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UNIVERSITÀ DI ROMA



Space Mission Report  
Research Group of Prof. P. Gaudenzi

Activities:

1. Satellite Systems Design Procedures
2. Tactical Microsatellites Constellation
3. Cubesat technological mission
4. Cost Engineering: UML modeling
5. Mission Pre-Phase A Studies:
  - I. GEOSAT
  - II. FINGERSAT
  - III. FLORAD
  - IV. EDiM
  - V. LIRAS

References

1. D. Di Domizio and P. Gaudenzi “*A Model for Preliminary Design Procedures of Satellite Systems*” – Published on *Concurrent Engineering* 16, 2, 149-159
2. E. Lamboglia, H. Joumier, P. Gaudenzi, “*Non linear and multivariate regressions for Space Engineering parametric Cost Models*” - published on *Association for the Advancement of Cost Engineering* (AAACE, August 2008)
3. F. Carpi, A. Tralli, D. De Rossi and P. Gaudenzi, “*Martian jumping rover equipped with electroactive polymer actuators: a preliminary study*”, *IEEE Tran. On Aerospace and Electronic Systems*.
4. F. Capece, R. Cetta, A. Cecchini, L. Cosma, and P. Gaudenzi “*Cubesat Mission with technological demonstrator payload for high data-rate downlink and health monitoring*” – Symposium on “Small Satellite Systems and Services”- 31st May – 04th June 2010, Madeira (Portugal)
5. F. Capece, R. Cetta, A. Cecchini, and P. Gaudenzi “*Study on air-launched constellation of tactical micro-satellite for defense use*” – Symposium on “Small Satellite Systems and Services”- 31st May – 04th June 2010, Madeira (Portugal)
6. G. Belvedere, G. Filippazzo, C. Portelli, and P. Gaudenzi, “*UML modeling of the cost and schedule estimation of satellite subsystems in a concurrent engineering design environment*” – EuSEC 2010, 23–26 May, 2010 Stockholm (Sweden)
7. Reports of Master in “Satellites and Orbiting Platform”, University of Rome “Sapienza



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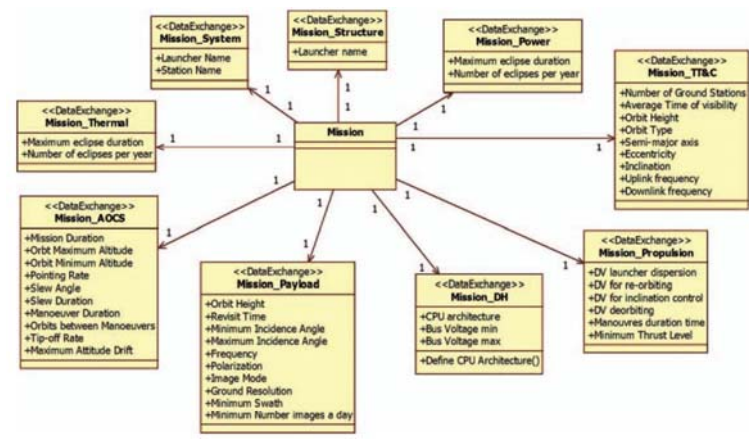
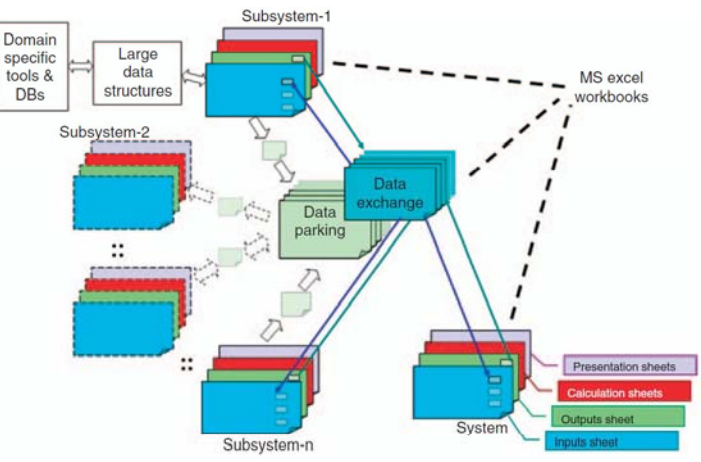
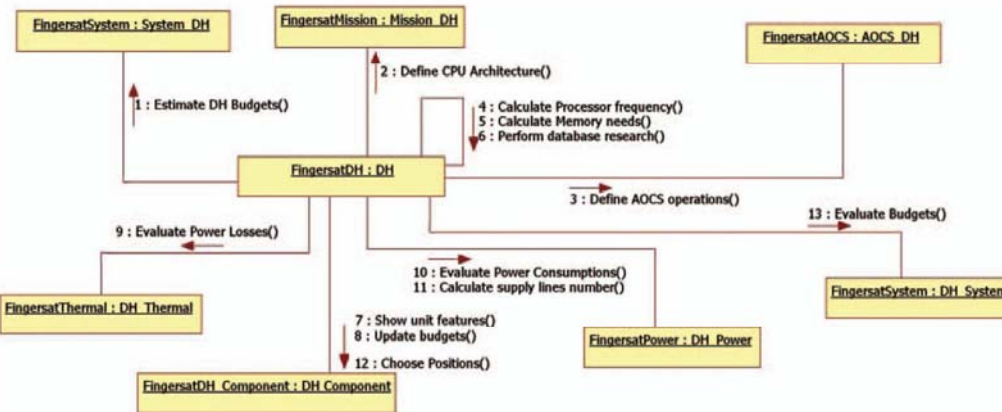


Research Activity	A Model for Preliminary Design Procedures of Satellite Systems
	2006 • 2007

A space mission can be described in terms of space, ground and launch segment: The space segment (the spacecraft) consists of a payload and a bus, composed by several subsystems. Ground segment must interact from ground with the spacecraft both for the payload and for the bus purposes and is responsible for receiving the telemetries of the spacecraft and the payload's data, and for sending to the spacecraft. The activities of the launch segment are related to the phases of a space mission that safely takes the spacecraft from the earth surface to the final orbit.

