,0	44.00
Self study	70,0	56.00

Total learning time: 125 h

CONTENTS

Atmospheric Models and Ascent Dynamics

Description:
Understand and model how atmospheric variables—pressure, temperature, and air density—vary with altitude and affect the ascent dynamics of a weather balloon.

Specific objectives:
The student will be able to:
- Determine the environmental conditions that the probe components must withstand.
- Size the autonomy of the battery-based power supply system.
- Assess the need for a heating system and size it accordingly.
- Define the basic parameters for flight planning.

Related activities:
- Introduction
- Basic training
- Exams

Full-or-part-time: 7h 56m
Theory classes: 2h 50m
Self study : 5h 06m

Environmental and Navigation Sensors for the Probe

Description:
To understand the operating principle and characteristics of environmental sensors for temperature, humidity, and pressure, as well as the sensors used to determine the orientation and altitude of the probe, such as the magnetometer, IMU, and barometric altimeter.

Specific objectives:
Select, configure, and properly integrate sensors in the probe design.

Related activities:
- Introduction
- Basic training
- Exams

Full-or-part-time: 7h 56m
Theory classes: 2h 50m
Self study : 5h 06m

LoRa Technology for Long-Range Communications

Description:
Configuration and operation of LoRa modules for communication between the probe and the base station.

Specific objectives:
Transmit the measurements acquired by the probe to the base station.

Related activities:
- Introduction
- Basic training
- Exams

Full-or-part-time: 9h 30m
Theory classes: 5h
Self study : 4h 30m

Image Acquisition and Processing Using a Microcontroller

Description:
Use of an STM32 microcontroller and a CMOS camera with FIFO memory for image processing and the extraction of geometric information. Introduction to basic image encoding, management of communication interfaces with the camera, contour detection, and simple image processing techniques aimed at determining the balloon diameter.

Specific objectives:
Estimate the balloon diameter using image processing techniques and analyze its influence on the ascent dynamics.

Related activities:
- Introduction
- Basic training
- Exams

Full-or-part-time: 7h 56m
Theory classes: 2h 50m
Self study : 5h 06m

Temperature Control

Description:
Study of heat transfer mechanisms (conduction, convection, and radiation) and how they vary with the altitude of the probe. Introduction to thermal modeling of the system, describing the dynamic evolution of temperature in response to a heat source. Analysis of basic thermal control strategies, including ON/OFF control and PID control, applied to the regulation of the probe temperature.

Specific objectives:
The student will be able to design the probe heating system to maintain its components within a temperature range suitable for proper operation.

Related activities:
- Introduction
- Basic training
- Exams

Full-or-part-time: 7h 56m
Theory classes: 2h 50m
Self study : 5h 06m

Autonomous Battery Power Supply System

Description:
Description of battery characteristics, including capacity, discharge curves, self-discharge, and output impedance, as well as commonly used monitoring circuits. Regarding power conditioning circuits, the basic operation of linear and switching regulators is introduced, together with the main characteristics that determine their application. Additionally, the use of charge counters for monitoring the autonomy of the power supply system is presented.

Specific objectives:
The student will be able to size the battery system to achieve the required mission autonomy, select the voltage regulators for the different subsystems, and design a power supply monitoring system.

Related activities:
- Introduction
- Basic training
- Exams

Full-or-part-time: 7h 56m
Theory classes: 2h 50m
Self study : 5h 06m

Configuration, Programming, and Development Environment for STM32 Microcontrollers

Description:
Introduction to the capabilities of STM32 microcontrollers, the STM32CubeMX configuration environment, and programming using STM32CubeIDE and the HAL libraries. The use of basic microcontroller peripherals is studied, including digital input and output ports, analog-to-digital conversion, PWM signal generation, timers for pulse counting and capture, as well as the main serial communication interfaces: UART, SPI, and I2C.

Specific objectives:
The student will be able to program the STM32F401 microcontroller for the control, coordination, and integration of the different subsystems of the probe.

Related activities:
- Introduction
- Microcontroller configuration and programming
- Subsystem design and programming
- Assembly, integration, and validation of the complete probe
- Launch
- Exams

Full-or-part-time: 40h 05m
Theory classes: 9h 05m
Laboratory classes: 11h
Self study : 20h

Electronic Schematic and PCB Design Using Altium

Description:
Training in the use of the professional Altium tool for electronic design, covering schematic capture and printed circuit board (PCB) design. The content includes familiarity with the working environment, library and component management, PCB routing and design rule checking, as well as the generation of the documentation required for manufacturing.

Specific objectives:
The student will be able to develop the design of the electronic board for their subsystem and generate the files and documentation required for its manufacturing.

