"Spazio per tutti"
A Hands-on Experience toward Space Engineering

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Abstract – **"Spazio per tutti", Space for Everybody, is a pilot project organized jointly by the University (Politecnico di Milano) and the Space Industry (Carlo Gavazzi Space), with an operational support by Odisseospace and the endorsement by the Italian Education Ministry Regional Authority (IRRE Lombardi). "Bridge projects" between high school and University are a common best practice of IRRE Lombardia, the local public education authority, allowing students ready for their last year in the high school to taste the flavour of the University.**
The added value of our pilot project has been twofold: the selection of a real problem, and its solution thru a pre-feasibility study with hands-on activities.
The two weeks workshop has been organized for 30 highly motivated students, selected by means of a regional competition.
The topic 'monitoring green belts around Milano city area, using cost effective space born technology' has been presented to the students at the beginning of the workshop by the local Ministry for Environment.
A full immersion workshop like this allows reaching multiple purposes: young students focus on a concrete problem, they know the challenge of the University one year in advance and strengthen their problem-solving attitude.
The pilot project scheme could be easily exported to other scientific education contexts.

Index Terms – Hands-on Education, Remote sensing, Space engineering, University Orientation.

INTRODUCTION

The summer workshop for students took place in June 2006: the aim was to propose laboratory activity at the University, giving the possibility to develop a design on the basis of specifications.
Provincia di Milano, the local authority in charge for the Environment protection policy, announced the topic, which was the monitoring of green belts in the Milano city area and surroundings.
It was necessary to provide the scientific background to the participating high school students, starting from their theoretical Physics and Math knowledge, and letting them understand the problem of access to space. In other words we needed to explain them what is making difficult the access to Low Earth Orbit (LEO).
With this background, brought suitable classes to a homogeneous level, the attendees were able to better understand and appreciate services like the GPS or Iridium or IKONOS, available thanks to the engineering effort already spent to design and operate them.
Furthermore the students had to be able to integrate these tools, for the service required by the Province.
Students have been selected through a regional competition, on the basis of an original paper they presented on the space exploration.

THE WORKSHOP TOPIC

High resolution satellite images are a supporting tool for an efficient governance of the Provincia di Milano and Parco Sud environment. Provincia di Milano already experimented the use of satellite images where IKONOS pictures, of a limited portion of the Province where acquired and processed. The positive response allowed starting in 2005 the entire Province mapping: acquired images are to be post-processed to classify objects on ground and extract soil usage maps.
In particular, features on the territory will be identified, such as monumental trees, concrete-asbestos roofs, fuel stations on the roads, and any other features, of interest for the various Province offices.
In addition to the thematic maps, satellite based images are being used as a support for the CTR (Carta Tecnica Regionale, regional thematic map) raster as an alternative to the ortho-photo.
They are a better alternative to orthophoto because they are more detailed and easier to be updated. Also non-predictable events (territory misuse, hydrography changes, landfields identification…) can be easily detected and in a very short time.
For the workshop topic, the proposal is to test the feasibility of mapping the green belts: the trees plantation by Provincia di Milano near a large metropolitan area, like Milano is, brings several advantages:

- CO_2 emissions partial absorption;
- microclimate biasing, with a local cooling of the lower atmospheric layers;

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- creation of ecological niches for antagonist animals to undesired species (predatory birds both diurnal and nocturnal, insectivorous mammalian and birds);
- creation of recreational areas for the citizens, for sport, without having them to leave the city area;
- didactical function for new generations of citizens on the thematic of environment conservation and protection.

Green belts maintenance is of outmost importance because they are the only element to preserve biodiversity of the fauna. Forestation, or re-forestation, means finding green areas non-connected and best locations for the belts to interconnect them in the near future.
High resolution satellite images are a precious tool for this project in order to create a map database to support then the political decision and the practical implementation.
Moreover, it is needed to identify non impermeabilized areas, intended as the ideal candidate area for the reforestation. These non-concrete covered areas must be further identified as grass, trees, woods, trees rows, cultivations or shrubs.

THE ORGANIZING NETWORK

The workshop has been a great opportunity to consolidate an already existing network among institutions working in Milano area, sometimes unknown to the students and their families. In addition to the Politecnico, the biggest Italian Technical University, there were other two universities involved: the Università degli Studi di Milano Bicocca, with the Earth Observation Department, and the Università degli Studi di Milano, with the historical site of the Observatory of Brera. Local government was involved thru the Province authorities.
The productive world was represented by the high-tech industry like Carlo Gavazzi Space, working in the Space sector. All of this has been a clear example of synergic work, combining the excellence of the high-tech enterprise, the local government and entrepreneurs associations, all of this being a sample of the Education, Research and Production society in Lombardia and the Milano area.