The procedure proposed in this work is focused on the preliminary design of the space segment. During the first stage of the process of spacecraft design, mission team analyzes mission requirements and produces system and payload constraints for system and payload specialists. These requirements regard the choice of orbit properties, the lifetime, operations, and the main features of the instruments. Then engineering team, supervised by a system engineer, are responsible for designing the spacecraft. Each engineering unit, corresponding to a subsystem, the payload, or the system itself, has to follow simple sizing rules relevant to a specific discipline. All the engineering units are the main players of the design phases. Each unit aims to design a subsystem, characterizing it by a series of *design parameters*: factors describing a specific feature of the unit. Some parameters belong entirely to a single subsystem and are used only for internal evaluations of subsystem design; other design parameters, since a concurrent logic is assumed, are typically exchanged among subsystems: the computations of one subsystem are the input for the analysis of features of another one. The present model of satellite design aims to describe the interaction among the design units and allows a contextual

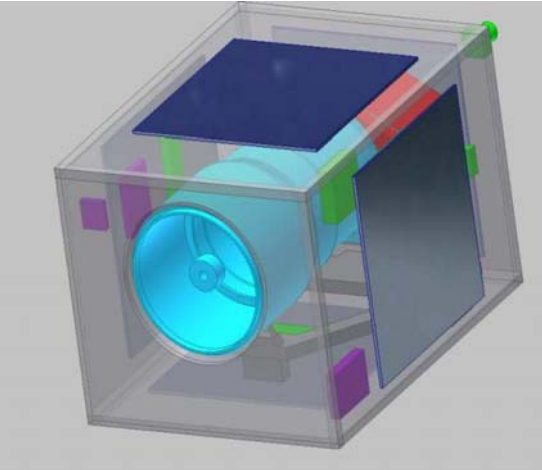
evaluation of the effects that a change of a parameter adopted in a single subsystem could produce in the others. The documentation of the design procedure is a necessary support to analyses describing the interactions between. This documentation uses UML formalism, implementing, collaboration, static, activity diagrams. In this article, UML diagrams are then used to describe the Concurrent Design approach to the preliminary analysis of a spacecraft.



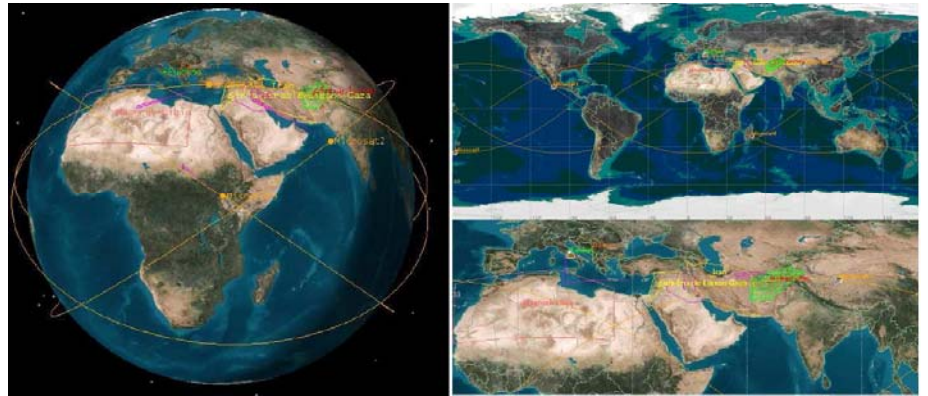


Research Activities	1. Study on air-launched constellation of tactical microsatellite for defensive use
	2. Cubesat mission with technological demonstrator payload for high data rate downlink and Health Monitoring
2009 • 2011	

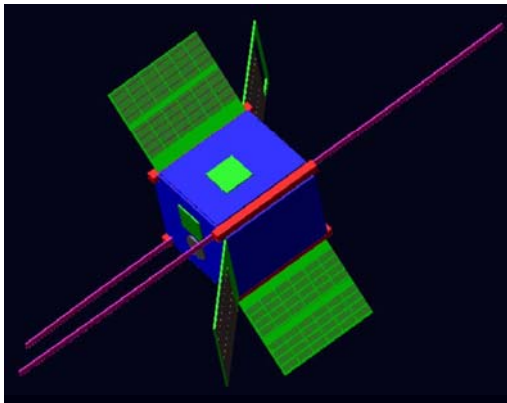
The first study presented concerns the study of a constellation of four identical microsatellite for tactical use carrying on board an optical payload. Such constellation has been studied exploiting the possibility to implement an air-launch capability, which will be useful in case the constellation needs to be responsively deployed to promptly react to a sudden arisen need. The most suitable orbit for such a constellation has been chosen by means of a simulation performed through STK software between a LEO RCO and for a LEO SSO. Concerning LEO RCO, the time required to insert into orbit the four microsatellites constellation with RAAN shifts approximately equal to 90 deg to have a uniform coverage in time of the target area is approximately 19h 40'. For a LEO SSO, the time required to insert into orbit the four microsatellites constellation at RAAN shifts approximately equal to 45 deg to have a uniform and homogeneous coverage of the target area is approximately 9h 30'. Once the orbit has been chosen and the proper payload identified, the spacecraft design study started. Also cost analysis has been carried out at the end of the study, to assess the cost of such a solution.