Related activities:
- Introduction
- Electronic schematic editing and printed circuit board (PCB) design of the subsystems
- Subsystem design and programming
- Assembly, integration, and validation of the complete probe
- Launch
- Exams

Full-or-part-time: 35h 45m
Theory classes: 4h 45m
Laboratory classes: 11h
Self study : 20h

ACTIVITIES

Introduction

Description:
Introductory lecture presenting the course, in which the project to be developed is introduced, its objectives are explained, and its structure is described through the division into functional subsystems, which are assigned to the different working groups. In addition, the overall organization of the course, the assessment system, and the laboratory operating rules are detailed. Within this framework, the different phases of the project according to the CDIO methodology are presented and explained: Conceive, Design, Implement, and Operate.

Specific objectives:
Information about the objectives and organization of the course.

Full-or-part-time: 2h
Theory classes: 2h

Basic training

Description:
Lectures, with occasional support from practical demonstrations, aimed at providing the basic knowledge required for the development of the project. The contents are structured into the following blocks:
- Atmospheric models and ascent physics: International Standard Atmosphere (ISA) model, forces, and terminal velocity.
- Environmental sensors: orientation using inertial and magnetic sensors, environmental sensing, and data fusion.
- Power supply system: batteries, monitoring systems, and voltage regulation.
- Heating system: thermal generation and control using MOSFETs and PWM modulation; temperature control strategies.
- LoRa communication systems: fundamentals and configuration parameters.
- Image acquisition and processing: encoding, segmentation, edge detection, geometric fitting, and calibration.

Specific objectives:
Basic knowledge for sizing the probe and designing the different subsystems.

Full-or-part-time: 28h 30m
Theory classes: 13h 30m
Self study: 15h

Training on microcontroller configuration and programming

Description:
Lectures, with occasional support from practical demonstrations, aimed at introducing the capabilities of STM32 microcontrollers, the STM32CubeMX configuration environment, and programming using STM32CubeIDE and the HAL libraries. The use of digital input and output ports, acquisition and conversion of analog signals, PWM signal generation, pulse counting and capture using timers, and serial communications (UART, SPI, and I2C) are covered.

Specific objectives:
Training for the control and integration of the different subsystems using the microcontroller.

Full-or-part-time: 18h
Theory classes: 7h 30m
Self study: 10h 30m

Training in professional tools for electronic schematic editing and printed circuit board (PCB) design

Description:
Lectures, with occasional support from practical demonstrations, aimed at developing competencies in the use of the professional tool Altium for electronic schematic editing and printed circuit board (PCB) design. The course covers the working environment, schematic capture, library and component management, PCB design and routing, design rule verification, and preparation of the documentation required for manufacturing.

Specific objectives:
Specialized training for the design of the probe's electronic boards.

Full-or-part-time: 14h 30m
Theory classes: 4h
Self study: 10h 30m

Design and programming of the subsystems

Description:
Design and validation of each subsystem. Each working group will design the subsystem assigned to them, assemble it on a protoboard, and develop the corresponding control firmware.

Specific objectives:
- Design and validate the battery-based power supply subsystem.
- Design and validate the heating subsystem.
- Design and validate the atmospheric measurement subsystem.
- Design and validate the localization and orientation subsystem for the probe.
- Design and validate the communications subsystem.
- Design and validate the image acquisition and processing subsystem.

Material:
- Windows PC
- STM32F401 NUCLEO development board
- Specific components for each subsystem
- Analog Discovery Studio
- Climatic chamber

Software: STM32CubeMX, STM32CubeIDE, WaveForms

Delivery:
- Final report
- Documentation of the microcontroller configuration and programming for integration
- Demonstration of the system operation for evaluation

Full-or-part-time: 19h
Laboratory classes: 7h
Self study: 12h

Electronic schematic editing and printed circuit board (PCB) design of the subsystems

Description:
Each working group will design, using Altium Designer, the electronic schematics and printed circuit boards (PCBs) of the subsystems it has developed.

Specific objectives:
Obtain the documentation for the fabrication of printed circuit boards

Material:
- Windows PC
- Altium Designer

Delivery:
- Schematics for the final report
- Gerber files for manufacturing
- Bill of Materials (BOM)

Full-or-part-time: 10h
Laboratory classes: 4h
Self study: 6h

Assembly, integration, and validation of the complete probe

Description:
The components will be soldered onto the boards corresponding to each subsystem. Once individually verified, they will be assembled to form the probe together with the sensors, heaters, and external batteries. A single firmware will be developed and programmed into the microcontroller, integrating the functionalities of all subsystems. After the assembly is completed, comprehensive testing of the probe will be carried out, reproducing the environmental conditions expected during the launch.