OBJECTIVES

The methodology we used is based on an *hands-on* experience, a practical didactic approach with real experiences within both the Industry and at the University.
The aim is to develop in the students the synthesis capability and thru *problem posing* and *problem solving* to let them design in team. The student, using state of the art tools, analyse, understand, and make decisions within a working group, always followed by a tutor.
The project allows to develop personal skills, with an increased motivation to study and to the University choice in Science and Technology field.
A website based platform allowed to monitor the progress of the work , with a forum for ideas exchange also beyond the workshop duration
Although the main focus of the pilot project was to orient young students to scientific University level studies, by being put in contact (a year in advance) with the challenge of the University, a full immersion workshop like this allows reaching two other main: Methodological and Social.

The Scientific Method in practice

Young students enthusiasm is focused on a concrete problem, They learn, in practice, a problem-solving attitude based on a solid technical-scientific knowledge. The scientific method they have studied at school becomes an asset to understand and face complex problems. A key is given, which consists in collecting and understanding the quantitative information for making a decision.

Social added value

The students have the chance, several years in advance, to face with the needs of the local community. Finally, the students have to trade off between technical and economic requirement, which is always the case in the real life. They are requested, as responsible citizens, to make an effective use of the public resources, identifying priorities and evaluating the cost-benefit ratio.

WORKSHOP COURSE

Overall the workshop lasted 60 hours, spanning two weeks, six hours every day for five days a week.
Three steps have allowed the students to enter into the topic:
- A theoretical background on space exploration was provided;
- Some practical experiences on-the-field or in-the-lab were organized;
- The pre-feasibility study was done and presented to the local Minister.

The workshop contents have been arranged in two didactic modules:
- MODULE 1: THE SPACE ENVIRONMENT
- MODULE 2: SATELLITE-BASED EXISTING SERVICES;

each module containing both lectures and laboratory activities.

TABLE I
LECTURES AND LABS OVERVIEW IN THE TWO DIDACTIC MODULES

Module	Lecture or Lab	Activity	Hours
1	Lect.	Launch environment: vibrations	2
		Orbital mechanics	2
		Ionizing Radiation effects	2
		In space: thermal behaviour	2
		On board autonomy	2
		Communications	2
1	Lab	Thermal vacuum test	8
		Satellites observation	4
2	Lect.	GPS	2
		Satellite constellations	2
		Radar interferometry techniques	2
		Usage and interpretation of remote sensing data	2
		Spectral signatures	2
		Data Post-processing	2
2	Lab	GPS use	2
		Ground station use	2
		Big ground station visit	4
		Ground truth on-the-field missions	2
		Workgroup	10
		Final presentation	2

Didactic module 1: The space environment

The theoretical lectures have span through

- The space environment and the launch environment, to answer the question: what is it the key difficulty to reach the Space outside Earth's atmosphere?
- Celestial mechanics basics, to answer the question: how do satellites fly and which type of satellite constellations exist?
- Remote sensing basics, in different wavelengths to answer the question: what can we 'see' from space?
- Space telecommunications, to answer the question: how to relay data back to the Earth?

The lectures for the first module have been aiming at giving confidence to the student with the problem of accessing Space, which explains the high costs in reaching the Low Earth Orbit, for example.

The labs of this first module have been :

- Thermal-vacuum testing of various insulating materials, to understand basics of heat transfer in space vacuum opposite to heat transfer in air by free convection; a thermal vacuum test to compare isolation capability of different materials has been set up, and temperature measurements have been variously predicted and compared with actual test data.

FIGURE 1
THERMO-VACUUM TEST

- The observation of satellites, the ISS and Iridium satellites flares, from the historical astronomical observatory Milano-Brera, where famous Mars observations in the XIX century were made from by Giovanni Schiaparelli, who pretended he had found the Mars canals.

Didactic module 2: Satellite based services

In the second module it has been unveiled why it is worth the effort of accessing Space, demonstrating several different technologies available from space born applications, ranging from global positioning services, like the GPS, to remote sensing, to global messaging.