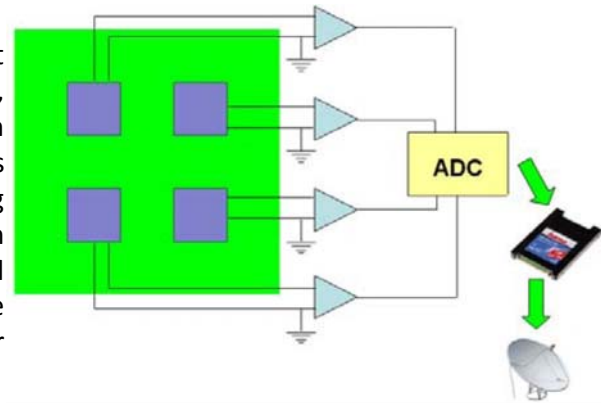
CER (Cost Estimate Relationship) been used to evaluate both the *Recurring* and the *Non-Recurring Cost*



The second work presented dealt with the study of a Cubesat platform used as a technological demonstrator: two different and ambitious experiments has been evaluated: the first one consist in the possibility of off-line monitor the health of the structures, by means of piezoelectric patches attached to an internal panel, connected to a microprocessor able to acquire the electrical signal produced by the piezoelectric elements once the structures vibrate; the second experiment is the installation of a C-Band patch antenna to let the nano-satellite communicate through a high data rate



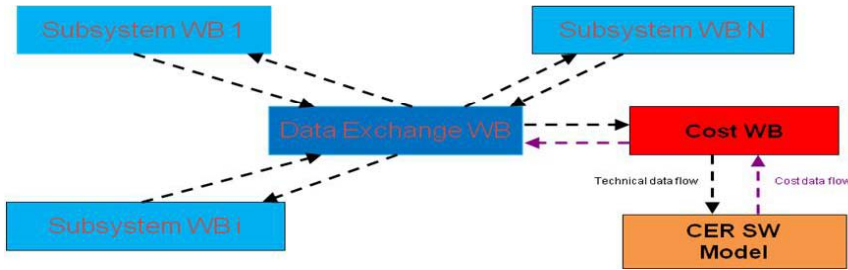
link with ground stations. The health monitoring experiment has been demonstrated on ground, through the realization of an experimental setup: piezo patches has been attached to a vibrating structure; the signal has been acquired by a microcontroller, and stored in its RAM memory; the signal has been over-the-air transmitted to a remote PC.





<b>Research Activity</b>	<b>A UML modeling of the cost and schedule estimation of satellite subsystems in a concurrent engineering design environment</b>
	<b>2008 • 2011</b>

Quantifying expected development times and costs of a project is essential at project management level. Taking into due consideration the fact that the overall costs and schedule hypothesis of a project are determined by the choices made during its preliminary design phases, it is of paramount importance to perform a reliable and as accurate as possible cost estimate during the feasibility design stages. A methodology to reach this objective is to know the influence of the technical characteristics of the products to be developed on their overall cost of development, production and disposal. A known technique to perform a cost estimate of a product based on its technical features is the Cost Estimating Relationships (CER) parametric model, a set of mathematical functions obtained by statistical analysis of historical cost data that link technical parameters of equipment to their cost. Concurrent engineering methodology is a proper environment to ease the cost estimating by means of CER statistical models since it takes into account the technical aspects of all the disciplines involved in the design: by linking the values of the technical variables that model the products to be developed to their associated CER models, it is possible to get a fast economic evaluation of the products as far as the applicability of the CER equations is verified.

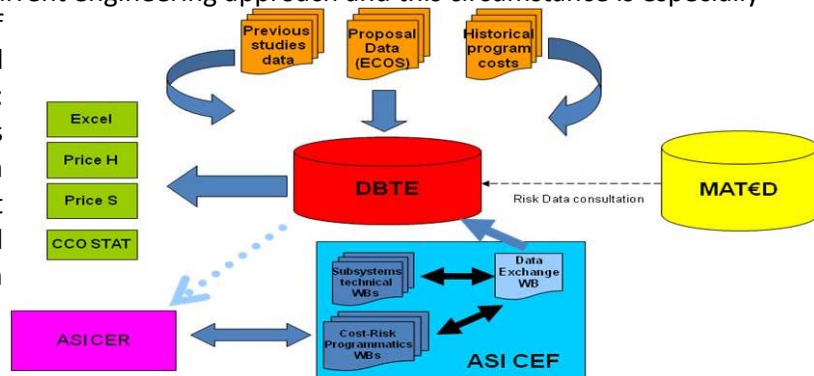


Concurrent engineering methodology is a proper environment to ease the cost estimating by means of CER statistical models since it takes into account the technical aspects of all the disciplines involved in the design: by linking the values of the technical variables that model the products to be developed to their associated CER models, it is possible to get a fast economic evaluation of the products as far as the applicability of the CER equations is verified.

