Bachelor's Degree in Space Technologies

EETAC-UPC-BarcelonaTECH

Aprovat per la Junta d'Escola de l'EETAC el 11 d'octubre de 2017

1. Motivation

1.1 *Societal benefits*:

Space, for its economic, societal, and security applications will be (is, in fact) a key technological issue for countries, companies and international organizations. Nevertheless, in many arenas (political, industrial, societal), Space is still identified as a future endeavour with a limited impact on current, real economy. Nothing can be further from reality: in the near future, we will see a tremendous increase in space applications (in all areas, from science to communications) and of its economic outcomes.

To obtain all the benefits arising from space technologies and applications, it is essential to have a well-prepared, motivated workforce with ample knowledge of all aspects of space engineering and technologies, as well as of its applications and its effects on the society.

1.2 *Closing the cycle of space studies at the UPC*:

This document presents the scheme for a Bachelor's Degree in Space Technologies, completely taught in English at the School of Telecommunications and Aerospace Engineering of Castelldefels (EETAC) of UPC (Universitat Politècnica de Catalunya – BarcelonaTech). Its inclusion in the study plans of our university will complete the whole academic chain on this topic, starting with these proposed degree studies, following with a master (Master in Aerospace Science and Technology, MAST), up to a doctorate program (Doctorate on Aerospace Science and Technology, DoCTA); both, the MAST and the DoCTA are already existing academic programs. This structure will give a great self-consistency to our study plans, then resulting in the integral formation of our students.

A search shows that there is but a small number of universities around the world offering similar undergraduate degrees (see annex 1), and so these studies would be almost devoid of any competition. This, as well as offering the degree completely in English, could allow us to recruit students of any origin (but probably mainly from Europe).

These studies will potentially be very attracting to prospective students. Space technology, by its state-of-the-art component, and because of its pioneering and exploration character, brings a wealth of promise to future generations.

1.3 *Technological environment*:

The EETAC is very well-suited to host these studies in the Barcelona area. In the same campus there is an ESA Business Incubator Centre that could benefit from batches of young space engineers (and the degree will benefit of the presence of early-stage space applications companies in the campus). It seems natural that synergies should appear by the presence in the same campus of this cluster of young, dynamic companies and the proposed degree in Space Technologies.

2. Study plan

2.1 *Benchmarking with other similar studies*

We have analysed the study plans of similar degrees (mainly the *Astronautics Degree* of the University of Southern California, and the *Master of Space Studies* of the International Space University), the reference books on the subject (listed in the bibliography), and have consulted with several experts to identify the needs and subjects relevant to this degree (a complete list of experts can be found at the end of this document).

In the study plan, each topic is followed by a figure that gives the number of 25-hours blocks devoted to it (divided into 10 hours of teaching and 15 hours of student's individual work; that is a European Credit Transfer System, or ECTS, credit).

2.2 *Study plan*

The study plan –completely adapted to the European Higher Education Space scenario– is divided into thematic blocks: the first two blocks, spanning four semesters (1A, 1B, 2A, and 2B), are centred in the scientific and mathematical foundations of the discipline, as well as including a few subjects introducing some topics specific to space engineering.

The third block (fifth and sixth semesters, 3A and 3B) deals with an advanced study on the technologies and subsystems found on board satellites (which will already have been introduced in the subject *Spacecraft Systems Engineering* taught in the third semester). All the subsystems and the means to go beyond the atmosphere (*Rockets and Launchers*) are dealt with in this block.

Finally, the last block of two semesters (4A and 4B) focuses on the applications of space, a description of the Ground and User Segment, and mission design (*Mission Analysis and Design*), together with a Final Degree Thesis which is a requirement to obtain the degree. The Final Degree Thesis has a work-load of 18 ECTS, and the goal would be to have most of our students performing professional-academic works in close collaboration with international companies and/or research centres.

The subjects marked in blue will be coordinating the CDIO project for its semester (see section 3.2). Part of the grade (up to a 25%, but yet to be determined) of the subject will be directly related to the CDIO project.

