Special Master Course in Aerospace Engineering
Topics of the Courses (Academic Year 2024-2025)

These are only general indications about the content of each course, to provide students some insights in order to help them in courses' selection. Topics actually dealt with within the courses could slightly differ, so that the official syllabus to be presented at the exam will be the one agreed with the instructor during lectures.
Additional information can be requested to the instructor of each course (e-mail: name.lastname@uniroma1.it)

ADVANCED CONTROL OF SPACE VEHICLES (1st period, Prof. Fabio Celani)

Main aim of this course is to introduce students to tools from modern control theory applied to design and analysis of attitude control systems for space vehicles. Those tools are important for designing advanced attitude control systems for which advanced performances are required. Students will be introduced to software applications that support analysis and design by those tools.
For further information please visit https://sites.google.com/a/uniroma1.it/fabiocelani_eng/teaching/acsv

ADVANCED TOPICS IN AEROSPACE ENGINEERING (2nd period, Prof. Antonio Paolozzi and Prof. Fabio Curti)

This course provides an opportunity to gain in-depth knowledge and understanding of critical and advanced engineering principles within aerospace engineering. Particular focus will be given on advanced and emerging technology areas which are relevant to the aerospace industry. Fundamental knowledge and current research methods will be applied on a wide range of topics, with critical review of the state of art and insights on future technologies. Also social, legal, medical, economical issues are considered, with different case studies suggested by expert staff of the aerospace industry, national space agencies and defense. The students will have the opportunity to understand the interaction of the aerospace engineering with different disciplines and how to solve complex problem in a multidisciplinary context.

AERODYNAMICS OF CONTINUOUS AND RAREFIED FLOWS (1st period, Prof. Maurizio Parisse and Dr. Stefano Carletta)

General introduction. Physical properties of the atmosphere, the upper atmosphere. Fundamentals of thermodynamics.
Aerodynamic forces and moments acting on a missile. Drag force, spin damping moment, lift and normal forces, overturning moment, Magnus force and moment, pitch damping force and moment.

ASTRODYNAMICS (1st period, Prof. Paolo Teofilatto)

The Earth Gravitational Field. Keplerian Trajectories. Inertial reference frame and orbit parameters. The problem of time. The Two-Lines Elements. Ground track. Impulsive orbital Transfers. Perturbations. Averaging. Satellite lifetime.
Special Orbits. Interplanetary fights: direct transfer orbits. Gravity assist. Inner and outer low energy transfer trajectories. Ballistic Reentry. Reentry Corridor.

ATTITUDE DYNAMICS, DETERMINATION AND CONTROL (2nd period, Prof. Giovanni B. Palmerini)

Introduction to the course (relevance of attitude, angles as attitude descriptors, frames, basic dynamics & kinematics). Attitude representations (direction cosine matrix, Euler angles, quaternions). Inertia, principal axes. Euler equation, homogeneous solution for a spinner, general case for a non-spinning spacecraft. Disturbing torques (gravity gradient, aerodynamic, solar radiation pressure torque, magnetic). Attitude Determination basics and hardware (Earth and Sun sensors, star trackers, magnetometers, GNSS). Passive and Active control. Gravity gradient stabilization, and related damping techniques. Spinner (control during orbit acquisition and during operations, dual spin architecture). Momentum exchange control. Desaturation. Momentum bias concept. Magnetic Control. Characteristics of attitude actuators (reaction thrusters, wheels, magnetotorquers). Introduction to time-optimal control. Remarks on flexibility and sloshing effects.

DESIGN OF ELECTRONIC SYSTEMS FOR SPACE: HARDWARE AND SOFTWARE DESIGN TECHNIQUES (1st period, Prof. Augusto Nascetti)

The module focuses on the design of electronic systems for space applications introducing system-level approaches, board-level design techniques and component-selection considerations. On-board computer design for satellites and launchers will be addressed in detail with practical examples. Software and firmware design methods for reliable autonomous operation of digital on-board electronics are presented. With this module the student will acquire knowledge in the design of satellite's on-board electronics and will have the chance to put in practice the acquired knowledge with practical hardware and software design exercises.

