

Multidisciplinarity and innovation ASP projects







ALTA SCUOLA POLITECNICA













POLITECNICO DI MILANO POLITECNICO DI TORINO



Multidisciplinarity and innovation ASP projects

Preface

This book marks the fourth cycle of students that have completed their course of studies in the Alta Scuola Politecnica.

Created in 2005, the Alta Scuola Politecnica programme draws on the experience of the Politecnico di Milano and the Politecnico di Torino, two universities with different histories, conditions and methods, but that share the desire to offer their students a highly-innovative course of studies.

From the outset, this ambitious project aimed to create an axis of learning between Turin and Milan. Today, as we witness the growing economic and social bonds between these two cities – both of which are key to the Italian economy – we are increasingly confident that we made the right decision five years ago, a decision that during this time has come to fruition and has evolved and improved.

We believe that, particularly in light of the current global economic crisis, universities should do more than simply issue degrees but should also prepare their students to meet the demands of labour markets with respect to new know-how and professions. In this sense, the Alta Scuola Politecnica provides an added value with respect to the traditional academic approach. ASP students are given the opportunity to continuously gain insight from one another as well as from courses offered by both universities and from projects proposed by companies, thereby developing the managerial skills and the comprehensive training that employers are increasingly seeking even from graduates in technical disciplines. The chance to work in teams, as well as the know-how gained from managing projects (as illustrated in this book) and the internship opportunities, substantially enrich the learning experience. We strengthen polytechnical training through a multi-disciplinary approach and method, yet we do not lose sight that our primary goal is to provide students with specific and technical skills in addition to knowledge. It is not by chance that 90% of ASP graduates find employment within one month of earning their degree.

This is therefore an important achievement that confirms that the path we chose to follow in 2005 is the best one for the future and one that encourages us to continue pursuing this project with the same enthusiasm shown by our ASP students.

Prof. Giulio Ballio, Rector, Politecnico di Milano *Prof. Francesco Profumo*, Rector, Politecnico di Torino

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<u> Reply</u> concept

Along with an ever diversely assorted graduate education offer with 13,000 new degrees or diplomas granted every year, an excellent post graduate training system makes Piedmont and the province of Torino a centre of attraction for young talents. Moreover, thanks to the presence of more than 200 research centers, today Piemonte ranks 12.5% of Italy's investments in R&D and it is the second Italian region for private R&D investment. The region invests 1.8% of its GDP in innovation, and the private sector investment in R&D constitutes almost 80% of the total R&D expenditure.

Partnership with public and private institutions, network between territories, support to innovation and research are main objectives for the Torino Chamber of Commerce which promotes the economic development and the local businesses growth.

The Chamber offers a wide range of services to nearly 238,000 companies working in the province and listed in the public Register of Enterprises: training, technological innovation, collection and distribution of information, fostering of business relations at home and abroad, creation of services and financing of projects designed to assist new businesses, promotion and organization of events, access to financing, information and consultancy for companies involved in foreign trade.

A particular attention is dedicated to the different levels of education, from professional courses to post-university Masters, with a special focus on high education systems and international training, which represent a significant tool for the attractiveness and worldwide relations, together with the solidity of the industrial fabric, the pro-business mood of the public administration, the quality of life in a creative, cultural and artistic context.

This is the reason why the Torino Chamber of commerce, three years ago, decided to cooperate with the ASP, the advanced international Faculty, founded by Politecnico di Torino and Politecnico di Milano, to enhance links between the two cities.

Italian Chambers of commerce work to build local area networks between research centers and enterprises, individual enterprises, institutions, territories and cities, as well as technological networks. Torino, Milan and Genoa Chambers of Commerce support the development of North-western macroeconomic region by means of projects.

Figures are significant: north-western Italy (Piemonte, Lombardia, Liguria) is one of the European biggest areas, with a population of almost 15 million people and more than 1.270.000 enterprises. It is an integrated territory that can proudly compete with the other European polycentric regions.

The North-western region needs economical and infrastructural actions, as the new railway connection between Torino and Milan, but also stronger cultural relations, focusing in particular on art, with a special attention to the contemporary art, education and organization of international events, as Torino Celebrations of 150 years' unity of Italy and Milano Expo 2015.

Torino Chamber of Commerce: working with businesses to build the future

www.to.camcom.it



The Compagnia di San Paolo, founded in 1563 as a charitable brotherhood, is today one of the largest private-law foundations in Europe.

It pursues aims of public interest and social use, in order to foster the civil, cultural and economic development of the community in which it operates. The Compagnia is active in the sectors of scientific, economic and juridical research; education; art; preservation and valorization of cultural heritage and activities and of environmental assets; health; assistance to the socially deprived categories.

In 2009 the Compagnia awarded 682 grants in its areas of activity, amounting to 121.4 million euros. Notably, 118 grants were awarded in the Research sector, amounting to 30 million euros, and 45 grants were awarded in the Education sector, amounting to 13.8 million euros.

The Compagnia pays particular attention to advanced research and to the development of scientific and technological centres of excellence, seen both as catalysts and multipliers of research and higher education initiatives. It supports the reinforcement of Torino's university system, especially through the promotion of excellence at Politecnico di Torino and the University.

The commitment of the Compagnia in the field of Education is focused on university and postgraduate education, starting from the growth of human capital, internationalisation and the provision of infrastructures, with special attention to the conditions that assure equal access. In this context, the ASP's focus on excellence and innovation – besides characterising it as a valuable initiative *per se* – gives this programme the capacity to enhance the global attractiveness of the Universities involved and foster, within the leaders of the future, a specific attention to the interdisciplinary and international dimension of nowadays society. The programme also represents an interesting synergy among educational institutions located in the north-western region of Italy.

The Compagnia has supported ASP since 2007: the grants are aimed at funding scholarships for the ASP course beginning in the year, requiring a special attention to students not based in Piedmont, or with an immigrant origin.



Cariplo Foundation, established in 1991 as a nonprofit organization with the purpose of furthering the common interest and the public good in various fields, is today – thanks to the sheer size of its assets (over 7 billions euro) – one of the world's leading philanthropic entities annually funding grants to organizations for the fulfillment of selected projects and initiatives.

The Foundation's assets, which are the fruit of the labour of generations of men and women, though considerable, are not sufficient to solve the many problems afflicting the civil society in Lombardy, Italy and the entire world. Therefore, Fondazione Cariplo efforts focus on the improvement of the living conditions in the local community. To Fondazione Cariplo this means improving the living standards of individuals as well as their social, cultural and economic environment. Fondazione Cariplo nurtures those conditions which enable individuals to achieve their potential, express their personality, freely pursue their inclination and fulfill themselves. Fondazione Cariplo gives priority to financing specific projects rather than providing general aid to organizations. This is, in fact, the only way to precisely assess whether a program is innovative and responds to the needs of the community.

The Foundation nurtures a breeding ground for scientific research, technology transfer and the development of applied research findings, by backing synergic actions geared to the creation of networks and partnerships, the participation in international projects, the development of human capital, the production of better knowledge and improved scientific communication, as well as the dissemination and enhancement of applied research findings. Being up to date on all projects and initiatives already put in place by the public administration and professional associations, the Foundation can assure that none of the funded projects is a duplicate and it fulfils its role as a convener and catalyst, multiplying resources and their effectiveness.

In 2009 Cariplo Foundation awarded 1.054 grants in its various areas of activity, amounting to 175.5 millions euro. 105 grants were awarded in the scientific research and technology transfer area, totaling 32.9 millions euro. Between 2007 and 2009 the scientific research sector of Cariplo Foundation received about 1.500 applications, processed 1.150 funding requests, and funded 440 projects.

Cariplo Foundation pays particular attention to the support and promotion of human capital development, particularly by focusing on a limited number of projects whose purpose is to start activities capable of achieving excellence in university and post-university studies. Furthermore the Foundation is also firmly convinced that actions supporting "excellence human capital" must entail a close connection between training and teaching activities, on one hand, and research and exposure to an advanced international scene, on the other.

These are the reasons underlying Cariplo Foundation decision to support the ASP, an advanced international Faculty able to attract the best young foreign students and capable of Italian high profile graduates education.

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The European Patent Academy is proud to be one of the main sponsors of the Alta Scuola Politecnica Summer School - *Management of Innovation*.

An understanding of the role that Intellectual Property plays in today's economy – and the vital importance to any enterprise in fostering innovation and seeking to protect it – is needed by every university student.

By encouraging IP teaching beyond law faculties in scientific, engineering and business faculties, the European Patent Academy also aims to facilitate the transfer of technology and innovation from universities to industry and contribute to a better understanding of the European patent system.