The research activity carried on describe a cost and time estimating process for preliminary design phases performed within the concurrent engineering design environment developed by the European Space Agency (ESA) and known as Integrated Design Model (IDM). The methodological approach used for this description will be based on a Unified Modeling Language (UML) representation of the cost estimating process itself. The core of the work describes how the cost and schedule estimating process is tailored within ESA IDM concurrent engineering design environment. A key point during the design process is the consideration of the economic aspects of product design, development and production, and how the technical aspects may impact the total costs that will be incurred. As previously stated, the programmatic aspects include schedule and cost estimates. Possible techniques for cost estimates are the following:

1. bottom up;
2. parametric;
3. analogy.

Each technique can be tailored to a project design phase since the amount of information and details available in every phase increases moving from the preliminary to the detailed design and production ones. The parametric and analogy methods are generally employed during the preliminary design phases but the one that best fits CE needs is the parametric one because of the intrinsic nature of the concurrent engineering approach and this circumstance is especially true for ESA IDM. This one relies upon the exchange of technical parameters among the Excel™ workbooks of all the disciplines involved during a concurrent design session: linking all the relevant technical cost drivers of the various subsystems and equipment to cost workbook and from there to a CER software model may allow to perform a fast and accurate cost evaluation, as far as the CER model validity is applicable, during all the prefeasibility design stages.



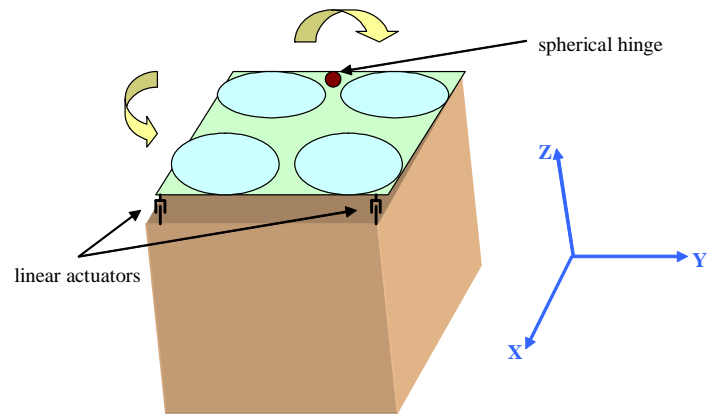
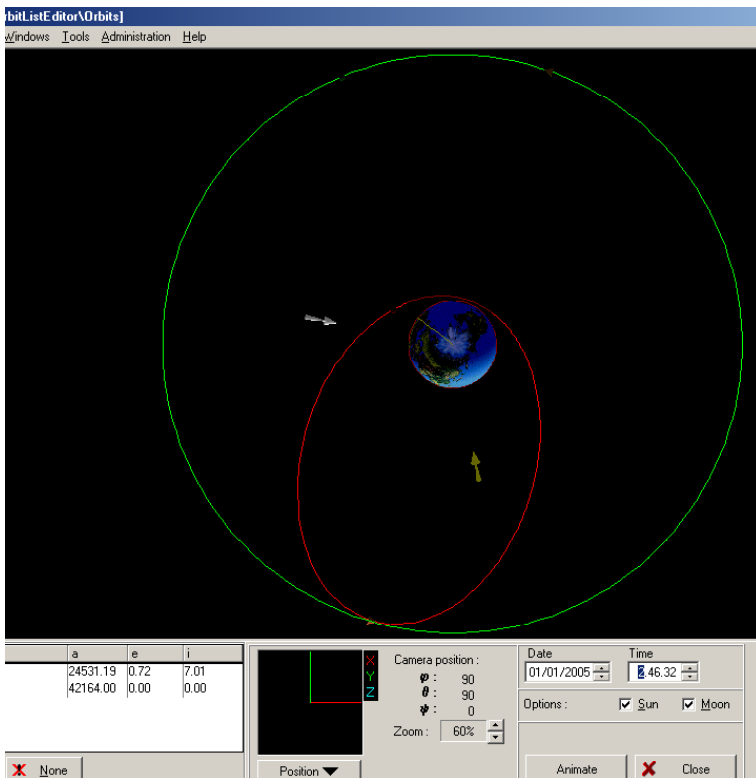


<b>Mission Project</b>	<b>GEOSAT</b>
	<b>2002 • 2003</b>

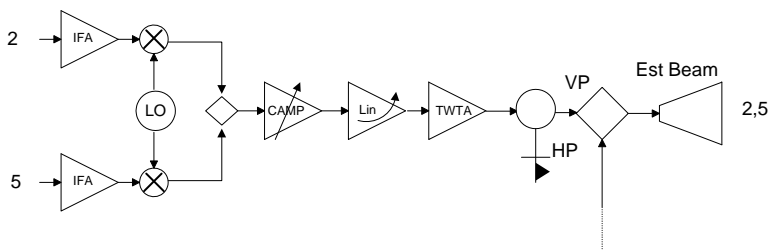
The GEOSAT mission aims to develop a communication satellite. It offers a good opportunity to provide North America and Europe by broadcasting wide-band services such as video, telephony and data.

The overall capacity consists of 2 Mbps data streams that can be either added together or divided into smaller bands to fit user requirements. A broadcasting video service needs between 2 and 6 Mbps uncoded channels, whereas a high quality stereo quadraphonic channel requires about 256 kbps so that a good compromise is splitting the 2 Mbps into 8 streams of 256 kbps and each sub-stream can be divided, on its turn, in 4 channels of 64 kbps.