First year (Basic Science)
CDIO Project: CanSat

1A Semester

- **Introduction to Space** (6 ECTS)
    - Short history of space exploration
    - Types of orbits and their applications
        - Geometry of conic curves
        - Orbital elements
    - Space environment
    - Rockets and launchers
        - Tsiolkovsky's equation. Stage rockets
        - Fuel families
    - Satellite subsystems
        - Structure
        - Attitude determination and control
        - Propulsion
        - On board data handling
        - Thermal control
        - Communications
        - Electric Power
        - Tracking, Telemetry and Command
    - Satellite applications
        - Earth observation and meteorology
        - Telecommunications
        - GNSS
        - Science from space
        - Technology testing

- **Calculus** (6 ECTS)
    - Real and complex numbers. Elementary functions.
    - Differential and integral calculus in single variable functions.
    - Series of numbers. Convergence criteria. Power series.
    - Differential and integral calculus in several variables functions.
    - Inverse and implicit functions. Coordinate systems and changes of variable.
    - Curves and surfaces. Parametrizations. Determination of longitudes and areas.
    - Differential operators. Stokes and Gauss Theorems. Conservative and solenoidal fields.

- **Algebra** (6 ECTS)
    - Vector spaces. Linear applications. Diagonalization.
    - Differential equations and linear systems with constant coefficients. Properties and solutions.
    - Affine and Euclidean spaces. Orthogonality. Orthonormal bases. Gram-Schmidt method. Metric problems.
    - Scalar and vector fields.

- **Computer Science** (6 ECTS)
    - Hardware description
    - Linux and Windows Operating systems
    - Functional programming (e. g. Matlab), and procedural programming (e.g. C)
    - Programming environments
    - Introduction to software engineering

- **Physics** (6 ECTS)
    - Kinematics and dynamics of point-like masses.
    - Newton's principles.
    - Gravitational force. Friction force. Hooke's force.
    - Work and energy.
    - Dynamics of a system of particles. Linear and angular momentum.
    - Fundamentals of the Physics of Fluids.
    - Waves: characteristics and basic properties. Transversal and longitudinal waves. Wave equation.
    - Reflexion, refraction and diffraction. Doppler effect.
    - Superposition and stationary waves. Interference. Dispersion. Group velocity.
    - Fundamentals of Thermodynamics.
    - Coulomb force, electrical charge and electrostatic field.
    - Electric potential.
    - Electrostatic energy. Capacity.
    - Electric current.
    - Magnetic field. Sources of magnetic field.
    - Magnetic induction.
    - Maxwell Equations.

1B Semester

- **Classical Mechanics** (6 ECTS)
  - Rotation of coordinate axis. Rigid solid statics, kinematics and dynamics. Inertia tensor.
  - Introduction to analytic mechanics: Lagrange equations.
  - Mechanical oscillations. Normal modes. Equilibrium stability.
  - Introduction to statics of deformable solids and elasticity.

- **Thermodynamics** (6 ECTS)
  - Temperature and dilatation
  - Ideal and real gases. Equations of state.
  - Zeroth Principle.
  - Mechanisms of heat propagation.
  - First principle. Conservation de la Energy.
  - Segundo principle. Entropy and disorder.
  - Introduction to propulsion systems.
  - Kinetics theory of gases. Maxwell-Boltzmann distribution

- **Advanced Mathematics** (6 ECTS)
  - First order ordinary differential equations. Cauchy problem. Resolution of elementary differential equations.
  - Existence and unicity of solutions. Higher order equations.
  - ODE and linear systems. Laplace transform.
  - Resolution by series. Orthogonal polynomials.
  - Fourier series. Fourier transform.
  - Complex variable functions. Cauchy-Riemann equations. Integration and Cauchy theorem. Residuals.
  - Partial derivatives equations. Classification.
  - First order equations. Method of characteristics.
  - Second order equations. Variable separation.
  - Calculus of variations. Euler-Lagrange equations.

- **Probability and Statistics** (6 ECTS)
  - Probability.
  - Random variables.
  - Stochastic processes. Monte Carlo methods.
  - Statistics.