The interdisciplinary nature of IP is reflected both by the programme of this Summer School and its participants. The diversity of topics, ranging from law and economics to business and management, offers a broad perspective with participants gaining a first hand insight from highly qualified lecturers, all with their own area of expertise. The Summer School will provide the participants with a first class experience, invaluable for their future careers.

The European Patent Academy is responsible for all external training activities of the European Patent Office and is constantly working to encourage and support Intellectual Property training at universities across Europe.

Accenture is a global management consulting, technology services and outsourcing company. Combining unparalleled experience, comprehensive capabilities across all industries and business functions, and extensive research on the world's most successful companies, Accenture collaborates with clients to help them become high-performance businesses and governments. With more than 181,000 people serving clients in over 120 countries, the company generated net revenues of US\$ 21,58 billion for fiscal year ended Aug. 31, 2009.

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We have extensive relationships with the world's leading companies and governments and work with organizations of all sizes - including 96 of the Fortune Global 100 and more than three quarters of the Fortune Global 500.

In Italy, Accenture works for 15 of the first 20 financial national groups, for the first 4 insurances companies and for 11 of the first 15 industrial groups.

Accenture supports ASP because believes in high potentials: "Talents make the difference".

The greatest challenge is to build up a mosaic of different skills in order to face market request of specialization.

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The Boston Consulting Group is a global management consulting firm and the world's leading advisor on business strategy. Founded in 1963, BCG has 69 offices in 40 countries.

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Our goal is therefore to help ASP students better understand the challenges and opportunities of a consulting career. We are highly committed to develop initiatives to meet, interact and support ASP students in their growth.

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Summary

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SPH

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Waves As a Valuable Energy Source

Self Powered Floating Device for sea traffic detection, transmission and safety

PoliPante

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An integrated prognostics and logistic support system for the engines of an aircraft fleet

An integrated prognostics and logistic support system for engines of a civil aircraft fleet

An Integrated Prognostic and Logistic Support System for the Engines of a Military Aircraft Fleet

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Training to innovation in the "Alta Scuola Politecnica"

S. Benedetto, F. Bernelli-Zazzera, P. Bertola, M. Cantamessa, S. Ceri, C. Ranci, A. Spaziante, R. Zanino

The contemporary world is increasingly characterized by highly complex problems, which can not be faced through disciplinary approaches; the most significant innovations typically stem from the cross-fertilization of disciplines and are supported by collaborative processes among experts from different fields. Starting from this perspective, ASP's main challenge is exploring the field of multidisciplinary innovation; innovation certainly requires the strong expertise and solid foundations that ASP students can only obtain by taking advantage of their MSc studies; but often crucial innovation comes from the combination of different deep competences. The focus of ASP programs is the design process, a process by which complex problems are addressed and treated in order to find solutions. But what do we mean by complex problems?

In many cases, the technology to use is not very clear or it is partially unknown. Examples include designing safe and efficient systems for the discharge of toxic waste, or inventing new electronic devices to give deaf people the chance to listen without compromising some other brain functions. These problems require a good capacity for innovation, attitude to incremental designing, and multi-disciplinary expertise.

In other cases, the technology is clear but the design goals are not agreed upon. This happens, for example, when the introduction of new technological products brings about social, technical or environmental controversies; a world-famous example is the Mose system for water level control in the Venice lagoon. In such cases, designers should alternate between problem setting activity and problem solving activity for a long time before finding a solution which is "good enough", by taking into account its deployment within the surrounding environment.

Complex design is therefore an activity which deals with complex and dynamic environments, and requires considerable cognitive capacities, talent for interpersonal relations, capacity to manage organizational and communicative processes, awareness of the interests and the interactions that take place within the specific contexts, and flexibility in adapting to the cognitive processes upon which the design process is based.

The ASP program offers a series of six full-immersion, one week courses (dedicated to: innovation management and its impact upon society and environment; decision making; modeling and creativity) as well as multidisciplinary projects carried on within groups, led by professors of the two universities and with external commitment from the private and public sector (10-15 projects per cycle). This program is hereby presented in terms of its didactic principles and objectives, its organization and management, its early results and future challenges.

1. "Alta Scuola Politecnica": history, mission, organization

The "Alta Scuola Politecnica" (ASP) is a school of excellence rooted within the two major Italian Universities of Engineering, Architecture, and Design, named the Politecnico di Milano (PoliMi) and Politecnico di Torino (PoliTo). The ASP program was jointly proposed by the Rectors of the two institutions to the Italian Ministry of Education in 2004, and was one of the three schools of excellence which were selected and launched within Italy at the time (the Ministry was headed by Letizia Moratti, who is currently the city mayor of Milano). ASP is also part of the so-called MI-TO alliance, a link between Milano and Torino that extends beyond education given that the two cities have strong economic ties as well as partnerships in



Meeting of the ASP Scientific Committee, December 2009. From left to right: S. Ceri (ASP Vice Director), M. Cantamessa (ASP Board), F. Bernelli (ASP Board), A. Spaziante (ASP Board), R. Zanino (ASP Director), Yongqi Lou (Tongji University, Shanghai, China), K. Osterwalder (Rector, United Nations University, Tokyo, Japan), E. Goles (Universidad Adolfo Ibanez, Santiago, Chile), S. Benedetto (ASP Board), R. C. Armstrong (MIT, Cambridge, USA)

banking institutions and service companies, and even offer a yearlymusic festival. PoliMi and PoliTo have very similar histories, tradition, profiles and objectives; together they graduate about 25% of Italian students in Engineering and about 40% in Architecture; they also jointly manage PoliTong, a campus offering a bachelor program in Engineering in the Tongji University of Shanghai.

Being a school of excellence, ASP selects every year **150 young and exceptionally talented students** among the applicants to

THE ALTA SCUOLA POLITECNICA



the Master of Science (MSc) programs in Engineering, Architecture and Design at the Politecnico di Milano and the Politecnico di Torino. The qualification of ASP students is easily documented by a few numbers: they are chosen in the top 5-10% of their Bachelor of Science (BSc) classes, with average BSc mark above 28.5/30; about 87% of them achieved their BSc degree with an final grade of 110/110 or more. The resulting ASP Community is made up of very motivated students with a passion for innovation. While roughly 60% of students are selected among BSc population of the two Politecnici, about 40% of students are selected from different schools, and specifically 25% are foreign students from about 20 different countries; more than 1/3 of them are women. All ASP activities take place in English. ASP has been in operation since 2005, it graduated the first four cycles of MSc students, whereas the 5th and 6th cycles are currently enrolled, and the procedures for selecting the students of the 7th cycle have started. ASP is managed by an Executive Board (EB) made up of 8 professors (the co-authors of the present paper), 4 from each university, who broadly represent the various disciplines which are present in PoliMi and PoliTo.

The **mission** of ASP is to provide society with high-profile graduates combining in-depth (vertical) disciplinary knowledge from their MSc programs with interdisciplinary (horizontal) skills that are needed to work in a truly multidisciplinary environment. Such a program is offered to all ASP students, regardless of their diversity. In order to achieve this target, the two-year ASP program is built around two major elements:

- full-immersion, one-week ASP Interdisciplinary Courses, dedicated to the development of interdisciplinary expertise between the very different disciplinary backgrounds of the ASP students;
- continuous, two-year ASP Multidisciplinary Projects, developed by small multidisciplinary teams of students, academic tutors, and companies or public institutions.

The ASP program runs in parallel with the MSc programs offered by the two Politecnici; it is designed so as to minimally interfere with normal activities of MSc studies by designing the course calendar in accordance with the (hard) constraints imposed by the two universities, and by granting students maximum flexibility in project work when performing their activities. At the end of their ASP studies, students who complete the program receive a double degree from PoliMi and PoliTo as well as the ASP diploma (in 10-15% of cases with merit). Graduates from ASP have founded the ASP Alumni Association as a lively and well-connected cluster of former students who maintain strong roots to the ASP School and who periodically meet for performing cultural and social activities together. In view of their qualification, ASP graduates are expected to significantly contribute towards the development of a future class of innovation-aware top-quality professionals in Italy.

2. Focus and challenges in the ASP cultural project

ASP's main focus and challenge is exploring the field of multidisciplinary innovation. The vast majority of graduate education today focuses on specific disciplinary fields. Innovation certainly requires the strong expertise and solid foundations that ASP students can only obtain by taking advantage of their MSc studies; but it is commonly noticed that crucial innovation comes from the combination of differing and in-depth competencies. Every organization, firm or institution is aware of the fact that the chances of creating innovation strongly depend on the capability of fostering cooperation between different experts. The most significant innovations come from the openness to new perspectives, from the availability to change standpoints, and the ability to combine a plurality of expertises. As a result, the ASP cultural project, first of all, aims to complement the MSc education (120 credits) with 30 additional credits, equally subdivided between courses and projects, so as to expose its students to a multidisciplinary method for managing complex problems by fostering the capacity of ASP students to address multidisciplinary problems and tackle them in an innovative way. While the MS studies give them extensive, deep, highquality skills in focusing on a specific discipline, ASP allows the best students of our universities to broaden their competence by developing their ability to manage complexity and promote innovation. Complex problems are difficult to address but are at the same time the best opportunity for innovation and change. But what do we mean by complex problems? What are the most adequate capacity and skills to address these problems?