DESIGN OF ELECTRONIC SYSTEMS FOR SPACE: RELIABILITY ENGINEERING
(1st period, Prof. Luigi Schirone)

The module deals with approaches to analyse and design quality and reliability of space systems. Functional and failure modelling of a space system and other basic concepts related to reliability prediction are introduced. The main techniques for reliability estimation (standard-based) and for assessment of failure criticality (FMECA analyses) are presented. An introduction is also given about methods for reliability increase and their correct design. Real flight hardware will be used as a case study to practice the acquired concepts.
For further information please visit https://sites.google.com/uniroma1.it/luigischirone-eng/home

DESIGN OF SPACE VEHICLES (1st period, Prof. Maurizio Parisse)

Space environment: gravity gradient torque, aerodynamic torque, magnetic torque, solar pressure torque.
The spacecraft system and its sub-systems.
- Propulsion
Propulsion system type: cold gas, hot gas. Monopropellant, bipropellant, dual-mode
- Structures and Mechanisms
Loads, methods of analysis, monocoque, skin-stringer.
- Power
Photovoltaic solar cells, batteries, radioisotope thermal generator (static, dynamic)
- Attitude and orbit control system (AOCS)
Passive control technique, Active control technique, sensors and actuators.
- Thermal
Environment characterization; single mass isothermal modelization, coarse thermal analysis.
- Communications
Fundamentals, communication links, ground stations.
Some typical architectures: the simple spinner, dynamics and stability; the dual spinner, dynamics and stability, Landon’s rule; the tether system.
References: Charles D. Brown, “Elements of spacecraft design” AIAA Education Series.

DYNAMICS AND CONTROL OF SPACE STRUCTURES (1st period, Prof. Paolo Gasbarri)

The course deals with the problem of modeling flexible structures and the related problems related to their control in the space environment. The basic principles of structural dynamics for space-continuous and discrete systems will be recalled. Particular attention will be devoted to modeling the effects of gravitational forces on the dynamics and micro dynamics of large flexible structures. The course will study the concepts of advanced modeling using multibody techniques. Lagrangian and quasi-Lagrangian formulations will be presented and compared with Newtonian approaches. During the course techniques for active and adaptive control of vibrations will be studied. Hand notes will provided by the teacher during the course.

ELECTRICAL POWER SYSTEMS FOR SPACE EXPLORATION (2nd period, Prof. Luigi Schirone)

The course is intended to provide advanced knowledge about Electrical Power Systems in satellite and other space vehicles. Information about operating principles, constraints arising form space environment and peculiar design techniques are provided for the most common approaches used in space vehicles for power generation, storage and management.
For further information please visit https://sites.google.com/uniroma1.it/luigischirone-eng/home

ELECTRONICS FOR SPACE TELECOMMUNICATION SYSTEMS (2nd period, Prof. Augusto Nascetti)

The aim of the course is to introduce the students to the design of a satellite link. Starting from the basic concepts of analog (AM, FM) and digital (ASK, FSK, PSK) modulations, the course analyzes the performances of the different techniques with respect to the noise. FDMA, TDMA and CDMA multiple access techniques are presented. System-level aspects of satellite links (Doppler, range, visibility, atmospheric effects, etc.) are analyzed and the link equation is discussed in detail. Finally, the link design process is described, and several examples are given. During the course, practical sessions in the Ground Station of the School of Aerospace Engineering will be arranged to show the reception and decoding of the signals from amateur satellites in low Earth orbit.