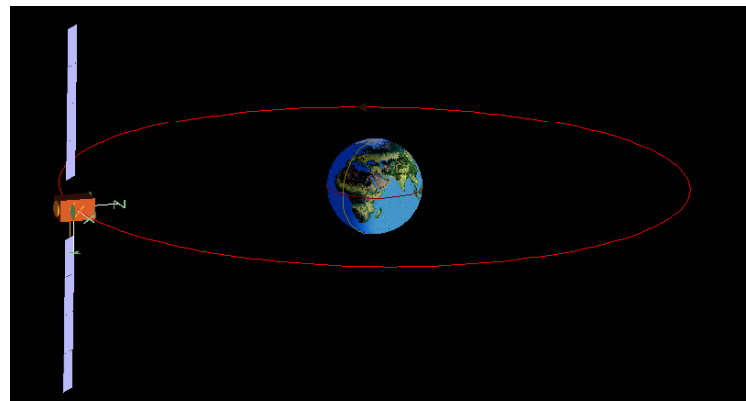
We intend to develop a flexible and dynamic communication system, capable to vary the parameter links according to the type of service and quality constraints.



For this purpose, two different technical solutions have been investigated: conventional geostationary satellite with a capacity of more than  $500 \times 2$  Mps channels in Ku band, and a second one more challenging, able to offer more than  $4000 \times 2$  Mbps channels in the Ka band. Both payloads consist of transparent transponders which receive incident signals from either Europe or North America and then broadcast it to the area of concern.



Transmitter chain.





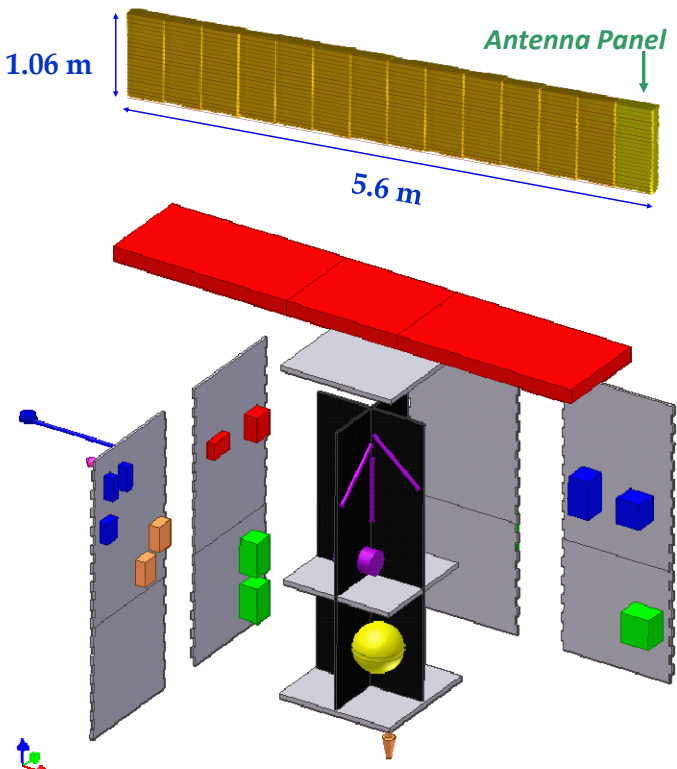
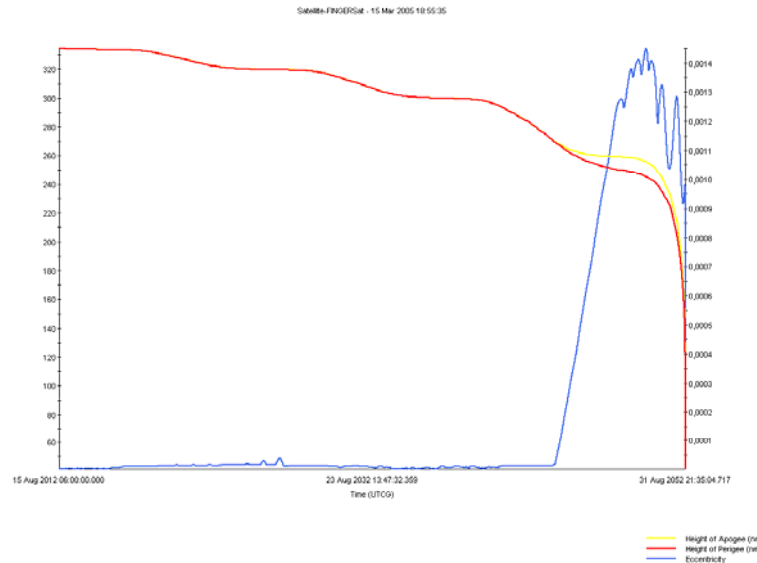
Mission Project	FINGERSAT
	2005 • 2006

The mission named FINGERSAT is a space mission, performed by a 1-tons class of satellite mounting a SAR (Synthetic Aperture Radar) payload.

The mission analysis activities focused on contributing input for the selection of an appropriate class of orbits for the FINGERSAT mission via a comparative analysis of the respective merits of different options.

After comparative merit analysis, a controlled Sun Synchronous Orbit (SSO) was selected as baseline and a more in-depth analysis was performed taking into account:

1. Launch window and launcher options
2. Global coverage and revisit time
3. Orbital evolution and stability, mission lifetime
4. Correcting the injection dispersion and station keeping
5. Ground station visibility conditions
6. Eclipses
7. Thermal and radiation environment



Different configurations are analyzed to reduce global coverage time, using equally spaced satellite in a singular plane or in equally spaced planes. Time to cover the 20°-60° latitude zone is evaluated.