The focus of ASP cultural project is the *design process*, a process by which problems are addressed and treated in order to find a technical solution; this emphasis on the design process is probably the most qualifying aspect in the mission of the two universities. The term "process" designates a tension field, where the designer usually needs to move back and forth from problems to solutions many times. Designers begin by understanding the problem, which often includes gathering and analyzing "requirements" from customers or users. Once they have specified the problem and have analyzed its requirements, they are ready to formulate a solution, and eventually implement that solution.

Many standard design problems, albeit in many cases technically very difficult, are well understood and well covered; they typically fall within one technical discipline. These technical problems have a solution that can be identified by using standard design procedures and a linear problem solving method. The logic followed in this process can be represented as a chess game. In the chess game the problem is clearly given: how to checkmate the king of the opponent in the smallest number of moves and before your opponent checkmates your own king. All the actors share the same goal: winning the game. Even technical requirements (the rules of the game) are clear and both the opponents have to follow them. In standard design problems, the best designer is the one who finds out the solution first. Clearly framed problems are mostly addressed by students in their MSc studies, where learning specific technical abilities allow them not only to find good technical solutions to problems, but also to program and optimize the solving process. This strong competence is the solid background that is essential in order to approach technical problems, and it is the main asset upon which students build up their careers, once they enter into the labour market. In many cases, however, real problems are not shaped in a way that allows the application of standard design procedures for their solution. There are in fact many technical problems where the technology to use is not very clear or it is partially or totally unknown, problems that have not been addressed before, or that have been addressed without finding good solutions. Examples include the project of safe and efficient systems for the discharge of toxic waste, or inventing new electronic devices to give deaf people the chance to listen without compromising some other brain functions, or designing a seismic architecture with a good balance between safety and aesthetic criteria. All these problems share the same features: while the goals are pretty clear, technology is unclear and must be selected or discovered. These problems require a good capacity for innovation, an aptitude for incremental designing (testing many options before finding the best one), and the adoption of multi-disciplinary expertises (combining and mixing different skills at the same time).

In other cases, the technology is clear but the design goals are not agreed upon. This happens, for example, when the introduction of new technological products brings about social, technical or environmental controversies; examples include the high speed rail in Northern Italy, which improves communication throughout Europe but at the same rises local resistance due to its impact upon local environment and lifestyle; or the introduction of the Mose system for water level control in the Venice lagoon, a sophisticated technological system with possible controversial impact on the precarious environmental situation of the lagoon (both cases were used as case studies in ASP schools). Social and political conflicts emerging in connection with the introduction of these technologies cannot be simply considered as a boring noise distracting the designer from purely technical tasks, as the solution of complex problems hardly ever comes through simple technology-driven decisionmaking. When the technical solutions are not neutral, and they have to take in account a complex set of social, environmental and economic interests, they call for designers who are able to consider the existence of multiple interests and actors, who know how to negotiate with these actors and how to manage conflict situations. In such cases, designers should fluctuate alternate problem setting activity and problem solving activity for a long time before finding the "right solution", or a solution which is "good enough" by taking into account its deployment within the surrounding environment.

Complex design is therefore an activity which copes with complex and dynamic environments, and requires considerable cognitive capacities (aptitude for learning), talent in interpersonal relations (human and social interaction), the capacity to manage organizational and communicative processes, awareness of the interests and the interactions that take place within the specific contexts, and flexibility in adapting to the cognitive processes upon which the design process is based. The ASP courses seek to sustain and to enhance these fundamental skills, all of which are increasingly crucial in the development of innovation.

The issue of interdisciplinary studies in technical domains is receiving attention in many higher education institutions, and different approaches to this education framework are experimented. The interested reader can refer to [1-4] to explore some alternative approaches. To our knowledge, no University has vet tried to mix competencies from architecture, engineering and industrial design, and the majority of programs are built as self-standing curricula, not as an additional workload to a regular Master course.

3. ASP Courses

Three fundamental skills are to be considered as the most relevant ones and are addressed in the six courses that comprise the ASP program, which can be subdivided into three tracks.

• The first track focuses on providing the capacity to **under**stand the socio-technical and environmental context where innovation takes place. Such economic and social context is in a state of profound change, characterized by the progressive internationalization of innovation, production, and dis-



The ASP 5th cycle class at the 2009 Spring School on Global Change and Sustainability in Bardonecchia, including among its lecturers former Minister T. Padoa Schioppa

tribution processes. Designers are increasingly involved in projects with ever-widening ranges, and need to be aware of the socio-technical and environmental context in which innovation occurs and develops. The first ASP course is focused on the contribution of social sciences to the understanding the role of techno-sciences in the innovation process, with the aim of fostering the students' capacity of *interpreting the* socio-technical context in which innovation takes place and develops; their ability to understand how values and normative cultures shape and guide innovation and technical design; their attention to ethical issues and to the effects upon society of socio-technical innovation [5]. The second ASP course, introduced in the 5th cycle, addresses the *trade-offs* and dilemmas of sustainability by paying attention to the economic, social and ecological effects of technology for solving problems such as the world-wide energy and water supply.

• The second track is focused on the ability to manage com**plex processes**. Designing in complex environments requires the ability to mobilize and manage human and economic resources as well as organize the process in order to maximize efficiency and, at the same time, sufficiently understand needs and demands stemming from the external environment in order to reinterpret them in a non-conventional fashion, effi-

ciently interact with varied interests, and strategically transform external limits into opportunities. This is an array of skills often underdeveloped by standard professional education but which is, however, increasingly central to the process of innovation development. The third and fourth ASP courses, focusing on project management and decision making, aim at providing students with these skills; the former presents methods and cases aimed at developing strategic analysis skills, project and innovation management capabilities, skills and experience in group work, external communication capacities; the latter is focused upon the management of decision-making processes, conflict resolution, and the ability to involve external actors in essential strategic decisions. Beneath good innovative and design abilities, therefore, lies the capacity to recognize and to appreciate all the various actors and decisions involved in the design process as a whole.

manage complex problems. Complex problems require not only the ability to represent them appropriately (in a manner that is not excessively simplistic), but also specific tools to solve them. The most difficult challenge in ASP is providing an intuition about the vast diversity of the methods that can be used for approaching complex problems. Two main paths that were historically developed within our universities in order to respond to these highly challenging situations: on the one hand, a top-down approach, typical of engineering, based on the technical development of *logic models* allowing the representation and management of specific problems, and on the other hand, a bottom-up approach to the development of design skills, typical of architecture and design, based on creativity and the promotion of new visions. The two final ASP courses, focused on these two different and complementary approaches, seek to provide participants with the skills not only to understand and appreciate these approaches, but also to grasp and then possibly re-utilize the underlying cognitive frameworks.

• The third track is focused upon **paradigmatic methods to**

The table below indicates the six courses that were offered during the academic year 2008-09, ordered according to the modularization which was described above. The main academic tutors of the 6 courses are professors from PoliMi and PoliTo, with one exception (Prof. Bucchi from University of Trento).

March 17-20	Bardonecchia
5 th cycle	Winter School
April 21-24	Bardonecchia
lity 5 th cycle	Spring School
July 27-31	Sestriere
5 th cycle	Summer School
March 16-19	Bardonecchia
4 th cycle	Winter School
April 21-24	Bardonecchia
4 th cycle	Spring School
July 27-31	Torino
4 th cycle	Summer School
	March 17-20March 17-20Sth cycleApril 21-24July 27-31Sth cycleMarch 16-19April 21-24April 21-24July 27-31July 27-31July 27-31Ath cycle

4. ASP Projects

Multidisciplinary projects are the educational context where students have the possibility to apply transversal (horizontal) skills - learned through ASP courses - to complex problems stemming from real-life contexts. Multi-disciplinary projects are the most original and challenging ASP endeavour, as their structure and organization is significantly different from the classical projects offered during master studies; they offer students stimuli to concrete experimentations of how to deal with complexity in real or realistic settings - and students respond to such stimuli in a very diversified way, in some cases generating extremely good results (measured through results such as patents and publications, or the appreciation of project's stakeholders), and generally going through a very productive learning experience.