- **Chemistry (6** ECTS**)**
  - Properties of the elements. Atoms, atomic structure and bonds.
  - Periodic table of elements

- Atomic numbers, electronic and atomic structure
- Periodic properties
- Classification of bonds
- Crystalline structure, imperfections in solids and diffusion.
- Crystalline systems and structures
- Crystallographic directions and planes
- Point defects
- Imperfections
- Diffusion phenomena and mechanisms
- Temperature dependence of diffusion
- Solid solutions. Phase diagrams. Alloys
- Compounds
- Acids and bases
- Reactions and chemical equilibrium. Electrochemistry
- Redox reactions
- Cell potential
- Free energy and electric work
- Electrochemical processes in batteries
- Corrosion. Corrosive and antioxidant agents
- Dissolutions. Polar and non-polar compounds
- Basic organic chemistry
- Combustion
- Reaction mechanisms
- Chemical kinetics
- Chain reactions. Explosions
- Dependence of reaction velocity with temperature
- Combustion. Examples of combustion on rocket engines
- Materials: alloys and composites

Second year

2A Semester

- **Electromagnetism** (6 ECTS)
  - Sources of electric field
  - Dielectric media
  - Conductive media
  - Sources of electromagnetic field
  - Magnetic media
  - Electromagnetic waves

- **Numerical Methods** (6 ECTS)
  - Numerical linear algebra.
  - Systems of linear equations.
  - Numerical methods for partial differential equations.
  - Finite differences methods.
  - Optimization techniques.

- **Electric Systems** (6 ECTS)
  - Circuit analysis in DC and AC
  - Transformation. Regulated and non-regulated buses
  - Electric power generation. Primary and secondary batteries. Solar cells. Fuel cells

- **Theory of Structures** (6 ECTS)
  - Analysis de structures:
    - Basic structures
    - Isostatic and hyperstatic systems
    - Analysis of isostatic triangulated structures: knots method; sections method
    - Analysis of hyperstatic reticulated structures: Cross method; rigidity matrix method
    - Introduction to finite elements method
    - Buckling of slender, compressed parts: Euler formulation
    - Structural security: Method of limit states
    - Determination de stresses on structures

- **Space Environment** (6 ECTS)
  - Neutral environment: the high atmosphere
  - Ionized environment: plasma in LEO
  - Terrestrial magnetic field
  - Van Allen belts
  - Meteoroids and space debris
  - Lunar and Martian environment
  - Interplanetary environment
  - Other solar system environments

2B Semester

- **Electronics I** (6 ECTS)
  - Basic concepts. Kirchoff laws, Joule's law
  - Electronic devices: diode, transistor, oscillators
  - AD & DA Converters. Sampling Process
    - Types,
    - Sampling process: Noise, Nyquist, antialising filter

        - Signal reconstruction, interpolation
    - Analog Signal Processing (Low Frequency)
        - Filters
        - Amplifiers
        - Noise, distortion
    - RF Systems (High Frequency)
        - Parameters, Noise, Distortion
    - LASER systems
        - Optical Transmitter: LASER.
        - Optimal detection: Photodiode

- **Astrodynamics and Orbital Mechanics** (6 ECTS)
    - Equations of motion. Two and three body problems.
    - Kepler equation.
    - Coordinate and time reference systems
    - Orbit determination. Lambert problem.
    - Orbital manoeuvers.
    - Launch windows.
    - Perturbations.

- **Systems Engineering** (6 ECTS)
    - Systems design
        - Stakeholders expectations
        - Technical requirements
        - Logical decomposition of complex systems
    - Product realization
        - Product implementation
        - Product integration
        - Product verification
        - Product validation
        - Product transition
    - Technical project management
        - Technical planning
        - Requirement management
        - Technical risks management
        - Technical data management
        - Effective documentation
        - Technical assessment
        - Decision analysis
    - Optimization
    - Simulation
    - Life cycle analysis

- **Fluid Mechanics** (6 ECTS)
    - Continuous media. Fluids properties.
    - Fluid Statics.
    - Integral form of the conservation laws.
    - Differential form of the conservation laws.
    - Potential flows.
    - Dimensional analysis.
    - Compressible flow.
    - Viscous flow.