FLIGHT MECHANICS OF LAUNCH AND REENTRY SYSTEMS (1st period, Prof. Paolo Teofilatto)

Launch toward East: advantages. The ECI Frame and orbital parameters (target conditions). The EFI frame and the Launch site equation. Launch windows. Launch sites. Launch systems from movable platform. Tsiolkovsky Formula. Single stage to orbit ? Optimal Staging.
Planar equation of motion and Losses Equation. Gravity losses. Phases of flight. Stage re-entry and dispersion ellipses.
General equation of flight. Ballistic Reentry. Peak of heat and peak of load. Entry corridor evaluation. Entry with lift. Entry Capsule control.
The Flat Earth approximation.
The SCOUT launcher. Engines and actuators. Aerodynamic data. Stage separation. Q-Guidance.
ICBM re-entry.
CHASER: AIM-9X Sidewinder Aerodynamic stability derivatives from A11, actuator (canard fin deflection) and sensors (acceleration and rate gyro)
Interception Algos: Pure Pursuit (PP) guidance. Interception Algos: Collision Triangle and Proportional Navigation (PN) guidance. Interception Algos: Augmented Proportional Navigation (APN guidance). CHASER: Short period dynamics @ two different combat scenarios.
(topics in italic are additional ones, mandatory for students following MBDA course)

FUNDAMENTALS OF ELECTRONICS (2nd period, Prof. Augusto Nascetti)

Starting from a general introduction to electronic systems the course will provide the basic knowledge about analog and digital electronic circuits. The syllabus includes: basic electrical circuits; linearity, dynamic range and frequency response of electronic systems; modelling of electronic circuits; feedback theory (positive and negative feedback); main electronic devices and components (op-amp, diode, MOSFET); analog electronic circuits (amplifiers, filters, non-linear circuits); digital electronics (microcontrollers, FPGA); A/D and D/A conversion.

FUNDAMENTALS OF NUCLEAR ENGINEERING FOR ASTRONAUTICS (2nd period, instructor to be defined)

The course will provide the basics necessary to physical understanding of nuclear energy systems and radiation protection. The main objectives are (a) knowledge of benefits and key aspects of engineering, technology and safety associated with the ' nuclear energy use in space applications, (b) identification of the main features of the systems of nuclear power generation , and of the connected systems for conversion and propulsion, (c) knowledge of the state of the international research and perspectives of nuclear energy use for space applications . The Course is organized as follows:
Fundamentals: Physics of nuclear reactions: radioactive decay, sources of radiation, interaction of ionizing radiation with matter, nuclear reactions. Physics of nuclear fission: neutron flux, impact Sections, Fast neutrons and thermal neutrons, the slowdown, the moderators, the resonances of capture, burn - up. The nuclear fusion reactions. Basic concepts of radiation protection: Unit Radioactivity, dosimetry, the Environmental Radioactivity, Radiation Effects on humans, protection systems, exposure limits.
Nuclear energy for Space Applications: advantages over other energy sources. Nuclear energy generators. Engineering and technological aspects of the Space Applications of Nuclear Power: shielding of Radiation Heat Transfer, Materials. Elements of Physics Reactor. Nuclear fission reactors configurations for onboard needs and size. The Nuclear Safety in the different stages of a Space Mission. Nuclear Energy perspectives in peaceful applications.
Systems for Nuclear Power Generation and Propulsion: Classification of systems. Systems of radioisotopes. Conceptual projects of Nuclear Reactors. Static (thermoelectric and thermoionic) and Dynamic (Bryton , Rankine , Stirling , magnetohydrodynamic) conversion systems. Reactors with solid, liquid and gas kernel. Fuels. Heat tubes reactor. Electro-nuclear propulsion systems. Thermo-nuclear propulsion systems. Advanced Systems. The International Space Nuclear Programs .

HYBRID PROPULSION AND NEW LAUNCH SYSTEMS (1st period, Prof. Antonella Ingenito)

Definition of propulsion by rocket : static performance of rockets for launch to space missions ; definition of thrust and drag ; equation of motion of a rocket ; state variables and control ; constraints on the trajectory . Performance of single-stage and multistage rocket . Definition of thrust requirements for performing space missions. Definition and classification of Propellants for hybrid engines. Process Combustion : subsonic combustion . Influence of the initial conditions of the propellant . Calculation of the temperature of combustion in conditions of chemical equilibrium. Sizing and design procedures for (a) Injection system (injectors), (b) nozzle, (c) thrust chamber. New launch systems: (a) gun launch to orbit (ram accelerator and railgun), (b) launch from aircraft in subsonic flight, (c) airbreathing SSTO launch vehicles.