Multidisciplinary projects are proposed either by professors of the two universities (in response to a public call issued by



the EB) or by sponsor companies (i.e., companies paying to ASP fees for given services; one of them is the possibility to propose a project); they are selected by the EB by highly ranking complex multidisciplinary design problems, which can give to ASP students an ideal project setting. Projects cover the entire lifecycle of students in ASP, from "day one" (at the opening

of ASP courses), when students express their preferences on the project they like to join, until the "final exam", where project results are discussed and evaluated. In building what's becoming more and more the pattern of successful ASP projects, the following ingredients are used:

• Selecting the "right" problems and the "right" teams. Problems are chosen after a thorough selection process; they have to be inherently multidisciplinary, from the dual perspective of technical content and application context. Problems should require input from a number of technical domains, so that no single "expert" can provide a sufficiently complete contribution; they should not exist in isolation, henceforth the validity of solutions should not only depend on their inherent technical merit, but also - if not mostly - on their capability to address the requirements of a number of stakeholders, who often have conflicting views. Teams are selected on the basis both of the expected skills of their members, indicated within the project description, and the individual interest of the student on the project, as perceived after attending a short presentation (all projects are described to all students during a project presentation day). Students are matched to teams by the EB, by making sure that all students get one of their best choices, but at the same time by making sure that all required expertises are included in every team; teams normally consist of 5-6 students, and a project may be associated to one, two, or three teams; projects that are not selected by students are also discarded at this point. In the end, we experienced that students are satisfied with the matching process, that allowed students in the multidisciplinary teams to apply both the disciplinary competencies being developed in their various MSc courses and the knowledge achieved through the ASP courses.

- Having an outer organization acting as a "client" of each project. The role of external organizations is not only providing guidance and access to data and information, but most of all anchoring students to deal with real-life issues and to decision-making problems that are undertaken in reality. In most cases, external organizations perform this task very well and are driven by the belief that project results, though not immediately applicable, can be starting points for further investigation within each organization.
- Selecting a team of academic tutors with multidisciplinary competencies. The success of a project is clearly associated with the tutors' capability to provide students with diversified intellectual stimuli and multidisciplinary guidance. We have set as a requirement that academic tutors, similarly to students, should represent a variety of disciplines, and should belong to both institutions. This procedure has generated opportunities for exchanging and sharing experiences between the two universities, and has given to our students the possibility of getting advice in the various disciplinary contexts of each project.
- *Defining a coherent work-plan for approaching projects.* Work follows a given structure, starting from a study of the current state of the art, then moving to an in-depth analysis of the requirements existing in a complex situation ("problem setting"), and finally designing a solution ("problem solving"), at



least at the stage of a conceptual design and feasibility study. Many teams then go much beyond such a minimal stage, and deploy working solutions (e.g., prototypes of lamps, drug diffusion schemes based on innovative chemical substances, nanotechnology-inspired designs of gloves and home textiles, designs of intermodal exchange stations in given locations, and so on). Adoption of project guidelines provides the project teams with a methodology that is useful in avoiding the risk of "skimming the surface", without going beyond a preliminary analysis. A team's work is monitored at various phases (an "initial interview", semester-based project reports, a mid-term project presentation allow the EB to rapidly detect cases where the work-plan deviates from expectations and team work appears to be misfocused, possibly leading to a clarifying discussion with the tutors). The final objective of delivering, documenting, and motivating a design solution teaches to students that designing is the underlying competence that - despite of the obvious differences in domain knowledge - is common to all professionals in the fields of engineering, architecture, and design.

 Having two-three teams working on each project.
 After an initial period of research and analysis, generally performed together, each team must define and pursue a different direction in tackling the problem. This requirement narrows the scope of each team's effort, thus limiting the risk



of performing a very broad (but possibly inconclusive) work. At the same time, teams have the perception that the direction they take is not the only way to face the problem, but simply one of the possible alternatives; in some cases, crosscomparison between the works of different teams deepens students' overall understanding of the problem.

Asking students to manage projects "professionally", including financial resources. Teams are asked to deliver a series of interim reports and perform a mid-term review presentation. Deadlines and milestones provide participants with a structured and disciplined approach that helps in delivering results, especially since the problems at hand are very "open ended". Moreover, each student has a budget for covering expenses related to the project (e.g. for buying books, for technical visits or for attending conferences, for buying materials to be used for building prototypes, etc.). Though the amount of money is small (and sometimes remains under-spent), students must take management decisions; they understand that a lack of resources (within reasonable limits) can not be used as an excuse for not completing the work assigned to them. Besides this, students gain a hands-on understanding of the role of financial resources in performing project work.

In the five ASP cycles so far, a total of 56 projects have been launched; we are therefore in the position of attempting an ini-

tial generic categorization. Although not all the projects fit into a rigid classification, we can cluster most of them within two categories:

- "design-driven" projects
- "technology- & research-driven" projects.

Design-driven projects are characterized by extensive multidisciplinarity and a focus on innovation scenarios that are mostly unexplored from a technical, structural and functional point of view. Technology- & research-driven projects address a technological innovation scenario characterized by a narrower multidisciplinarity, where the field has already been explored through research activities, though typically less from the perspective of technology transfer and industrial applications. The two different clusters usually generate different final outcomes: design-driven projects deliver a final study that explores the problem situation, compares possible solutions, and goes deeper into evaluating the feasibility of the most promising and innovative option; technology- & research-driven projects start from a more restricted project brief and aim to deliver a feasibility study and a real application of new technological solutions.

Examples of the former include the development of complex systems with a broad spectrum of technologies involved, such as:

- Italian High Speed Railway Lines: Safety, Performance and Environmental Impact FERROVIE DELLO STATO S.p.A (I)
- Sensor-vision-enabled autonomous robotic helicopter for civil applications in urban environments - AGUSTA WEST-LAND (III)
- Space hotel design ThalesAleniaSpace (IV)

or projects concerned with the integration between architecture and engineering:

 Malpensa Airport railway access: intermodal connection with the Milan-Turin high-speed railways in the framework of the 5th Logistic Corridor – FERROVIE NORD MILANO Esercizio S.p.A - AUTOSTRADA TO-MI (II)

- Engineering and architecture for supporting sustainable development in Ecuador: the case study of Guayaquil's barrios
 UNIDO (III)
- Home Emergency Multiplicity (IV)

Examples of the latter case include the development of highly innovative projects with focused interdisciplinary, such as:

- Smart drug delivery SOLVAY, BRACCO (I)
- Environmental nanotechnologies CRF, INRIM (III)
- Integrated prognostics and logistic support system for the engines of an aircraft fleet - AVIO (IV)

The outcomes of projects of the first three ASP Cycles (2007-2009) are reported in [6-8] and available on the ASP Web site [9], together with the project books of the fourth and fifth cycle.

5. Preliminary indicators of ASP performance

A preliminary indication of the performance of the ASP students during their first cycle in completing their studies and of their current employment was performed in 2008. A similar study is being conducted now for the 2nd cycle. As a first indication of success in their studies, 88% of the students completed the MSc with 110/110 or more (59% cum laude). The questionnaire was submitted online during the spring in 2008; 64 replies were collected, i.e., 50% of the total 1st cycle ASP graduates. All of the percentages below refer to the subset of students who replied, unless otherwise noted.

Most of the students (73%) found a job in less than one month after graduation, nobody needed more than 2 months, and 17% of them had already started to work before graduation. Half of them work for a private firm, while 28% entered a PhD program, 19% work in a professional studio and 3% work in a Public Administration; 22% of them are now working or studying in a foreign country. Among ASP students who have chosen private companies and professional studios, 31% work in the field of business services, 13% are in the automotive field, while the others are in 10 different fields (including biomedical, finance, and ITC). Among the PhD students, 22% have been admitted to universities abroad. In the companies, ASP graduates are employed mainly in R&D (19%), design (19%) and IT (13%), which are typical activities for graduates from the Politecnico di Milano and the Politecnico di Torino, but some of them (34%) are also employed in non-strictly "typical roles", such as human resources, administration, finances, and retail.

The present survey highlights the capacity of the ASP graduates to find good and stable jobs, mainly in R&D or design sectors. The close contact of ASP with enterprises helps ASP students to relate to them, and the first reports on how ASP students are appreciated by companies and universities seem to be equally positive.

6. Conclusions: the challenges ahead of us

In conclusion, the ASP cultural project faces challenges in several areas: Can students who simultaneously attend different disciplinary programs find the time to work together in ASP? Can ASP work being scattered in two regions? Will ASP provide interdisciplinary skills through courses and at the same time put students at work on multidisciplinary problems without losing focus? Six years after the beginning of ASP operations, we believe that these questions are positively answered, especially by looking at the enthusiasm of the ASP Alumni association which was created to maintain the ASP community and its values beyond the end of ASP studies. More information about ASP and their Alumni Association is available on the Web sites [9-10].