- **Signal Processing** (6 ECTS)
    - Laplace Transform. Transfer function. Stability
    - Fourier Transform. Frequency response.
    - Sampling. Digitized signal.
    - Z-Transform. Transfer function. Stability
    - Discrete Fourier Transform. Frequency response.
    - Digital filters.

Third year

3A Semester

- **Electronics II** (6 ECTS)
    - Sensors and transducers
    - RF Front-End
    - Digital Systems
    - Boole algebra, logic gates, state machines
    - Programmable electronic systems:
        - Microprocessors and microcontrollers
        - DSPs
        - FPGA

- **Rockets and Launchers** (6 ECTS)
    - Tsiolkovsky's equation. Delta V. specific impulse. Ejection velocity.
    - Rocket engines: combustion chamber, nozzles.
    - Types of rocket engines:
        - Solid rockets: fuels, grain and port geometry.
        - Liquid rockets: pressure fed vs. pump-fed; non-cryogenic vs. cryogenic propellants; monopropellants vs. bipropellants; non-hypergolic vs. hypergolic propellants.
        - Hybrid rockets.
    - Launch vehicles. Rocket staging.

- Launch vehicle dynamics.
- Launch environment.
- Launch bases.
- Rocket engines for space propulsion. Introduction to Grid Ion Thrusters.

- **Fundamentals of Telecommunication** (6 ECTS)
    - Introduction to Information Theory
    - Transmission channel for satellite communications
    - Sampling methodology
    - Telecom systems models
    - Digital Modulation: baseband signal, passband signal, IQ decomposition.
    - Channel Coding
    - Multiplexing and multiple access: FDMA, TDMA, CDMA, OFDMA
    - Synchronization
    - Equalization

- **Control Theory** (6 ECTS)
    - Introduction to Control Systems. Feedback Control systems.
    - Introduction to Physical System Modeling
    - Root-locus Analysis
    - Time response of feedback systems
    - Frequency Domain Analysis of Feedback Systems
    - Case study: PID Controller
    - Advanced Control Systems: Optimal and Robust

- **Spacecraft Systems Engineering** (6 ECTS)
    - Dynamics of satellites
    - Celestial mechanics and mission analysis
    - Launch vehicles
    - Satellite subsystems
    - Ground and user segment
    - Documentation management
    - Tracking, telemetry and command
    - Structure
    - Electric power
    - On board computer and data handling
    - Space propulsion

3B Semester

- **Tracking, Telemetry and Command** (3 ECTS)
    - Telemetry: data formats
    - Commands
    - Techniques and communication protocols

- **Structure subsystem** (3 ECTS)
    - Design requirements. Launch phase
    - Materials
    - Satellites configuration
    - Structural analysis
    - Mobile mechanisms. Tribology

- **Thermal Control** (3 ECTS)
    - Transport del heat: convection, conduction and radiation
    - Optical and thermal properties of materials
    - Energy balance
    - Thermal analysis
    - Passive systems
    - Active systems

- **Attitude Determination and Control** (3 ECTS)
    - Rigid solid mechanics
    - Attitude representation: Euler angles, quaternions, director cosines
    - Attitude sensors
    - Actuators
    - Control Algorithms

- **Power subsystem** (3 ECTS)
    - Electric power system functions
    - Control, Management and power distribution. Regulated, quasi-regulated and un-regulated buses
    - Primary and secondary systems
    - Batteries
    - Photovoltaic systems
    - Fuel cells
    - Nuclear systems

- **Space Propulsion** (3 ECTS)
    - Propulsion requirements: orbital manoeuvers and station-keeping
    - Cold gas propulsion. Butane-based systems.
    - Rockets de combustible solid and liquid
    - Propulsion electric

- Propulsion electrodynamics
- Solar sails

- **Communication** (3 ECTS)
  - Electromagnetic spectrum: regulation and management
  - Communication techniques: modulation, bandwidth, noise, spread spectrum, multicarrier transmissions.
  - Atmospheric effects, radio signal propogation
  - Antennas
  - Transponders
  - Transceptors
  - Link budget

- **On Board Data Handling** (3 ECTS)
  - Environments de radiation. Single Event Effects (SEUs, SELs, SEBs)
  - Communication buses
  - Rad-hard processors
  - Signal processing
  - Lossy and loss-less Compression
  - Packetization