LAW IN SPACE ACTIVITIES (2nd period, instructor to be defined)

The course is intended to provide basic knowledge on the following topics: a) laws regulating the space activities. b) complete the knowledge acquired in the courses of engineering with the deepening of the legal regulation of the aerospace activities. The content of the course takes into account the relevant change that the law regulating the space activities underwent since the first Treaty of the United Nations (1967). The course is divided into four modules. The first concerns the basic principles governing the aerospace activities; the second module concerns the rules applicable to space applications, particularly remote sensing and satellite navigation, launching and the international space station. The third module examines the main legal and institutional issues related to space activities in cooperation between European states (EU and ESA). Finally, the fourth module deals with the development of national legislation in the field of space activities, with reference to Italy, and in a comparative perspective.

LIFE SUPPORT SYSTEMS (2nd period, Dr. Claudio Paris and Dr. Marco Sabatini)

Earth environment: ecosystem, water cycle, carbon cycle, nitrogen cycle; atmosphere; magnetosphere, radiation environment. Space environment: upper atmosphere, gravity (Earth, Moon, Mars), radiations (cosmic rays, solar particle events, Van Allen belts, different radiation levels at ISS, at the Moon, during a trip to Mars, at Mars), space debris (micrometeoroids, shielding). Effects of space environment on human body: bone loss, muscle loss, motion sickness (ear), vision problems, cardiovascular system (shift of fluids), effects of radiation: different particles, dose limits, possible risks (cancer, Alzheimer, bone loss). Countermeasures: exercises and history of exercises, radiation (dosimetry, shielding, pharmacological), immune system, psychology. History of human space exploration: from Gagarin to the ISS, ISS-related accidents and incidents and lessons learned (Apollo 1, Valentin Bondarenko, Soyuz 11, space suits, …), space exploration (Moon, Mars, unmanned/manned, travel duration). Basic of life support systems: open loop vs closed loop, budgets (air, O2, water…), physical-chemical LSS, regenerative LSS, CELSS, bioregenerative LSS, description of main subsystems: air revitalization, water management, waste management, closing the loop. Physic-Chemical Life Support Subsystems: atmosphere management (carbon dioxide reduction/removal, oxygen generation, atmosphere monitoring and control), water management (urine recovery, hygiene recovery…), waste management. The International Space Station as a case study: history of the design, description of modules, description of LSS systems. Terrestrial applications derived from LSS for spacecraft: basic ecological research, atmosphere, water and waste regeneration, biomass production and research. Space suits: history, design, LSS in the suits, pressure in the suit and procedure to donning and doffing, future space suits. Bioregenerative life support concepts: plant physiology (photosynthesis, phototropism, gravitropism), effects of microgravity, algal systems, higher plants, fungi, animals, experiments (Biosphere 2, Veggie, Melissa). Future Life Support Systems: artificial gravity, hibernation (human, animals), bioprinting, nanotech, lunar base, Martian base. Astronauts: selection and training, spaceflight operations, social and psychological effects (MARS 500), psychology of Survival (Antarctic exploration).

