Course Syllabus for
DAUSY National Ph.D. Program in Autonomous Systems
(year 2022-23)

Course title	Modeling, filtering and controlling aerospace systems
Scientific Discipline Sector	ING-INF/04
Hours of instruction	20 hours
CFU	2 CFU
Semester, period	Second semester, April-May 2023
Goal	The main objective of the course is to study how to model the dynamics of space systems and the environment where they are operated, and to co-design ad-hoc algorithms for autonomous navigation and control of spacecraft. During the course, the mathematical tools to support the development and implementation of problems related to dynamics modeling, navigation data filtering, and control will be presented and described in details. In particular, the course will include an overview on space mission, orbital maneuvers, and on the analytical methods and techniques for formulating mathematical models of the orbital and rotational dynamics. Going into the details of the Attitude and Orbital Control Subsystem, the lectures will focus on two main aspects: navigation and control. For the navigation task, the most used filtering techniques in the space framework will be reviewed, together with a detailed overview on the sensors equipped on-board, and how to model them. On the other hand, classical and modern control techniques for attitude and orbital control will be described, highlighting how to co-design the mission and the controller and which are the major mission/spacecraft-related constraints to be included into the development of the controllers. To complete the course, an overview on the actuators available on board for maneuvering the satellite will be given, with some details on how to model them when explicitly included or not into the design of the controller design. The lessons will include both theoretical contents and numerical examples.

Syllabus	Basic notions on dynamical systems, stability, linearization Aerospace topics: space missions coordinate reference systems; rotations and translations; rigid body attitude kinematics and dynamics; orbital dynamics modeling and simulation of space missions in MATLAB/Simulink environmental disturbance actuation system Filtering techniques: Kalman filter Extended Kalman filter Particle filter Multiple-weight particle filter Control techniques: state-feedback; linear quadratic regulator proportional integral derivative sliding-mode control model predictive control (classical and robust).
Bibliography	VALLADO, David A. Fundamentals of astrodynamics and applications. Springer Science & Business Media, 2001. MARKLEY, F. Landis; CRASSIDIS, John L. Fundamentals of spacecraft attitude determination and control. New York, NY, USA:: Springer New York, 2014. DE RUITER, Anton H.; DAMAREN, Christopher; FORBES, James R. Spacecraft dynamics and control: an introduction. John Wiley & Sons, 2012. WERTZ, James R. (ed.). Spacecraft attitude determination and control. Springer Science & Business Media, 2012. Slides and support material from lecturer.
Examination method	Group project (3/4 people, to be defined according to the number of students)– development of a space simulator including a filtering technique (not necessarily limited to the ones analysed during classes) for navigation and a control scheme for either attitude or orbital control.