- **Space Law and Policy** (3 ECTS)
  - International space law
    - Outer space treaty
    - The rescue agreement
    - The liability convention
    - The registration convention
    - The Moon agreement
    - Electromagnetic spectrum management: the role of ITU
  - National space law
    - EEUU
    - UE and Canada
    - China and India
  - Space policy
    - EEUU space policy
    - EU and ESA space policy
    - Other actors (Japan, China, Russia and India)
    - International cooperation
  - Space economy
    - New space economy: private business
    - governmental model

- **Aerospace Materials** (3 ECTS)
  - Introduction to steel and aluminium structures:
    - Materials properties
    - Section classification
    - Section resistance: axial force; flexing moment; combined stresses
    - Elements resistance
    - Interaction of flexing moment and axil compression
    - Soldered joints
  - Introduction to composite structures:
    - Material properties
    - Laminates
    - Delamination

Fourth year

4A Semester

- **Ground and User Segment** (6 ECTS)
  - Ground stations
  - Satellite tracking and localization
  - Flight operations system
  - User segment

- **Mission Analysis and Design** (6 ECTS)
  - Mission analysis
  - Orbit families.
  - Earth observation geometry. Swath, field of view.
  - Orbital design and maintenance.
  - Constellations.
  - Prediction of satellite observations.
  - Interplanetary orbits. Patched conic trajectories. Porkchop plots.

- **Telecom and GNSS Satellites** (6 ECTS)
  - Communication satellites
  - Management of the geostationary orbit and of the electromagnetic spectrum.
  - Link budget
  - Communication services
  - LEO communication satellites: Iridium and Globalstar
  - Global navigation satellites: GPS, Glonass, Galileo, BeiDou
  - Reference and time System. Satellite orbits and constellations.
  - Position, velocity, and time estimation
  - Navigation message

    - Multipath, selective availability

- **Scientific Satellites** (6 ECTS) (includes Remote Sensing)
    - Passive sensors
    - Pixel and resolution. Swath. Revisit time
    - Multispectral observations. Cover identification and ground truth
    - Multispectral indices
    - Active sensors: radar and lidar. Synthetic aperture radar
    - Meteorological Satellites
    - Astronomical satellites. Atmospheric effects
    - Satellites for geology
    - Satellites for biology

- **Elective topics, including professional practices** (6 ECTS)

4B Semester

- **Elective topics, including professional practices** (12 ECTS)

- **Bachelor Thesis** (18 ECTS)

1A	Physics (6)	Calculus (6)	Algebra (6)	Introduction to Space (6)	Computer Science (6)
1B	Classical Mechanics (6)	Thermodynamics (6)	Advanced Mathematics (6)	Probability and Statistics (6)	Chemistry (6)
2A	Electromagnetism (6)	Numerical Methods (6)	Electric Systems (6)	Theory of Structures (6)	Space Environment (6)
2B	Electronics I (6)	Astrodynamics & Orbital Mechanics (6)	Systems Engineering (6)	Fluid Mechanics (6)	Signal Processing (6)
3A	Electronics II (6)	Rockets and Launchers (6)	Spacecraft Systems Engineering (6)	Fundamentals of Telecommuni-cations (6)	Control (6)
3B	Tracking, Telemetry and Command (3)	Thermal Control (3)	Power Subsystem (3)	Structure Subsystem (3)	Space Propulsion (3)
	On Board Data Handling (3)	Attitude Determination and Control (3)	Communications (3)	Space Materials (3)	Space Law (3)
4A	Ground and User Segment (6)	Mission Analysis and Design (6)	Telecommunica-tions and GNSS Satellites (6)	Scientific Satellites (6)	Elective Topics (6)
4B	Elective Topics/Professional practices (12)		Thesis (18)		

Basic Science

Specific Topics

Subsystems

For all the space–related topics, the use of existing standards (as, for example, those defined by the ECSS[1]) would be mandatory. In this way, the topics will have a direct touch with the reality of space industrial processes.