LOW THRUST PROPULSION (2nd period, Prof. Antonella Ingenito)

The course will provide the basics of low thrust engines: applications and classifications for chemical and electrical LTE, exothermic and endothermic engines. Thruster Principles, The Rocket Equation. Specific Impulse. Thruster Efficiency. Monopropellant cold thrusters, Bi-propellant thrusters, Resistojet. Design of small thrusters: tank design, feed systems, catalyst, thrust chamber, nozzle. Electric Propulsion Background and Electric Thruster Types, Ion Thruster Geometry. Force Transfer in Ion and Hall Thrusters. Basic Plasma Physics. Coulomb force, Electric Field, Magnetic field, Lorentz equation, Maxwell's Equations . Plasma as a Fluid: Conservation Equations. Diffusion in Partially Ionized Gases. Diffusion and Mobility Without and Across Magnetic Fields. Sheaths at the Boundaries of Plasmas: Debye Sheaths, Pre-Sheaths, Child–Langmuir Sheaths. Generalized Sheath Solution. Ion Thruster Plasma Generators. DC Discharge Ion thruster. 0-D Ring-Cusp Ion Thruster Model. Magnetic Multipole Boundaries. Electron

and Ion Confinement. Power and Energy Balance in the Discharge Chamber. rf Ion Thrusters. 2-D Computer Models of the Ion Thruster Discharge Chamber. Ion Thruster Accelerator Grids: configurations and life; Ion Optics and Perveance Limits. Electron Back-streaming. High-Voltage and Electrode Breakdown. Hollow Cathodes.
Overview and History of Airbreathing hypersonic propulsion. Airbreathing engine design and sizing for given mission requirements. Inlet, combustor and nozzle design. Rayleigh equation for heat flux in subsonic and supersonic combustion. Performance. Solid and liquid Propellants. CFD for ramjet and scramjet applications.

MODELLING OF FLEXIBLE SPACE LAUNCHERS (2nd period, Prof. Paolo Gasbarri)

The course deals with the problem of modeling the dynamic behavior of an elastic launcher. Mathematical models capable of representing the dynamic behavior of a dynamic system with mass and stiffness varying over time will be presented and discussed. The descriptive equations of a variable thrust direction elastic launcher will be derived and discussed. Hints on the coupling problems between flight mechanics, structures and aerodynamics will be presented. Modeling of sloshing phenomena within a launcher will also be studied.

NAVIGATION (1st period, Prof. Giovanni B. Palmerini)

The concept of navigation. Fixing vs. deduced reckoning. Different classes of navigation. Time and space reference frames. Reporting navigation solution: fundamentals of cartography and geodesy. Navigation in real time vs. trajectography. Navigation as an element of the Guidance-Control-Navigation loop. Effects of navigation accuracy on system performance.
Satellite-based navigation. From TRANSIT (Doppler-count) to time-of-arrival systems. Required number of satellites in view. Pseudorange, linearized solution, effects of geometry, expected budget error. GPS, GLONASS, Galileo and Beidou systems: similarities and differences. Differential navigation and augmentation systems. From code- to carrier-phase-based observables: the issue of the ambiguity in the number of cycles. Fundamentals of RTK (Real Time Kinematics) and PPP (Precision Point Positioning) techniques. GNSS applications to land, air and space navigation. GPS experiments with lab's test bed.
Inertial Navigation. Stable platforms and strap-down architectures. Accelerometers and gyroscopes. *MEMS sensors. MEMS advantages and limitations. Performance of current MEMS sensors. Sensors' tests. Calibration and Alignment.* Optical gyros. Attitude reconstruction (cosine direction matrix, Euler angles, quaternions). Mechanizations. Instability of the gravity loop. Linearization of navigation equations' set. Errors.
Visual-based navigation. Feature recognition and Hough transform techniques. Experiments with lab's test bed.
Integrated navigation. Kalman filter. Proof of the optimality of the linear filter. Extended Kalman Filter (EKF) for non-linear process and/or non-linear observations. Examples and exercises. Insights about "beyond-Kalman" modern filtering techniques.
(topics in italic are additional ones, mandatory for students following MBDA course)

NUMERICAL MODELING OF SPACE STRUCTURES (1st period, Dr. Claudio Paris)

The design of astronautic structures is always a trade-off between weight, complexity, manufacturing cost and the ability of withstanding the loads during the launch and the operational life. One of the most powerful and commonly used tools for the structural design is the Finite Element Method (FEM). In the School of Aerospace Engineering FEM analysis is used for modeling the structure of small satellites and their payloads (such as CubeSats), and also for bigger structures (such as antennas, or separation systems such as the one developed for the LARES mission. The course will discuss the most common design techniques for space structures using statics and dynamics FEM analysis. Practical examples using FEM software will be presented to better understand specific problems. The course is focused on the following topics: Stress and strain state around a generic point by continuum mechanics theory, Use of most common software for pre and post processing in structural mechanics, Specific design techniques for space structures, Theory of Finite element analysis: static and dynamics, Practical Finite element analysis with freeware software.