According to the design drivers, the system engineer has produced, in accordance with subsystem engineers, a preliminary baseline design for each subsystem, and, where useful, a set of alternatives to be considered. Starting from this baseline, each subsystem team has to produce a comprehensive design of the subsystem architecture.

619	Global				lat 20°-60°
	n° planes	n° s/c	Coverage [%]	Time	Time
Configuration	1	1	99,69	3 <sup>d</sup> 15 <sup>h</sup> 52 <sup>m</sup>	2 <sup>d</sup> 8 <sup>h</sup> 52 <sup>m</sup>
	1	2	99,69	1 <sup>d</sup> 17 <sup>h</sup> 52 <sup>m</sup>	1 <sup>d</sup> 14 <sup>h</sup> 12 <sup>m</sup>
	1	3	99,69	1 <sup>d</sup> 11 <sup>h</sup> 51 <sup>m</sup>	1 <sup>d</sup> 11 <sup>h</sup> 51 <sup>m</sup>
	1	4	99,69	13 <sup>h</sup> 20 <sup>m</sup>	12 <sup>h</sup> 20 <sup>m</sup>
	2	2	99,69	17 <sup>h</sup> 59 <sup>m</sup>	17 <sup>h</sup> 10 <sup>m</sup>
	2	4	99,69	7 <sup>h</sup> 56 <sup>m</sup>	6 <sup>h</sup> 30 <sup>m</sup>





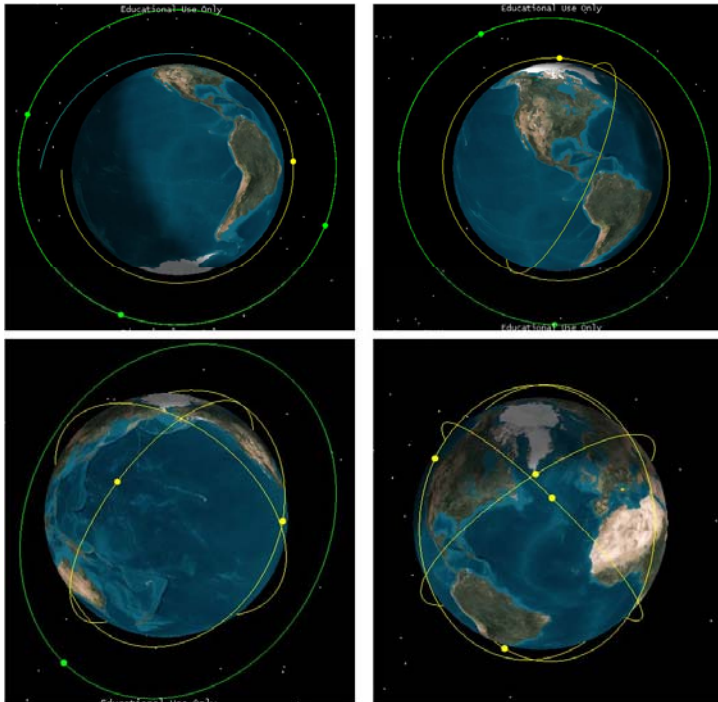
<b>Mission Project</b>	<b>FLORAD Constellation</b>
	<b>Costellazione FLOreale micro-satellitare di RADiometri in banda millimetrica per l'Osservazione della Terra e dello Spazio</b>
	<b>2007 • 2008</b>

The FLORAD study has been performed through an extensive use of the Concurrent Design Tool.

The FLORAD mission is a physics mission addressing tropospheric thermo-dynamical profile and hydrological content on Earth atmosphere exploiting a constellation of microsattellites with a MMW passive payload.

The constellation is composed by four identical microsattellites; the four satellites must be placed on four different proper orbital planes to maximize the payload acquisition time. These orbits are particular elliptical orbits capable to increment the time a satellite spent over a well-defined area.

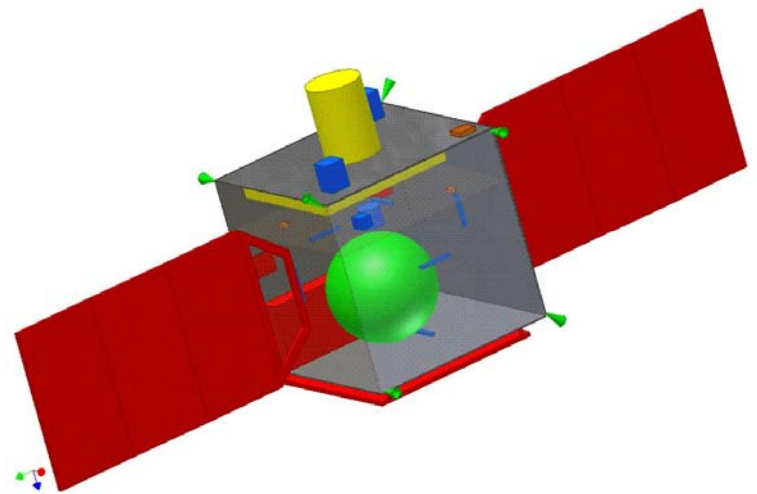
The mission analysis activities focused on the selection of an appropriate strategy for the constellation launch via a comparative analysis of the respective merits of different options. We have considered four different options:



- Four different launches;
- Single launch with orbit plane change;
- Single launch with electric propulsion;
- Single launch with orbit precession.