The initial funding, covering the start-up period (2005-2008), was provided by the "Ministero dell'Università e della Ricerca" and has made this project possible through a significant investment. Such initial funding has now been largely used, and ASP needs renewed support. We are therefore interacting with public and private institutions – primarily the Bank Foundations of Milan and Turin (Cariplo and Sanpaolo), which recently awarded ASP substantial funding for the forthcoming three years – as well as the two Chambers of Commerce, and the so-called ASP "Sponsors", i.e. private and public companies supporting ASP through a program which was set-up with the co-operation of the career services of both universities. ASP would simply not exist without the precious financial contribution of all these institutions, and our major challenge ahead is to generate continuous and sufficient support for ASP in future years.

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SUSTAINABLE PLANNING OF HOSPITALS IN URBAN AREA



SPH Sustainable planning of hospitals in urban areas

project

The project of the new Health City that will bring together three of the most important Health and Research Institutes of the city of Milan

PROJECT DESCRIPTION

The challenge Regional Council of Lombardia approved the hypothesis of an "agreement plan" in order to realize a new health centre near Milan. It will be named the "Health City" and will be built in the area of Sacco Hospital as well as the neurological institute Besta and the national tumour institute. New compound will arise in an area of about 250.000 square metres and will have a capacity of 1.405 sleeping accommodation. The agreement plan already defines sleeping accommodation separations between the three original hospitals and the surface area percentage dedicated to research & treatment and accessories functions.

"Health city" is new function where pathology treatment is combined with scientific research, keeping singular institute peculiarity and improving research and didactics role.

The team In order to have excellent result, the architectural project must answer to many requirements structured in different levels. The focus was on welfare activities and, where relevant, the indications defined by "Metaprogetto Piano - Veronesi" (12/12/2000); these were integrated and applied into the generally analyzed scenario. According to this point of view, the activities of ASP students involved in "Sustainable planning of hospitals in urban area" included the creation of a Masterplan of "Health City" project area. Subsequently students have to integrate new structures with Sacco Hospital, so they decide where localize new structure and they have to study green area placement, road networks and traffic flows. In parallel to these activities students have to study advanced themes related with transport flow and internal layout. The last one was analyzed from a functional and organizational point of view.

The results Starting with different backgrounds, ASP students develop a consistent project from an architectural and organizational point of view.

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The "Health City" area will be subject to big development during the next few years. In the northern area of Milan, where the project is located, human resource recruitment of 25,000 people is forecasted. From an accessibility point of view, it is a good area because is well connected with northern part of Lombardia and it's nearby Malpensa.

According to the Lombardia President, "Health City" will be finished in 2015. It will offer services for a huge part of the population and it's already possible to think about an expansion of its area. The decision for the place was made in light of a potential future expansion.



TASKS & SKILLS

Alberto Barbesta worked in analyzing modularity benefits and a case study of private public partnership in Italian health sector. He studied the benefits and disadvantages of each solution applied to hospital service model.

Gloria Forini analyzed the urban environment of Milan and the project area. She studied the integration of health care buildings with research and teaching as well as environmental sustainability and modularity needs. According to the "Piano-Veronesi Model", she created a functional layout.

Chiara Giverso. A biomedical engineer with mathematical modelling skills, blended with a passion for architectural design, who developed a Matlab script to manage the position of different units inside the hospital. She then focused on the possible development of research studies and treatments and she tackled the "challenging" task of rendering the 3D layout of the hospital.

Nyree Grifeo studied the existing at present accessibility and designed the future configuration by taking into account environmental, social and economical aspects through use of the isochrone curves method.

Stefano Predebon worked in analyzing which solutions for sustainability were embedded in modern hospitals by means of a case study method and developed an analysis about the queuing system in the hospital service model.

ABSTRACT

The new health & research centre will include three specialized hospitals and will improve the public health offer in the northwestern part of Milan. The nearby A.O. Luigi Sacco, which is one of the best European centres for treating infections and cardiovascular diseases, as well as two specialized hospitals like the neurological institute Carlo Besta and the national tumour institute.

The concept for this new centre is based on the final goal for increasing customer satisfaction. The principal users of this new centre will be patients and doctors, but it will also involve researchers and students. This is due to the fact that it will be one of the most important research centres of Italy and it will include a building with educational activities.

During these months, different choices were made. In the new centre there will be three macrofunctions - "stay in hospital", research and didactic - so it was very important to decide how to manage the project area as well as select the best solution for developing a project where use of space reflects relations between these three functions. Subsequently, it was necessary to understand the best solution for all the facilities, such as the path, parking and hotel areas. Finally we focus our attention on internal use of hospital space and the goal was to respect functional relations between facilities and hospital traditional function. In this last case, we also developed a concept of hospital room which is influenced by many case studies and which aims to ensure a comfortable environment for patient.

Building flexibility was ensured by the decision to build this new centre in an area where a future extension is possible, and by the planning choice to use a module.



1 A map focusing on the main urban interventions planned in Milan

UNDERSTANDING THE PROBLEM

This part was in itself probably a challenge. We had to improve the sustainability in planning an hospital, but first of all we needed to define what represents the term "sustainability" and the way you can apply this concept to an hospital. So we pointed out three main areas through which one can develop and deliver sustainability to an hospital: Environmental sustainability - This is a key point. An hospital is firstly a building located in a city or near populated centres. For this reason, it is essential to plan fast routes of access. In addition to that - and from an architectural point of view - it must "fit" in the existing and future landscape while trying to save as many green areas as possible. Economical sustainability - Historically, a hospital is built through public financing. Nowadays this is less and less true. The increasing costs of machinery and maintenance, for example, along with a attention to cost efficiency, made private investors very active in financing organizations with a public goal. The private investors' perspective also led to a more ac-

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2 Analysis of existing functions nearby project area and of planned development



3 Insertion in existing urban context of our project (red). Combination between the new project and A.O. Luigi Sacco (blue). Main road network nearby project area. Highway (yellow). Project area functional division in research & education, care and reception

curate management of the hospital's organization. Cost saving technology were developed to minimize energy consumption or even for energy co-generation. Similarly to an industrial sector, customer satisfaction is known to bring several advantages, just as in a hospital for patient satisfaction.

Social sustainability - A hospital also plays an important social



4 Starting from a module we can obtain a couple and a vertical structure composed by couple. We finally have our main building set-up and we show potential future expansions



5 Building orientation is relevant for environmental sustainability. Our goal was to maximize the south orientation

6 A.O Luigi Sacco is blue, while new

project is red. In

order to complete

themselves, two

hospitals must be

tightly connected



7 Description of "Health City". This plan represents the application of different concepts explained in previous pictures. Focus was on building orientation, project area functional division, the flush line for best orientation and main building modularity

function. Each patient must be supported in his/her recovery process before and after receiving the medication, paying attention to the psychological and emotional sphere. A patient shouldn't feel blocked in a condition of limited autonomy but should still feel that he/she is an important part of a community.

Starting from the concrete example we have – the plan to merge the hospital Besta and the Istituto Nazionale dei Tumori with the hospital Sacco in Bovisa area, Milan - we analyzed how to improve the hospital planning process by using sustainability as a target goal.

EXPLORING THE OPPORTUNITIES

First of all, we considered the development of the hospital concept over the years, focusing on the last decades. We analyzed several case studies in order to know more about new trends in hospital planning. Members of our group travelled to the US in order to visit some of the most outstanding healthcare districts and structures of the world. What was immediately clear to us is that nowadays hospitals are mostly research oriented; as a result, a significant amount of surgical operations are performed on daily basis by allowing the patient to go back home with-

out staying overnight. This is a key concept for three reasons. Firstly, it means there is the need to manage intense inflows and outflows of people from the hospital and who are attending dayhospital services on a daily basis. Secondly, when planning the inner structure of the building one should focus on the research area foreseeing future expansions and needs. Thirdly, since the patients in the stay-in area are the ones with severe disease, the rooms and the stay-in area in general should be planned in order to help them physically and emotionally in the best possible manner. Our goal was to develop solutions about these themes optimizing the financial resources' load. Each component of our theme tackled a particular side of the problems described. Due to the broad range of perspectives involved in planning an hospital we selected some major topics. We performed:

- A detailed urban and architectural planning for the new hospital in Bovisa area, Milan.
- A study about connection and mobility between the hospital and the city.
- A function analysis to optimize the location of the departments inside the building.



• A flow analysis of the patients in order to improve the performance of the healing service for the non-medical part of the process.

In the next paragraph we will describe our contribution to these themes in detail.