OPTIMAL CONTROL AND GAME THEORY IN FLIGHT MECHANICS (2nd period, Dr. Stefano Carletta)

The course of Optimal Control and Game Theory in Flight Mechanics aims at providing sophisticate theoretical and numerical tools for the design of advanced aerospace missions and operations. Relevant study cases selected from real mission scenarios will be simulated using GMAT, Matlab/Simulink software. The course is organized as follows:

(1) Theoretical background and introduction to optimal control: The basic concepts of astrodynamics and flight mechanics are reviewed. Emphasis is given to the mathematical and technical tools which will be used during the following classes.
(2) Optimal rocket trajectories and control: The problem of optimal control is introduced considering applications on rocket moving in the atmosphere. The module covers: optimal solutions to the problem of orbit injection (with impulsive and continuous thrust, staging and constrained performance of the actuators), optimal pitch control, optimal staging and sub-optimal guidance suitable for real-time implementation. Several guidance laws are compared together with numerical methods to solve the optimization problem. Exact and numerical solutions are discussed, providing the student the knowledge to apply the most appropriate one depending on the operative scenario under investigation.
(3) Optimal orbital maneuvers: The problem of orbital transfer in the presence of perturbations and in the multi-body environment is studied. The characterization of low-energy trajectories existing in such a dynamical framework is presented and optimal guidance strategies for low-thrust transit and ballistic captures are developed. At the end of this block, the students will manage advanced tools for designing modern low-energy / low-thrust missions.
(4) Dynamic game theory in flight mechanics: Dynamic game theory is introduced to investigate the motion of two noncooperative space vehicles. A variety of scenarios, including operations between two spacecraft in proximity (space) and missile interception (atmosphere), are modeled as zero-sum dynamic games. Numerical solutions for the mentioned scenario are discussed, introducing the students to the problem of optimization in multi-spacecraft environment.

Relevant study cases selected from real mission scenarios will be simulated using GMAT, Matlab/Simulink software.

ORBIT DETERMINATION (2nd period, Dr. Emiliano Ortore)

Orbital observation. Visual and radiofrequency observables, and relevant instrumentation required. Reference frames and time scale. A reminder of the orbital dynamics. Orbital parameters and their relation with kinematic parameters. Classical problems in orbit determination (Gibbs, Laplace, Lambert). Orbit representation: Two-Line Elements (TLE). Orbit determination in LEO and GEO. Ground-based and on-board orbit determination. GNSS-based and image-based orbit determination. Applications to lunar missions. Tracking of deep-space probes. Surveillance networks.

RADAR SYSTEMS FOR ASTRONAUTICS (2nd period, Prof. Giovanni Laneve)

1 – RADAR as a Remote Sensing technology: micro-wave systems introduction, scattering characteristics, radar equation.
2 – Synthetic Aperture RADAR (SAR): the mathematical basis for SAR, RADAR resolution cell.
3 – Geometry distortion.
4 – Radiometric Calibration
5 – Image Interpretation: acquisition mode, speckle, image processing.
6 – Applications: Altimeter, interferometry, radargrammetry, etc.