After comparative merit analysis the last option was selected as baseline and a deeper analysis was performed. The strategy used for constellation deployment is represented aside.

Once the operative strategy to deploy the four satellite composing the constellation has been identified, several CDF design iteration we performed to size the satellite subsystems, obtaining the final satellite configuration.





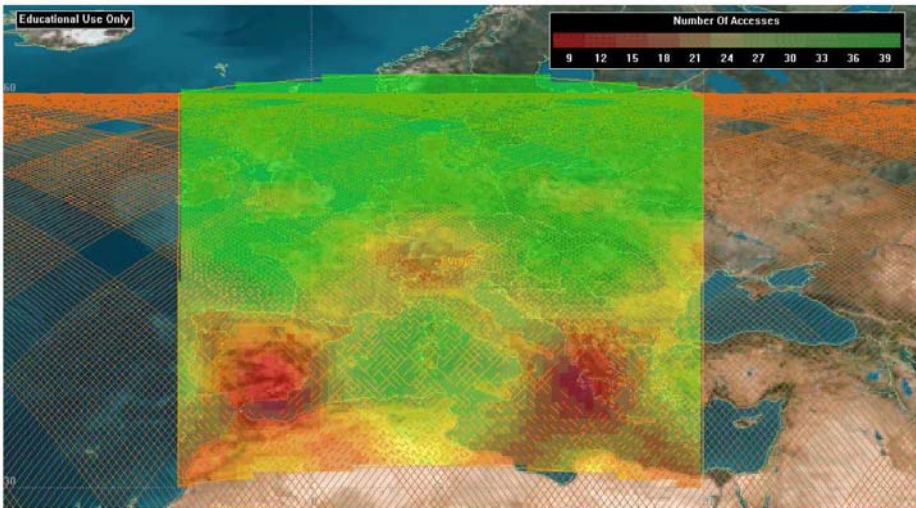
Mission Project	EDiM Satellite - European Disaster Monitoring
	2009 • 2010

The mission named EDiM (European Disaster Monitoring) has been realized with the aim of:

“Identification and monitoring of catastrophic events like chemical or petrochemical accidents, or nuclear plant accident, occurred in European territory for a period of 6 months from the orbit injection”

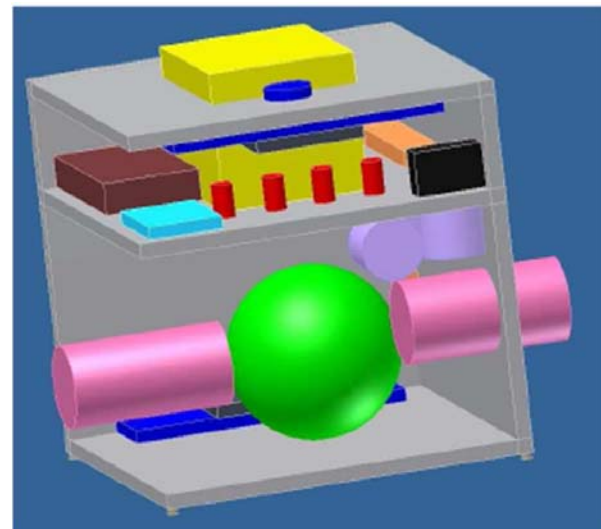
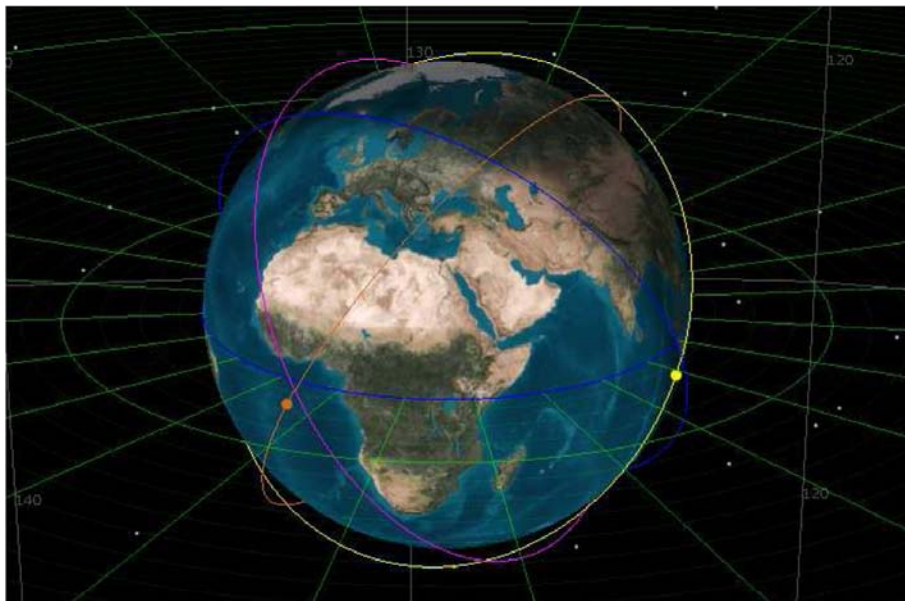
The fulfillment of the abovementioned objective must be reached according to the Operationally Responsive Space (ORS) criteria, in particular considering the possibility to develop the program with the aim to significantly reduce the project cost and time, with the respect to traditional large spacecraft project.

From these statements on, the preliminary design phase started with the definition of mission requirements, divided between General Requirements, Functional Requirements and Operational Requirements.