Based on their relevance for this degree, we have identified several elective subjects that could be taught in the degree. To be consistent with the 18 ECTS devoted to elective topics, as well as with their distribution among two different semesters, these topics should be of 3, 4.5 or 6 ECTS. The topics marked with an asterisk could be taught by professors currently at the EETAC:

[1] European Cooperation for Space Standardization (www.ecss.nl)

- Finite Element Methods
- Small satellites *
- Computational Fluid Dynamics *
- Digital Systems *
- Computer Aided Design *
- Astronomy and Astrophysics*
- Advanced materials
- Technical writing
- Planetary Sciences
- Astrobiology *
- Introductory Biology (ESAB *)
- Microgravity Sciences *
- Telemedicine *
- Rocket Propulsion
- Advanced Propulsion Systems
- Space Robotics *
- Space Astronomy *
- Technical Writing
- Nanotechnology *
- MEMS Systems *
- Space Business
- Space Policy
- Space Law
- Life Support Systems
- Product Assurance and Quality
- Computer Networks *
- Entrepreneurship and Innovation
- Sustainability *

This list is not complete and should be considered as an indication of possible elective topics. So, it must be a dynamic list, evolving as needs arise.

3. Teaching Methodology

3.1 *Generalities*:

The teaching methodology is one of the main aspects of the Grade Studies adapted to the European Higher Education Space scenario. By its applied character, engineering calls for active learning methods through which our students will egress the studies having acquired multiple transversal capabilities.

The offer of places, in order to assure a high-quality teaching, should be limited to 50 students. This figure allows the faculty to closely follow the development of the students, that those could put into practice the acquired knowledge, and at the same time allow the school, and the UPC, to keep the cost of the studies at an acceptable level.

To implement this active teaching strategy, it will be necessary to identify small projects based on the research experience of the lecturers. This will give to the studies a clear practical basis to allow the students to obtain an honest, hands-on knowledge of the subjects and, at the same time, improve abilities like team working, efficient work organization, communication skills, and project management.

3.2 *CDIO syllabus and projects*:

We plan to employ the CDIO (Conceive, Design, Implement, and Operate) syllabus since the first semester (www.cdio.org). This learning methodology closely follows the philosophy of the *Desired Attributes of an Engineer* as stated by Boeing (http://www.boeing.com/educationrelations/attributes.html). Hence, the aforementioned hands-on abilities (as well as systems analysis) become mandatory.

For the first and second semester *CanSats* are an excellent introduction for our students in the design process of a very simple “satellite”, and into topics related to electronics, telemetry, and control. These *CanSats* will be launched to a high altitude using meteorological balloons (to test their behavior in rather extreme conditions). The design and erection of a small hardware-based ground station would also be interesting, but it does not seem as a repeatable project. Students can also design a software-based ground station (using, for example, GNU radio and a cheap hardware, such as Raspberry Pi), and keep it as personal equipment.

In advanced semesters (starting in the third or fourth semester), CDIO would be more and more employed, culminating in the fifth to eighth semesters in which the students would participate in the design, construction, test, and operation of a *CubeSat* (or a comparable picosatellite, like the newer and still smaller *PocketQubes*). The cost associated with such a project is quite significant, and so it would be very important to have the commitment of private companies to get the necessary funds in the long term (as this should not be just a single project, but repeated for each group of students). As a benefit for participating companies, some of their products and devices will be used in the satellite, thus allowing new products to increase its TRL[2]. Employing COTS (Commercial-Off-The-Shelf) parts instead of space qualified devices would greatly reduce the cost of the total system.

If the funds prove to be beyond our reach, there exists the more economical alternative to using laboratory simulators, like EyasSat, that allow the students to understand the functioning of satellites with non-space [3]qualified hardware. The different modules are completely functional and can be studied and used as if it were a real picosatellite subsystem. In any case, satellite simulator systems –perhaps developed in-house– would be a very valuable asset for the teaching of many topics, and should be a part of our laboratories.

Another interesting possibility would be to design and implement a Concurrent Design Facility (CDF). This CDF would be further used to generate phase A studies of new satellite concepts, and could also be used for collaborations and/or contracts with companies and research centres.