ROBOTICS AND ARTIFICIAL INTELLIGENCE IN SPACE ENGINEERING (1st period, Dr. Dario Spiller)

The course is mainly divided into three parts:
Part I: Elements of robotics. The basic elements of Robotics are explained by referring to the manipulator, i.e., the kinematics along with the Denavit-Hartenberg parameters and the homogeneous roto-translation representation, the differential kinematics, the statics, and the dynamics. Moreover, the trajectory planning will be considered by using both traditional methods and advanced methods based on meta-heuristic optimization (e.g., the Particle Swarm Optimization). All the previous elements will be used to introduce some basic control algorithms.
Part II: Elements of Artificial Intelligence and Machine Learning. The basic elements of artificial intelligence and machine learning are explained, and examples related both to robotics and space exploration will be considered. Specifically, some basic elements for dealing with collection and pre-processing of data will be discussed. Then, simple algorithms from machine learning will be addressed, such as the random forest or the support vector machines. Convolutional neural networks will be described, also taking into account the possibility to put such algorithm on-board for autonomous satellites. Innovative recognition and "detection" algorithms on neural networks and/or on features extraction and latest generation matching techniques on EO / IR and SAR images. Examples dealing with remote sensing and space exploration will be shown. Finally, GAN architectures will be presented.
Part III: New algorithms for navigation of space systems based on AI. Starting from optical and infrared mavigation, sensor errors, as aberration, boresight, noise input, will be discussed, in order to explain elements of optical and infrared

tracking systems (e.g., missile seekers). Finally, AI image enhancement algorithms to increase the performance of an electro-optical sensor and algorithms for super-resolving the image / object with single will be described.

SATELLITE REMOTE SENSING: ACQUISITION SYSTEMS AND DATA PROCESSING METHODS
(2nd period, Prof. Giovanni Laneve and Dr. Emiliano Ortore)

Cap. 1 - Generalities on the remote sensing and physics principles. Introduction, remote sensing system, Properties of the electromagnetic radiations, source of the electromagnetic radiation, Interaction with matter, remote sensing indicators, Interaction of the electromagnetic radiation and the terrestrial atmosphere – – Equation of the radiative transport (RTE) – Estimate of the surface temperature. Description of the General Split Window Technique, using the thermal emission for estimating the sub-surface characteristics. Appendices: A – Beer law, scattering, absorption bands, refraction, surface backscattering, B – Description of the General Split Window Technique, C – Using the thermal emission for estimating the sub-surface characteristics. Exercises: Software PclnWin e PCModWin.
Cap. 2 - Remote sensing sensors. Photographic & electro-optical sensors. Micro-wave systems (active and passive), Lidar. Calibration techniques.
Cap. 3 – The remote sensing and the space environment. The terrestrial upper-atmosphere – the San Marco satellites data. The Space Debris – Techniques for the observation and monitoring. The atmosphere of the outer planets (Mercury, Venus, Mars, the giant planets).
Cap. 4 – Principle of remote sensing of the terrestrial atmosphere. Atmosphere sounding. Satellite based measurement of the atmospheric ozone. Occultation techniques with active systems.
Cap. 5 – Remote sensing orbits. Orbit properties. Orbit perturbations. The requirements of the orbits for remote sensing. Ground tracks. Remote sensing satellite constellations. Exercises: Software STK, Matlab Orbital Mechanics.
Remote sensing systems (Landsat, SPOT, NOAA, Sentinel, MSG). Appendices: A – Drift of the orbit operational parameters, B – Computation of the acquisition times at the ground station, C – Design of an orbit crossing a given station at a given crossing time. Tutorial: Software STK, Matlab Orbital Mechanics.
Cap. 6 – Acquisition systems and satellite images pre-processing. Ground receiving station, Image re-construction, enhancement and information extraction. Image registration. Map projection. Appendices: A - pixel Geo-location, B – Statistical analysis and enhancement of the images (Discrete Fourier Transform applied to the images, Wavelet, Principal Components, Maximum auto-correlation factors, MAF). Tutorial: Software ENVI, MATLAB Image Processing tool.
Cap. 7 – Theory and practices of image processing. Selection of the classification algorithms (Unsupervised and Supervised classification). Topographic models. Image registration (Ground Control Points, Mutual Information, invariant moments, contour matching). Change detection (algebraic methods, Multivariational Alteration Detection, MAD). Introduction to the processing of hyperspectral images (Modeling the measurements, linear un-mixing, pure pixels). Object recognition (Mathematic Morphology, Hough Transform). Tutorial: Software ENVI, Arcview, Image Processing tool di MATLAB.
Cap. 8 – Project of a Remote Sensing Sensor.