The first action undertaken was to choose the proper orbit, in order to successfully accomplish the mission requirements, mainly in terms of revisit time and spatial resolution. Once orbital parameters has been chosen, the successive step was to study the characteristic the payload to mount on board satellite should have to be able to correctly respond to the operational and functional requirements listed in the initial phase of project development.

Finally, preliminary mass and power budget has been decided by the system engineer, and the platform preliminary design accomplished.





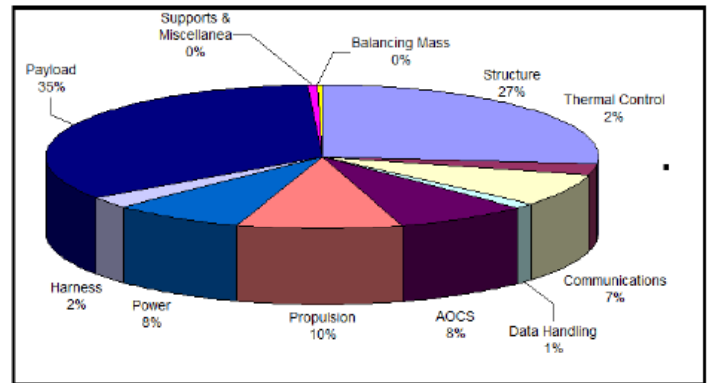
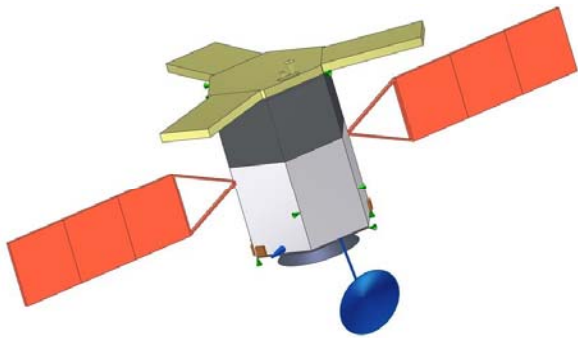
<b>Mission Project</b>	<b>LIRAS</b>
	<b>2010 • 2011</b>

The LIRAS mission is a Lunar Observation mission addressing the high-resolution mapping and vertical sounding of the Moon sub-surface for planetary analysis and studies by taking advantage of the antenna aperture synthesis technique applied to a single-frequency micro-wave (MW) passive payload.

The LIRAS mission is specifically aimed at the retrieval of thermo-morphological properties of the Lunar sub-surface within the first 10 meters of depth and at spatial horizontal resolution less than 5 km.

The main LIRAS products are:

- near-surface temperature;
- sub-surface temperature gross profile;
- sub-surface regolith thickness;
- regolith density gross profile;
- detection index of sub-surface ice presence;
- average thermal conductivity of regolith.



The LIRAS mission is the first Lunar mission of this type, experimenting the concept of antenna aperture synthesis (also called passive interferometry) in planetary exploration. The antenna aperture synthesis technique allows to reconstruct details of the observed scene at resolution much better than those obtained using conventional systems. The technology readiness level of the aperture synthesis technique can be considered mature since it is currently used for earth observations within the SMOS (Soil Moisture Ocean Salinity) mission. The LIRAS small-mission is devoted to the design of a small satellite at an orbit height of about 100 km, with a revisiting time period less than 1 Lunar month and equipped with a high-resolution microwave single-frequency MW interferometric radiometer.

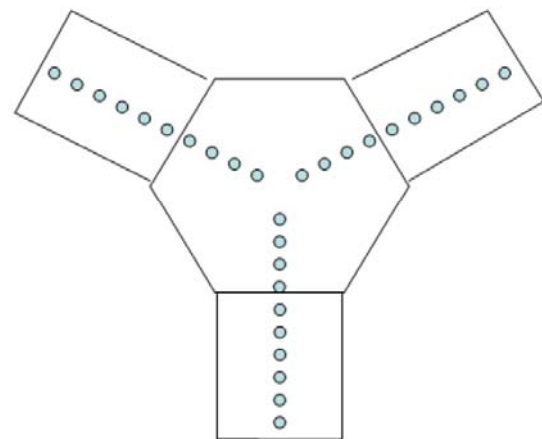
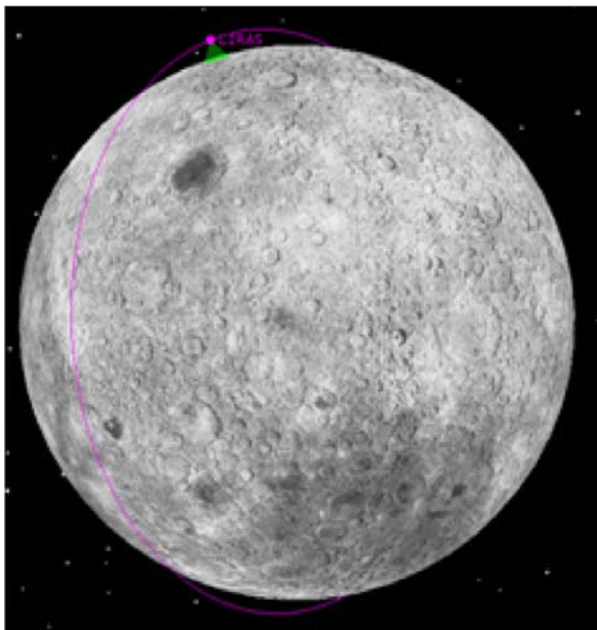


Figure 4.8: SS-PL LICEF distribution with respect to the hexagonally shaped hub