GENERATING A SOLUTION

The solution we identified for the hospital as a sustainable building involves very different input. We started from our specific case about Bovisa district while studying the surrounding urban area around which is expanding quite rapidly due to the proximity of the EXPO 2015 site. We planned the site in order to have very good connections with the main street and public transport, which is essential far from the city centre. A tool used for this purpose was an "isochrones curves scheme" which depicts the distance from the hospital time-wisely. In the architectural plan, great importance was given to maximizing green areas around the building and the exposition to the natural light for both financial and patients' wellness purposes. The actual plan of the building was realized by using an AutoCAD software support. The level of detail for the architectural planning ranges from

the urban study of the area to the location of the rooms and the department inside the building. The shape of the hospital gave us the chance to introduce a very innovative feature: a modular building pattern. This means considering a "fixed shape block" as the unit for the building construction. This allow one to more easily and flexibly add new departments or areas, as required by the development of the medical science. Inside the building we decided to optimize the flow of the medical personnel by studying the interaction among departments. We solved this optimization by problem using the software Matlab and by taking into account the legislative, functional and resource-based constraints of the departments. The stay-in area was the trigger opportunity we had to perform other types of innovations. We started from planning the rooms to be comfortable with the patient meeting his/her needs like respect patient privacy and to allow a family member to stay near the inmate during the hospitalization. Our objective was therefore to shape the overall hospital atmosphere in a way that is very different from the classical model.

- Inner gardens for all the hospital modules and window observation for all the rooms to incorporate nature in the hospital building,
- Common areas for informal meetings and for patients and families groups of support;
- Natural and full spectrum lighting jointly with relaxing colours, that reduces depression and patients stress perception;

are just examples of what we intend with "hospital experience" for a patient. One key contribution over this field is a prototype study for a patient room using Sketch-up software support. Another important study on "patient experience" was performed by taking into account the waiting time, for example, to receive some information or to obtain the results of a medical check. The tool used in this case was a queue analysis. The interesting thing is that such a simple tool can be used to model a lot of processes, ranging from the dynamics of the CUP (Centro unico di prenotazione) to the workload of the doctors. It is also really useful in finding the optimal number of players involved in a process in order to minimize costs.





















WAVES



WAVES AS A VALUABLE ENERGY SOURCE



WAVES

Waves As a Valuable Energy Source



ТЕАМ В

The aim of the Project involves the design of systems capable of converting sea wave energy into electric energy

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PROJECT DESCRIPTION

The goals of this project included the analysis and the development of a wave energy converter capable of exploiting sea wave energy in order to generate electric power. Sea waves are one of the most interesting and well distributed renewable energy sources in the world. Given the current state of the art, all existing sea wave energy conversion systems are designed to operate offshore in the oceans, where the height of waves is definitely high.

The main project requirement was to design a converter able to work properly with small amplitude waves, typical of closed seas like the Mediterranean.

In accordance with the ASP projects main feature, project development required a multidisciplinary approach in order to take into account engineering, economical, environmental and public acceptance factors.

The project has been developed in two different ways by two groups of students, in order to reach two distinct targets. Both activities started from the analysis of some different system architectures, in order to find an energy conversion method with a good compromise between efficiency, cost, reliability and mooring method. Legislative constraints have been evaluated as well.

Team A focused its work on a self powered floating device, a typical stand alone application, capable of supplying several signalling, detection and transmission devices installed on the floater itself. Such an application has a low power requirement (typical power size is lower than 1 kW) and can be used both for signalling purposes in ports entry-exit, in decommissioned offshore platforms and for detection-signalling purposes in the sea highways system. The selected system architecture is based on a linear generator moved by a spring-mass-damper system that can exploit the vertical component of a wave shape. Related to the port signalling application, cooperation with the Municipality of Gaeta has been developed, up to the point of identifying potential buoy positions in the Gaeta gulf.



Team B focused on a grid connected device in order to develop a floating wave energy converter that can be connected to a grid framework constituting a sea wave farm.

The selected system architecture is based on a pendulum-like conversion device that can exploit the pitch-roll components of wave shape.

Team cooperation with the Commune of Pantelleria allowed to define the power requirement of the island and identified a potential installation position for a reduced scale prototype near the island's coastline.



Sour

ENERGY 3

VALUABLE

4

WAVES_WAVES As

Self Powered Floating Device for sea traffic detection, transmission and safety

Michele Anti focused on the technology used to convert the motion to electricity and kept contacts with stakeholders. Maria Giulia De Donno worked on data collecting, feasibility, analysed marine forces and anchoring in addition to maintaining contacts with stakeholders.

Enrico Delogu studied the mechanical system and the device design.

Andrea Ferranti focused on the environmental impact and the legislation useful for the buoy installation.

Michele Rampanelli studied the mechanical system and the marine forces, and evaluated the economical impact.

ABSTRACT

The continuous growth in the global trade of goods in the last years has increased substantially traffic intensity over land and sea tracks. The demand for safety and security is increasing together with requests for peoples' wellness and life quality.

To satisfy all these requirements, a new solution seems to be the development of a new set of sea routes with high monitoring capabilities that will allow the displacement of a large part of heavy traffic from ground routes to sea routes. This new set of sea routes is commonly called the "sea motorways system".

To develop this new transportation system, it's essential to develop the entire information-telecommunication system used for the continuous monitoring of the sea-ways system. This can be based on a network of active buoys used to outline the route as well as to acquire traffic data, transmit it to the central control system and signal the presence of obstacles under the sea surface.

All these devices need a continuous power supply and a ground electrical network wire is much too expensive, nor does it provide a flexible and environmentally sustainable solution. For these reasons it is necessary to develop an autonomous system capable of generating energy without expensive fixed foundations.

Our project focused on the development of a self-sustaining buoy, creating the most flexible device capable of generating energy and which can be used around the world while respecting all environmental and legislative issues.

Although the market currently offers solutions that use the solar panels to generate energy for self sustaining buoy, they have several disadvantages: efficiency is very low, big surfaces are needed and they occasionally enter into contact with water and other threats, such as birds. The core of our solution is the wave motion: it presents significant advantages with regard to other CO₂-free energy sources, including predictability, high power density, a high utilization factor and a low visual and environmental impact.



UNDERSTANDING THE PROBLEM

The aim of our studies is to prove the feasibility of a stand-alone device capable of floating in the sea and auto-generating the energy it needs from waves. The stakeholders of the project are the Gaeta commune and Selex. Contacts with the latter have underlined two main purposes: the creation of a basis for a sea high-way management infrastructure (Selex) and the need for lighting systems used to signal obstacles (Gaeta). The main requirements of the project can be summarized as follows:

- Economical requirements: low costs of installation and maintenance must be guaranteed in order to create a competitive solution:
- Technical requirements: the design must be flexible given that the device can be used at different locations, it can be exposed to different wave climates and the power request can vary between 40 to 1000 Watts depending on the functionality. The possibility to connect sensors, electronic devices and GPS system should be considered and the buoy dimensions must be limited; the materials are supposed to be resistant to the marine environment while heavy and fixed foundations should be avoided;

1 Active coils at time t (indicated in red)



2 *Possible installation* sites chosen with the Local Authority of Gaeta

• Environmental requirements: environmental and legislative issues need to be stressed because there is an absence of specific regulations regarding wave energy converters, particularly in Italy. In the case of Gaeta, the environmental impact should be studied in detail since the landscape of Gaeta is a perfect mixture of myth, architecture and natural environment and the coasts include a variety of natural parks and marine oases.

EXPLORING THE OPPORTUNITIES

State of the Art: The major research activity on wave energy converters has been done in Norway, Scotland and Portugal. All current technologies are created for an ocean wave environment: in this part of the world the power flow is equal to 70 KW/m and the medium wave amplitude is equal to 10 meters or more. The current technology must be changed in order to create an energy conversion system which can work within the Mediterranean wave environment.

The device proposed in this poster uses some features of wave buoys already existing in literature, in particular the device considered as a starting point is the permanent linear generator buoy designed by University of Oregon.



3 *Design of the anchor*

4 Design of the self powered floating Device





Wave Energy Converte

5 *Life cycle assessment of a wave energy converter*

The feasibility: The first challenge involved the analysis of data obtained from the station of wave measurements of Ponza, an island in front of the Gaeta Gulf. On the basis of the analysis, project-waves-amplitudes and periods were determined and it has been concluded that a medium power flow of 4.2 KW/m can be obtained from the sea. This source can be enough for the power requirement of the buoy. The morphologic features of the seabed are ideal for our project (it is characterized by sediment and sand) and the water depth is not excessive (max 120 m). Finally, a survey with the qualified authorities has been done. Their approval gave us the possibility to conclude the feasibility study and to choose some possible installation sites.

Different solutions: Three different solutions were initially investigated: one of them used the swinging movement of a preserver over the waves by integrating a pendulum inside the buoy, the second device foresaw a spring-mass system with three generators working on three different axis, the third system works due to the relative motion between the magnet (linked with a float) and the coils (fixed to the seabed).