We should also take advantage of several international, student-oriented space projects, as were projects like SSETI and EMSO (both lead by ESA), in which our students could acquire experience. Our access to NASA-led projects for students is much more limited as usually the participating institutions must be US-based. However, occasionally the rules accept foreign members in teams lead by a US educational institution.

Another possibility is to provide facilities for model rocketry. This would enhance the knowledge of our students in chemistry, thermodynamics, fluid dynamics, structures… but rockets are often related to hazardous procedures and materials. A final decision will be taken after a thorough security analysis.

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[2] Technology Readiness Level (https://www.nasa.gov/content/technology-readiness-level/)

[3] http://www.eyassat.com

3.3 *Creativity spaces*:

To favour creativity in the CDIO projects (or any other kind of project in which our students are involved) we plan to destiny some equipment and spaces to allow a creative space. In particular, we envision two different kinds of project rooms:

- Shipshape spaces (especially labs, but also some lecture rooms, as well as the library), and
- Creative spaces (lecture rooms and some labs to develop, fabricate, and test hardware).

All these spaces will be equipped with a set of modern computers with access to the required software. Also some standard material (blackboards, post-its, printers, simple 3D printers, to cite a few) will also be available.

3.4 *Other considerations*:

Students will be asked (on a voluntary basis) to improve Wikipedia entries of the topics they are getting. The request will be at the beginning of the topic, but once accepted it will become mandatory, and the result will be evaluated by professors as well as by external experts.

We also plan a substantial collaboration with developing countries institutions in order to contribute to sustainable development issues. This plan, however, is still in its very early development phase.

4. Collaboration with companies and research institutions

4.1 *Relations between university and private companies*

For us, it is of paramount importance to develop collaboration agreements with national and international companies, space agencies, research centres, and other universities.

Universities are focused on basic research (its traditional orientation) as well as in the solution of specific problems of interdisciplinary nature, and of immediate (or mid-term) interest for society and companies. In this sense, the space industry is one of the great actors that will allow the analysis of problems like climatic change, environmental conservation, and the development of more efficient technologies, among other subjects. Hence, it would be highly desirable to have young engineers with excellent capacities in space engineering, as they can become a force multiplier for many different kinds of industries in the near or mid-term future.

The implication of European companies is completely essential for the success of this project, as many of our students will get a job on them; we also expect them to provide indications of their needs and their views on future space developments. On the other hand, the existence of a group of young, talented engineers with solid grounds in space disciplines should conform in itself an innovation engine that corporations should take profit of.

4.2 *Collaborations in research and development*

It must also be taken into account that most companies are risk-averse, and would not easily engage on high-risk, high-potential research topics. In this regard, our institution could adopt the role of pathfinders for complex, state-of-the-art applications and developments in space technologies, in close contact with industries and other research institutions.

This kind of studies could give rise to spin-offs following the model of *Surrey Satellite Technologies* or, on a more realistic scale for the short-term small companies focused in the nano and picosatellite market. These technological spin-offs are one of the preferred models for long-term fund-raising for universities due to the forecast of decreasing public investments.

To foster this interaction with companies, we plan to create an Industrial Advisory Panel to have an agile communication channel between the university and space companies and agencies. Their role would be to act as advisors and to help to identify needs and areas of development.

Our alumni must be our ambassadors in the companies and space agencies where they will be employed. If we give them a high-quality education, and this is in our hands, our former students can offer us in return the possibility of undertaking research and development together with their institution. In this way we can solve several of our problems. On the first hand, if the professors are involved in research and/or projects with companies, these endeavours can be used as a complement (or even instead) of the picosatellite project, improving the formation of our students. At the same time this will leverage the costs associated with the studies. On the other hand, if the projects have an associated funding this could help to finance our school. In fact, this should be one of the main resources to maintain the budget in the long term.

Obviously, to do so we will need a seed financial aid to start and upgrade facilities and laboratories that will allow us to collaborate with companies in state-of-the-art projects and missions. Our facilities must stand to the required quality level.

5. Degree associated costs

5.1 *Existing facilities*

The facilities, laboratories, and personnel required for the first two years of the Space Technologies degree are already present at the UPC. Nevertheless, it would be desirable to improve some facilities, and to give others a more space-centred flavour.