The labs of this second module have been a practical demonstration of some of these devices at work:

- Handheld GPS usage and position error determination, compared to a professional GPS station performance, including error-correction features;

FIGURE 2
ACTIVITIES AT BRERA OBSERVATORY

- Usage of space telecommunications: the students have sent messages (Globalgram) by means of a ground station connected to the OrbComm constellation.
- Ground station operation: data were received and sent while the CGS satellite SAFIR was flying over Milano, using a tracking antenna and a portable ground station
- Ground station visit, at Spino d'Adda, to get in touch with a bigger and pioneering Ground Station of the eighties, when the Olympus telecommunication satellite was first operated from here.

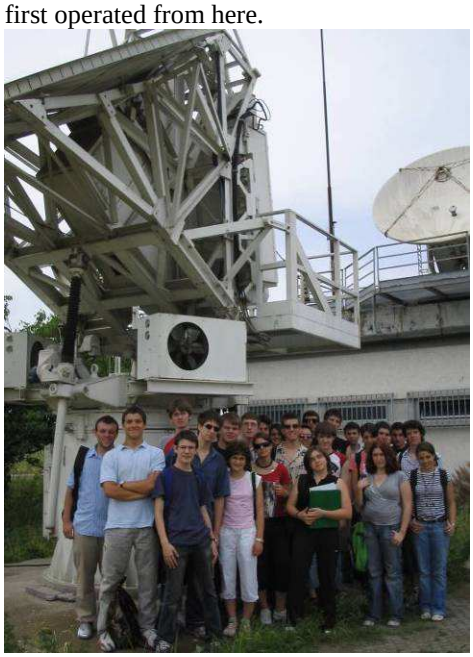

FIGURE 3
THE GROUP AT SPINO D'ADDA

- Remote sensing "ground truth" determination: multi-spectral images taken from satellite has allowed to predict the type of fields, vegetation, trees and wood, buildings expected in a certain area of Milano, and to compare them with the actual behaviour, during an onsite visit in the open field.

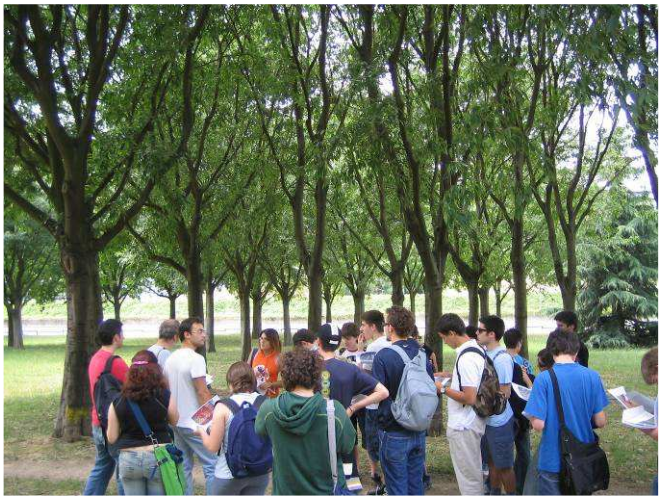

FIGURE 4
ONSITE ACTIVITY FOR "GROUND TRUTH" DETERMINATION

Reporting

During all the workshop, the students were asked to regularly report on the performed activities. For example, we are copying hereafter one excerpt of the reports provided by some of them on the thermal vacuum testing. It is worth noticing the text has been written by students, with some ingeniousness which we haven't removed from the text: main issue is that the lack of a physical-mathematical background has prevented them from using equations in explaining the observed phenomena, rather relying on the verbose description of what they had observed.
The short report is about a couple of samples of aluminium, heated by resistors: one of them is black painted and the other is not painted.
"We notice that in air the aluminum temperature black painted is about the same of the bare aluminum because we don't have radiation heat transfer, which would make the sample hotter.
Repeating in vacuum the same observation, however, the aluminum specimen temperature was hotter by 1-2 degrees because the lack of air isolated the samples and eliminated forced convection effects which have equalized the temperature in the first case".

WORKGROUP

Having the toolkit ready, namely the theoretical knowledge acquired in the classes of the two didactic modules and the corresponding laboratory activities, finally they could experience the teamwork, being mentored by professionals from the industrial world and researchers of the University, as a good practice of working and achieving good results.
The final part of the workshop has been the space-based service for the green belts monitoring design: three teams have been suitably formed: 1.the Engineers, 2.the P.R.'s (Public Relations), and 3. the Economists.
The Engineers were in charge of consolidating the technical requirement of the mission and summarize the challenge of the Spaceflight. They identified the data source, satellite family and type of sensor, and relevant technical parameters for mapping both the city and the province area. They are summarized in Table 2 and 3.