The decision: A mixture of the second and the third device has been chosen as the definitive solution because of its simplicity, high efficiency and small dimensions. Some of its initial features have

been changed in order to optimize the power conversion efficiency and to minimize the cost of installation and maintenance as well as the risk of floating away and the environmental impact.

GENERATING A SOLUTION

The technical solution: The final design of the buoy has the form of a linear generator. It converts the vertical movement of waves to electricity. The biggest point of innovation in respect to state of the art technologies is the insertion of an elastic component between the magnet and the spires. Its rigidity has been optimized in order to increase the amplitude of oscillation due to dynamic effects. A battery to store the energy has been implemented in the design in order to allow the system to also work in calm sea conditions. Standards current and voltages specifications have been guaranteed. Some innovative features have also been introduced in the anchoring technology: it consists of a rigid body linked with the seabed with three pre-stressed cables and opportune anchors (the shape of the anchors has been designed in order to support also vertical forces, indeed commercial anchors resist generally only to horizontal forces). The rigid body is submerged and it has a medium density lower than the one of water: due to this feature, the cables are always tense and the rigid body remains fixed





with respect to the seabed. This body serves as a guide for the movement of the buoy and no restrictions are given to vertical motion: only some chains are used for security reason in the case of catastrophic events. This geometry has been studied in order to emphasis the movement of the buoy due to the sea waves. Legislative and environmental issues: Legal procedures are the same of ordinary floating devices since there is a lack of "Ad Hoc" legislation. Some influences come from different types of renewable energy generators. The device proposed has some good features from an environmental point of view: wave energy is one of the greenest technologies since CO2 emissions are relevant only in the building of the buoy and do not represent a considerable quantity with respect to the power produced during its life; the anchor technology chosen is not very invasive and can be moved very easily. The life-cost analysis shows that a lot of material and sources are saved if a self powered device is used and finally the landscape impact is very limited. Moreover, the presence of these buoys can avoid disasters such ship collisions with hidden obstacles.

The social and economic impact: As seen in the abstract, the creation of a continuous monitoring and signaling sea-ways system is essential for the future development of commerce. The proposed



8 *A* conceptual wave energy generation park and generator schematic (the permanent linear generator buoy) designed by Oregon University

technology is nowadays quite expensive (0.60€/KWh) but it shows great future potential and the costs will gradually decrease. However the proposed device has certain clear environmental and technological advantages that can justify the initial investment.

Conclusions: Our solution presents a lot of characteristics that can make it a success: the system is environmentally friendly, its shape is compact and regular, it is completely self-powered, it can be integrated directly in the existing buoys and connected with different electronic devices. The power production is in compliance with user requirements and the reliability of the system is really high. Moreover, the interest showed by politicians, professionals and common people during meetings we participated in confirmed that this project could be very well accepted by the public with great expectations.

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PoliPante

Sour

ENERGY

TASKS & SKILLS

Andrea Gulisano, involved in the mechanical analysis and followed the construction of the prototype.

Emanuele De Cartis, involved in the mechanical and electrical conversion system analysis.

Nicole De Togni, considered the environmental and social impact of the device, focusing on its interaction with the sea and on the process for its public acceptance.

Paolo Longoni, focused on the economic aspects connected with the development of the device, exploiting its future market through a business plan of the idea.

Davide Pigoli, responsible for data collection and analysis; support in the design phase.

Claudio Salerno, evaluated power outputs and the conversion system.

ABSTRACT

Marine energy production is at its very early stages. At the moment no technology seems to be the winner. The aim of the project was that of designing a device for marine energy generation which transforms the power from waves (not that from tides or currents) into electric power.

The device the team was requested to design was supposed to generate electric energy for the island of Pantelleria (maximum peak 10 MW at summer) in order to contribute to the energy self-sufficiency of the island which, at the moment, obtains energy from diesel engines, an expensive and polluting (but reliable and easy to handle) technology. The proposed marine technology does not mean to substitute the whole traditional power generation system since marine energy is characterized by a certain variability which traditional systems are able to handle. Until now, lots of different Oceanic systems have been proposed. The case of the Mediterranean is of course a big challenge given the much lower power density and peculiarity of the sea waves (characterized by a small amplitude and a high frequency).

The proposed device, which seems to be a good solution for generating electric energy in Mediterranean conditions, is a pendulum driving a shaft inside an 8m diameter aluminium buoy which rotates into an alternator generating electricity; the latter will then go through an onshore static frequency converter in order to respond to the parameters of the grid in terms of frequency and voltage.

Each device (named PoliPante) is designed to generate a nominal power of around 270 kW for 1,850 equivalent hours. The plan is to install a farm of devices for 1MW (nominal power), at a relatively small distance from the coast, taking into account environmental laws and restrictions. The whole marine would include the creation of a Mediterranean Marine Energy Centre in Pantelleria which could function as an incubator, thereby giving birth to an economic market for all small islands in the Mediterranean which have to cope with energy issues.

UNDERSTANDING THE PROBLEM

Pantelleria is an island located in the middle of the Strait of Sicily, 120 km from the coasts of Sicily and 84 km from Tunisia. Its position makes it difficult and expensive to provide traditional sources of energy, yet it offers a significant renewable energy potential. Electricity demand is about 34 GWh per year with a power peak in the summertime (around 10 MW) due to tourism. The island is not connected to the electric grid on the mainland and energy is provided by diesel generators, thereby affecting the environment in terms of consumption of raw materials, pollution, noise and risks related to fuel transport. Moreover, until recent upgrades, the power plant was subject to frequent failures. As a consequence, the Municipality of Pantelleria is considering renewable sources in order to gradually reach energy self-sufficiency, as the Major stated during our meeting on the island. The aim of our project is to develop a feasibility study about the employment of a wave energy conversion device to be integrated with other proven power technologies, both renewable and traditional. To achieve our goal, we investigated economic, social and environmental factors as well as technical issues.

EXPLORING THE OPPORTUNITIES

Like all forms of renewable sources, wave energy is unevenly distributed over the globe. The power in a wave is proportional to the square of the amplitude and to the period of the motion. While the best wave environments have an annual average power density between 20-70kW/m, the sea nearby Pantelleria offers around 16kW/m. Since waves are of modest amplitude, we focused on other exploitable characteristics, such as frequency. Data from the hydrological station of Mazara del Vallo, which is on the coast of Sicily in front of Pantelleria, report an average wave height of 1.74m and an average period of 5.44s. As we verified during the Wave Energy Seminar in Lisbon in June 2009, almost all the operating wave energy conversion systems are used in oceans where the height of the waves is definitely higher than in the Mediterranean. It is not by chance that EMEC, the main European test center we visited in October



1 Orkney Islands, 7th October 2009. The team returning to Edinburgh

2009, is situated near the Orkney Islands where waves reach heights up to 23 meters.

A initital idea we explored was to combine both the mechanical and the electrical aspects of energy generation through a linear generator buoy. Environmental constraints and power requirements forced us to abandon this kind of device given that a huge number of buoys would have been required to cover just 1 MW of power, with evident problems of costs and social and environmental impact.

A second hypothesis was then developed. based on the relative motion between a pendulum and the structure of the buoy, and finally assumed to be feasible.

GENERATING A SOLUTION

The pendulum solution is able to produce a nominal power of 266 kW for an 8m diameter sphere shaped buoy, for 1,850 equivalent hours.

The system belongs to the family of point absorbers. In general, these are floating structures which exploit energy coming from all directions through their movements on the wave surface.



3 Outer rendering of the buoy

Such a system is suitable for the integration in a power generation infrastructure or for stand-alone applications. To validate the studies we decided to build a prototype to be tested in the wave channel of the Politecnico di Torino (Dep. of Hydraulic Eng.), in order to verify the dynamics of the system and to study the real feasibility of the latter.

Despite the environmental benefits of renewable energies, a low level of public acceptance is seriously slowing down the development of these systems. On the island, solar and wind power plants are thwarted mainly because of their encumbrance and visual impact. Since conflicts mainly arise as a result of a public lack of knowledge, we considered relations and communication with the public to be a fundamental aspect of dealing in every phase of the process in order to provide all necessary information. Participation was promoted from the very early stages, and a telephone survey was made to collect citizens' ideas on existing technologies for power generation and their opinion on waves as power source.

The device will have to deal with other existing uses of the sea. Restrictions due to natural reserves, prohibition of mooring and intersections with ship routes were identified in the preliminary planning phase, conditioning the selection of the project site. Unavoidable interactions with fishing and recreational activities can be compensated, from a socio-economic point of view, by the creation of new jobs associated with the new power plant, thereby bringing economic benefits to a local community which mainly depends on tourism.

Although the Italian law about wave energy is not fully clarified yet, the device will have to satisfy the environmental impact assessment as any other power plant. Some impacts could be expected, but effects on the natural habitat and on wild flora and fauna have been minimized by paying attention to both the seabed and the coast, with acceptable noise, visual impact and effects on the hydrography.