SPACECRAFT CONTROL (2nd period, Prof. Fabio Celani)

Main aim of this course is to introduce students to basic methods to control the attitude of a spacecraft. Basic tools for analysis and design of control systems will be introduced and applied to spacecraft attitude control.
For further information please visit https://sites.google.com/a/uniroma1.it/fabiocelani_eng/teaching/sc

SPACE TECHNOLOGY (2nd period, Prof. Antonio Paolozzi)

Technology and science are usually considered distinct disciplines. In this Course it will be shown that science is a key ingredient for developing new techniques and conversely technology is important for modern science to make new discoveries. Particular emphasis will be given to space missions and high energy physics experiment where aerospace materials are often used because of their high mechanical characteristics. Another part of the course is devoted to the technology of composite materials and to non destructive testing. The content of the Course includes : Use of non destructive testing for checking structural integrity of space structures manufactured in metallic and composite materials, Holographic interferometry as a non destructive technique, Practical problems of space missions from the structural and technological point of view (satellites, interplanetary probes and international space station) through real cases of space missions in which the School of Aerospace Engineering has been fully involved.

THEORY AND OPERATIONS OF FORMATION FLYING (1st period, Dr. Marco Sabatini)

Introduction (current and future missions involving formation flying). Linear circular keplerian case (Hill-Clohessy-Wiltshire equations, curvilinear vs Cartesian coordinates; periodicity). Linear elliptic keplerian case (Tschauner-Hempel, Melton, Yamanaka equations; periodicity). Mission to a comet with highly elliptic orbit and residual gravitational field. Linear circular perturbed case (J2 effect and special inclinations, drag effect, advanced linear models). Nonlinear dynamics (Newton approach, Lagrange approach, energy matching). Relative motions in terms of differential orbital elements. Relative attitude dynamics. Formation flying control (LQR, discrete LQR, PWM, impulsive, artificial potential). Formation flying navigation (RF, GPS, laser ranging, visual navigation). A case of formation flying: remote sensing missions. Orbital configuration. Lazy and tight formations. Rendezvous. The phases of a rendezvous mission. Approach safety and collision avoidance. The drivers for the approach strategy (location and direction of target capture, range of sensors, Sun illumination, communication windows). Docking. Mating systems. Special features of the GNC system for rendezvous and docking (mode sequencing and equipment engagement, fault identification and recovery concepts, remote interaction with the automatic system, automatic GNC system with man-in-the-loop). Special cases of formation flying. Tethered formations and space webs. Swarms of spacecraft.

THERMAL CONTROL AND THERMOMECHANICAL INTERACTIONS IN SPACE VEHICLES
(1st period, Prof. Maurizio Parisse and Dr. Federica Angeletti)

Fundamentals of calorimetry, postulate and equation of Fourier, main conduction parameters. Radiative heat transfer: laws of Planck, Wien, Stefann-Boltzmann, Lambert. Characterization of the space environment from a thermal point of view. The main radiative sources: the Sun, the Earth, the Albedo. Thermal modelization of the spacecraft. Thermal balance equations. Propulsion effects of the radiation: the solar sail.
General introduction to the interaction problems in space; historical review. Weak and full interaction and related description. One–way static and dynamic coupling, key parameters governing the phenomenon; examples. Two-ways static and dynamic coupling; integrated modelization of the space systems; examples. Thermal flutter and divergence; numerical approach to the solution. Review of some remarkable occurrences of thermally induced disturbances onboard of satellites; physical and mathematical description.
References: Robert D. Karam “Satellite Thermal Control for System Engineers”, Progress in Astronautics and Aeronautics.