TABLE 2
SERVICE SPECIFICATIONS, PROVINCE

Parameter	Type Styles
Area	1984 sq(Km)
Mapping frequency	Seasonal
Sensor	Aster
Resolution	15 m
Return time	16 days
Cost (archive: 2-3 days)	75€/3600km2
Cost (standard: 24 hours)	300€/3600km2

TABLE 3
SERVICE SPECIFICATIONS, CITY

Parameter	Type Styles
Area	182 sq(Km)
Mapping frequency	2-3 times /year
Sensor	Quickbird
Resolution	2.8 m
Return time	3 days
Cost (archive: 2-3 days)	16€/km2
Cost (standard: 24 hours)	41€/km2

The P.R. (Public Relation) team was in charge of the communication campaign design of the satellite green belts monitoring and they designed a poster, shown in Figure 5, for advertising the initiative and for the outreach of the project to the population.
The Economists were in charge of the cost-benefit analysis and the order-of-magnitude cost assessment of the initiative for the local government
Indicators, defined as physical measurements related to a physical, chemical, territorial parameter, having a relation with an environmental phenomenon, have been determined, to summarize in a single number all these characteristics.
With our project, the following indicators listed in Table 4 can be derived for the Province/ City area.

TABLE 4
ENVIRONMENTAL INDEXES

Index	Units
Urbanized surface	Km^2
Urbanized surface/ Total surface	%
Urbanized surface dedicated to public green areas	Km^2
Urbanized surface dedicated to public green areas/Population	Km^2/people
Rate of growth of the urbanized surface	Km^2/year
Agricultural surface/ Total surface	%
Natural Areas /total surface	%
Natural Areas /Urbanized surface	%
Fragmentation of the natural areas	%
Trees rows length	Km
Natural woods surface / total area	%

FIGURE 5
POSTER DESIGNED BY THE STUDENTS FOR THE INITIATIVE OUTREACH

FINAL PRESENTATION

The final ceremony has been a big party with the academic, industrial and political authorities, where the students have presented the public utility service.
The student wanted to share with the present authorities what they had learned in classes and experienced in the lab. Afterwards, they have summarized the requirements of the service requested by the Local government for monitoring the green belts: a thematic map has been presented, relevant to the area subject of the onsite exploration during the workshop, to confirm the satellite based imagery is providing accurate information which were verified by direct inspection on ground. The Normalized Difference Vegetation Index (NDVI) was derived from hyper-spectral images.

FIGURE 6
NORMALIZED DIFFERENCE VEGETATION INDEX: MILANO-QUARTIERE GALLARATESE AND MONTE STELLA

This allowed to make an estimate of the composition of an urbanized area compared to a city forest, in the vicinity of the explored area, as summarized in the pie charts in figure 7.