Specific objectives:
Have a fully functional probe ready for launch

Material:
- Printed circuit boards and components of the different subsystems
- Soldering equipment
- Windows PC
- ST-LINK on the STM32F401 NUCLEO development board
- Analog Discovery Studio
- Environmental chamber
- Software: STM32CubeMX, STM32CubeIDE, WaveForms, Visual Studio Code and Python.

Delivery:
- Complete probe
- Final tests
- Final report

Full-or-part-time: 25h
Laboratory classes: 11h
Self study: 14h

Launch

Description:
We will move to a safe location specifically prepared for the probe launch. At this site, the different system elements will be assembled, the balloon will be filled with helium, the sensors will be calibrated, and final functional checks will be carried out. Once the correct operation of the system has been verified, the data acquisition phase will begin at the ground stations, and the balloon will be released to initiate its ascent. The monitoring and data acquisition of the probe will be performed simultaneously by all ground stations from the different project groups.
After the ascent is completed and the probe has landed, it will be located and, if possible, recovered.

Specific objectives:
Measurement acquisition during the ascent

Material:
- Complete probe: balloon, parachute, gondola, and radar reflector
- Helium cylinders
- Ground stations: Windows PC and communication subsystem

Delivery:
- Final report

Full-or-part-time: 5h
Theory classes: 3h
Self study: 2h

Exams

Description:
Mid-term exam covering the content taught in the Basic Training and Microcontroller Configuration and Programming classes. The retake of this exam will take place during the final exam period.

Specific objectives:
Evaluate the knowledge acquired.

Full-or-part-time: 3h
Theory classes: 3h

GRADING SYSTEM

The assessment is based on a combination of exams and practical activities. Two exams will be held, one at mid-semester and another at the end of the semester, each contributing 12.5% to the final grade. The remaining portion of the grade will come from three practical activities, each accounting for 25%.
The first of these activities focuses on verifying the correct operation of the different subsystems independently (milestone 1). Once this phase is completed, students will move on to the design, fabrication, and assembly of the printed circuit boards (PCBs), as well as the integration of all components into a single system.
Before launch, a full system test of the probe will be carried out (milestone 2), during which its overall performance will be evaluated and the design to be flown will be selected. Finally, after collecting and analyzing the data obtained during the flight, a final report will be prepared, which will conclude the assessment process.

EXAMINATION RULES.

Attendance at the project development sessions is mandatory.

BIBLIOGRAPHY

Basic:

- Yajima, Nobuyuki. Scientific ballooning : technology and applications of exploration balloons floating in the stratosphere and the atmospheres of other planets . New York : Springer, 2009. ISBN 978-0-387-09725-1.
- Michael Stanley , Jongmin Lee. Sensor Analysis for the Internet of Things [on line]. 1. Springer Nature Link, 1 juny 2022 [Consultation: 13/01/2026]. Available on: https://link-springer-com.recursos.biblioteca.upc.edu/book/10.1007/978-3-031-01526-7#accessibility-information. ISBN 978-3-031-01526-7.
- José Meseguer Isabel Pérez-Grande Angel Sanz-Andrés. Spacecraft Thermal Control [on line]. Woodhead Publishing, 2012 [Consultation: 13/01/2026]. Available on: https://www.sciencedirect.com/book/monograph/9781845699963/spacecraft-thermal-control#book-info. ISBN 978-1-84569-996-3.
- Sylvain MONTAGNY. LoRa LoRaWAN and IoT for beginners. A LOW POWER, LONG RANGE, WIRELESS TECHNOLOGY [on line]. e-book gratuito. Université Savoie Mont Blanc / LoRa Alliance, [Consultation: 13/01/2026]. Available on: https://www.univ-smb.fr/lorawan/en/free-book/.
- Dogan Ibrahim. Nucleo Boards Programming with the STM32CubeIDE [on line]. Aquisgrán (Aachen), Alemania: Elektor Verlag, [Consultation: 13/01/2026]. Available on: https://www.amazon.es/Nucleo-Boards-Programming-STM32CubeIDE-Hands/dp/3895764167/ref=asc_df_3895764167?mcid=020a4eb7fb8d35aa82f3ac213f7498b6&tag=googshopes-21&linkCode=df0&hvadid=699725881654&hvpos=&h. ISBN 978-3-89576-416-5.
- Majid Pakdel. Fast PCB Design with Altium Designer [on line]. Central West Publishing. [Consultation: 13/01/2026]. Available on: https://www.amazon.com/Design-Designer-Industrial-Automation-Control/dp/1922617091. ISBN 978-1922617095.

Complementary:

- Wallace, John M; Hobbs, Peter. Atmospheric science : an introductory survey . 2nd ed. Burlington, Mass. : Elsevier Academic Press, cop. 2006. ISBN 9780127329512.

RESOURCES

Other resources:

Slides and documentation uploaded to Atenea