As stated before, a number of centres of our university already have some of the facilities we would need for these studies, and so the access to them is guaranteed. In particular, the NanoSat Lab (located at the ETSETB in Campus Nord) provides us an easy access to an electromagnetic shaker, a thermal vacuum chamber, Helmholtz coils, and a small ground station, as well as to general-purpose physics and electronics laboratories, among other facilities. So even the construction of a small satellite is a feasible endeavour.

We also have access to a research-quality 3D printing laboratory. Some of the 3D printers could be used just to produce mock-ups or laboratory models, while some can produce high-quality structures printed in space qualified materials.

5.2 *Required facilities and laboratory improvement*

In more advanced courses, it would be necessary to count with specific laboratories or to establish collaboration agreements with other institutions. Setting up this kind of collaborations would reduce the expenses while maintaining (even increasing) a high level of quality. By their part, the companies and research centres could start contacts with potential future employees, and students would acquire an invaluable exposition to a research or professional environment that would improve their aptitudes.

One of the most needed facility would be a cleanroom (class 8) to allow the development and construction of picosatellites or satellite subsystems. From the academic point of view, having this cleanroom would help our students to develop the required abilities to efficiently work on this class of facilities, that is very common in the aerospace industry, and would also allow the collaboration with private companies.

The creative spaces would require some budget to acquire modern, powerful computers, simple 3D printers, and specific software, among other materials. These rooms would also require some investment in consumables.

The case of software costs can be alleviated by maintaining copies in a single, central node that would act as a repository. Then, the computers in the creative and shipshape spaces could work with the required software acting as a mirror of the central computer.

5.3 *Dissemination and Marketing of the degree*

We have a powerful dissemination strategy to make the new degree well publicized. We have achieved an agreement with the SGAC (Space Generation Advisory Council, www.spacegeneration.org) to use its information channels to make the information available worldwide. To use their own words: “The **Space Generation Advisory Council** is a global non-governmental, non-profit (US 501(c)3) organisation and network which aims to represent university students and young space professionals to the United Nations, space agencies, industry, and academia”. This organization has over 4000 members in 90 countries, and National Points of Contact in 78 countries. It also maintains an effective distribution list, which could be used to spread the information about our new degree. There will be no cost for this dissemination action.

We also plan to be present (together with the UPC) in the main Education Fairs around the world, and use our own web to further publicize our space degrees (the B. Sc., as well as the master and doctorate referred to in the introduction of this document).

List of experts consulted (in alphabetical order)

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- Barnhardt, David (University of Southern California)
- Camps, Adriano (Universitat Politècnica de Catalunya)
- Crawford, Ian (Birbeck College, University of London)
- Gruntman, Michael (University of Southern California)
- Nasseri, Ali (Space Generation Advisory Council)
- Puig-Suari, Jordi (California Polytechnic University)
- Regel, Liya (Clarkson University, International Academy of Astronautics)
- Straub, Jeremy (University of North Dakota)
- Ventura Traveset, Javier (ESA Education)
- Wan, Stephanie (Space Generation Advisory Council)
- Welch, Chris (International Space University)
- Wertz, James (Microcosm; University of Southern California)

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- Wertz, J., & Larson, W., *Space Mission Analysis and Design*, Kluwer/Microcosm (1999)
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Annex I. Similar undergraduate degrees already existing

These B. Sc. Studies are comparable to the degree whose feasibility is being analysed

1. *Astronautical Engineering*. University of Southern California (USA)
2. Several B. Sc. Degrees at Samara University (Russia)
3. *Space Engineering*. York University (Canada)
4. *Astronautical Engineering*. United States Air Force Academy (USA).
5. *Astronautical Engineering*. Capitol College (USA).
6. *Space Science and Technology*. School of Astronautics, Harbin Institute of Technology (China)
7. *Rocket Technology and Cosmonautics*. Moscow Aviation Institute (Russia)
8. *Astronautics Degree*. Istanbul Technical University (Turkey)
9. *Ingeniería Spatial*. Universidad Nacional de San Martín (Argentina)