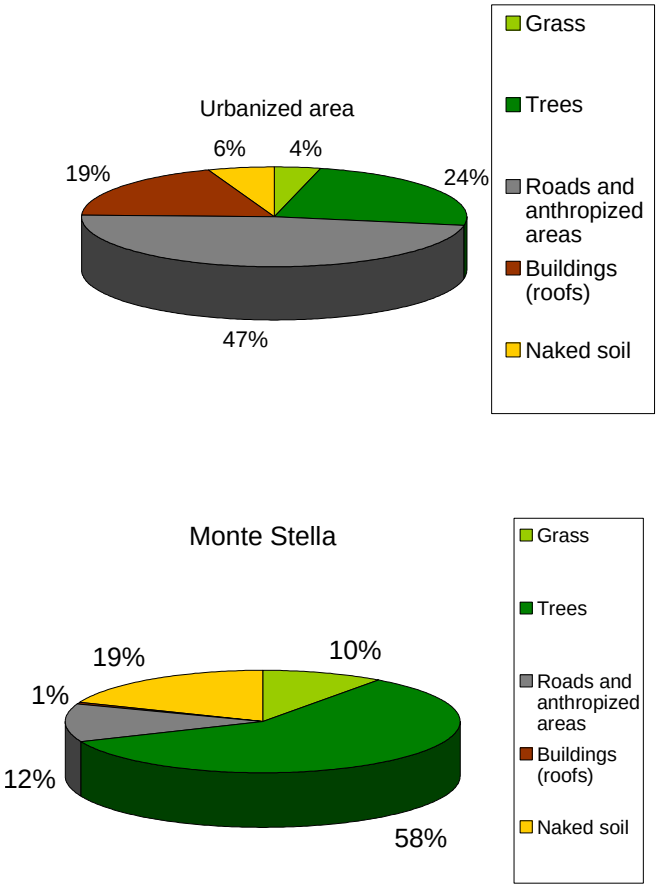

FIGURE 7
INDEXES OF THE SOIL COMPOSITION OF THE EXPLORED REGION

The overall cost was understood being not only the image purchase cost, but also the post-processing work, as explained in table 5.

TABLE 5
COST SUMMARY

Images cost+
Geo-referencing+
Ortho rectification+
Processing =
Effective cost

The conclusion of the work was that satellite images allow a quick and detailed images acquisition, both in time and space; the resolution can be adapted to the real needs.
However, the cost is quite high for small entities, like single municipalities, and the acquisition in the visible wavelength, although preferable for resolution reasons, has to considered critical in case of cloud coverage.

FIGURE 8
THE GROUP AT THE END OF THE FINAL PRESENTATION

The local Minister expressed appreciation for the work done, not only for the technical result but also for the sensibility to the necessary ratio between money spent and the result obtained in exchange.

LESSONS LEARNED AND APPLICABILITY/EVALUATION

A self-evaluation questionnaire allowed to judge the impact of the workshop on students skills against their expectations. The results, shown in Table 6 are very good.

TABLE 6
SELF-EVALUATING QUESTIONNAIRE

Skills developed	Score (1-6)
Specific Space knowledge	4.9
Team work capability	4.8
Problem solving	4.3
Project management capabilities	4.6
Decision making	4.6
Multi-disciplinary knowledge interaction	5
Communication skills	4.4
University choice	4.9

A student satisfaction survey have been done to understand the overall students appreciation of the workshop.
It is remarkable the educational function achieved in the form of a stimulus to know more.

TABLE 7
STUDENT SATISFACTION SURVEY

Feature	Score (1-6)
New skills have been developed	5.0
It was a stimulus to know more	5.4
I liked Team work	5.2
I can solve a real problem using what I know	4.8
Overall value	5.1

We believe this scheme is exportable to other contexts, provided the main subject has an impact on the students imagination like the Space Exploration.
In addition to this topic choice, the two following main elements are needed:

- a local network already established and working in the real life, between the University, the Industry and the local government, because the workshop has to be a simulation on smaller scale of something real, not an artificial construct;
- an institution willing to propose a real topic to a team of students because we want to bridge the gap between class exercises and real-life problems.

Students enthusiasm and the learning by doing will make the rest possible.
It is necessary to have clear objective defined at the beginning, the minimum theoretical background needed, to be put in lessons and the corresponding lab sessions: the University didactic skills are needed to identify the theory needed as a support, while industry can easily provide the help for conducting the hands-on experience with hardware and software.
It is important the final presentation day with the attendance of the authorities who have stated the challenge, because this is a continuous stimulus over the entire workshop.
Two weeks duration sounds a reasonable trade-off between a significant target to be reached and a time span which can allow keeping a very high attention and proactive participation.
The driving factors to ensure an outstanding interest by the participant students are mainly three: the commitment to a Public Institution, the Provincia di Milano in our specific case, to complete a feasibility study which requires a continuous and highly focused effort, the possibility of cross-checking physical phenomena studied in the handbooks with the real world ones and finally the subjects of the spaceflight and the Space exploration, which are highly inspirational and motivational per-se.

CONCLUSIONS

The pilot project “Spazio per tutti” has involved 30 students for two intense weeks at the end of the regular high school courses, in June 2006.
In 60 hours the theoretical background has been provided at the University, supported by hands-on activities with the Industry, allowed to answer effectively to a topic put by the local Government on the “green belts monitoring in the Milano city and province area”
The pilot project has shown the workshop is an effective tool, to orient the students to the University choice, sensitizing them to the local community needs and provide them a method to confront with new topics.
Constant monitoring of the confidence level of the students with the subject has allowed to finely tune the content of the workshop to the level of the class.
We believe, given some hypothesis presented in the paper, the workshop could be adapted to other fields different from the Space exploration.

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