Since the environment itself will have an impact on the device, we considered sea currents, corrosion, marine fouling and material intrusions or deposits during the design phase in order to avoid a reduction in the efficiency and failures. A visit to the CNR in Genova helped us with the collection of interesting data about suitable materials.



5 Sea-map of Pantelleria

The potential market in the Mediterranean area is constituted by more than 180 islands where the production of electrical energy is mostly conferred to diesel generators, with costs ranging between 0.30 and 0.44 \notin /kWh, up to 0.67 \notin /kWh depending on the accessibility of the site and the size of generators. Given that the wave energy devices will be complementary to the existing systems and, excluding any potential government incentives, the estimated cost will approximately total 0.4 \notin / kWh, including O&M.

The proposed solution differs from other wave energy devices because it deals with Mediterranean waves, thereby entering an innovative segment of the market with very few internal competitors given that, at the moment, there are only demonstration prototypes to be installed in completely different sea conditions. External competition should instead be carefully evaluated given that there is a wide range of substitute products, such as wind, solar or hydro energy, already at an advanced stage of testing, diffusion and acceptance, even if with a reduced possibility of improvement compared with wave power. In an organizational phase, a company conceived as a spin-off of

2 *Inner rendering of the buoy*



6 Empirical joint distribution of significant wave-height and period in Mazara del Vallo



7 Wave-height in Mazara del Vallo from May 2007 to May 2008

the Politecnico would outsource the production of the devices to specialized companies. R&D as well as the promotion and sale of the devices, provision of ancillary services prior to installation, monitoring, testing and post sales consultancy would be kept within the company. The evolution of requirements for the company would imply two different phases: a first phase lasting two years in which the device will be produced in its real dimension, development activities will be provided and the business structure will be initialized; and a second phase including the commercial launch and the starting of the production.

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IPROS



AN INTEGRATED PROGNOSTICS AND LOGISTIC SUPPORT SYSTEM FOR THE ENGINES OF AN AIRCRAFT FLEET



IPROS

An integrated prognostics and logistic support system for the engines of an aircraft fleet

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The research addresses a knowledge based system capable of assessing the health of an aircraft engine, in *addition to activating the logistic chain and minimizing the life cycle* cost

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PROJECT DESCRIPTION

The IPROS project addresses an issue of growing importance: that of maximizing up time equipment while minimizing maintenance and operating costs. The area of intelligent maintenance and prognostic-enabled condition-based maintenance of machinery is a vital one for today's complex systems in industry, aerospace vehicles, ships, automotive industry, and elsewhere. As manning levels are reduced and equipment becomes more complex, intelligent maintenance schemes must replace the old pre-scheduled and labor intensive planned maintenance systems in order to ensure that equipment continues to function. While fault detection effectiveness with very low false-alarm rates continues to improve, prognosis requirements are more ambitious and present very significant challenges to system design teams. Prognostics has the potential to be very beneficial in terms of both reduced operational and support cost and life-cycle total ownership cost of many types of machinery and systems. The evolution of diagnostic and monitoring systems for aircraft and other complex systems has led to the recognition that predictive prognosis is both desirable and technically possible. The objective of the IPROS project was to perform a feasibility study of an engine health monitoring and support system integrating engine prognostics directly into the logistics pipeline. Although different critical engine parts were analyzed, the effort was primarily focused on the engine gearbox since valuable data for this engine component were made available by the industrial sponsor. A knowledge-based system was defined as one capable of generating and integrating multiple information in order to efficiently assess the health of an engine, activate the logistic support chain and minimize the life cycle cost. All issues of an engine prognostics and logistic support system were addressed to assess its viability in managing just-in-time maintenance of the engines of an aircraft fleet and its economical benefits. The research defined the system, assessed its merits and evaluated its effectiveness when applied to actual engines. The two teams working on the project addressed different issues



of the project in a highly coordinated approach. Team A initially identified the most critical components of an aircraft engine, leading to the development of a prognostic algorithm for the fuel pump because of its high criticality in terms of reliability. Both teams then focused on developing prognostic algorithms for the gearbox by using different approaches and performed an economic analysis in order to understand the merits of the prognostic system. Finally, team B developed an algorithm for the logistic and maintenance support system in order to understand how an innovative approach can improve its economic convenience. All activities were performed for the operational scenarios of a commercial and of a military aircraft.

The research project was presented at the first international conference of the PHM society where it was well accepted and its merits recognized. The IPROS project addressed an aircraft engine, but its synergistic approach to health monitoring technologies, integrated reasoning capabilities, interpretation of fault-detect outputs, reliability assessment, maintenance and product support practices can serve as a paradigm for similar initiatives in other systems: from industrial machineries to food processing plants, from railways to marine applications.



An integrated prognostics and logistic support system for engines of a civil aircraft fleet

TASKS & SKILLS

Stefano Alneri focused on a prognostic algorithm for the fuel pump while also building an analytical model to reproduce the real behaviour of the component.

Giusy Cannone worked on the economic evaluation of the prognostic unit, focusing her attention on the development of the Discounted Cash Flow and the sensitivity analyses. Moreover, she is responsible for the review of the logistic and maintenance systems.

Marco Dondi worked on the economic evaluation of the prognostic unit, focusing his attention on the development of the Life Cycle Cost with and without the prognostic unit.

Lucrece Urielle Mekogue Dongue analyzed the different health monitoring sensors needed to obtain features which were subsequently processed for prognostic purposes.

Dejan Markovic worked on gearbox accelerometer data analysis, feature extraction and health status classification using both artificial neural networks and fuzzy logic; he also gave his contribution to the development of the software for the simulation of a civil aircraft fleet.

ABSTRACT

The area of Prognostic and Health Management is a complex engineering field undergoing rapid growth and with growing interest among academic and industrial communities. PHM combines many different aspects, technical and economic, usually examined separately. However, very little is known about the economical benefits. The objective of our research is to perform a feasibility study of an engine health monitoring and support system that integrates engine prognostics with economic aspects by focusing on civil aircrafts characterized by a scenario of use much different from the military one.

The first implemented activity was an overview of the failure modes of an aircraft engine in order to identify the most critical components in terms of reliability. The results of this analysis led to a focus on two components: the fuel pump for its highly critical state and the gearbox, in response to the investor's request.

The behavior of the fuel pump was analyzed through an analytical model because experimental data wasn't available; the decrease of the fuel flow rate to the engine is taken into account with the simulation of linear and quadratic losses. Data generated in this way are the inputs of the prognostic algorithm which exploits the minimum square method in order to reconstruct the fuel flow rate and determine the remaining useful life.

On the contrary, an analysis of gearbox failures was performed through experimental data provided by the industrial partner. In order to build a reliable diagnostic algorithm, different feature extraction and classification methods were evaluated.

In order to validate the convenience of the prognostic system, an economic analysis was implemented by comparing the Life Cycle Cost of a civil aircraft engine with and without the prognostic unit, completed by the Discounted Cash Flow Analyses. Sensitivity analyses on Net Present Values were completed in order to understand how robust the attained results actually are. Moreover – in order to consider costs related not to a single aircraft but to an entire fleet - a specific simulation software was developed.



1 *Plunger-type fuel pump of an aircraft engine*

UNDERSTANDING THE PROBLEM

Customers are increasingly expecting both reduced costs on flights and improved service performances. PHM allows one to effectively respond to these interconnected needs. A typical PHM architecture consists of: remote monitoring, data pre-processing, feature extraction, anomaly detection, diagnostics and prognostics followed by logistic decisions. Remote monitoring is implemented by placing different sensors in strategic locations on the engine; data pre-processing consists of all operations on raw sensor data prior to feature extraction; feature extraction is one of the most critical steps as it aims at extracting features that prove to be good enough for the following diagnostics and prognostic steps; anomaly detection consists in determining if the system operates by normally observing the features; if abnormal operation is detected diagnostic step determines the type of fault that has occurred; prognostics consists in determining time to failure (TTF) i.e. remaining useful life (RUL); by knowing the RUL, logistic decisions can be made (e.g. optimal maintenance and inventory management).

Furthermore, the prognostic system has to be justified by a reduction of costs that may allow for the offering of a more competitive offering to customers. This is a crucial issue in a competitive environment as the aerospace industry. Consequently, it is necessary to develop a Life Cycle Cost (LCC) model associated to costs of faults and maintenance in order to evaluate the comparison made between the situation without and with the prognostic unit.

2 Analytical 1D model for simulating the real behaviour of the fuel pump of an aircraft engine

3 Analytical 1D model for the reproduction of fuel losses of the pump

EXPLORING THE OPPORTUNITIES

The failure mode analysis of a civil aircraft engine revealed that the fuel system (fig. 1) has a high probability of failure; this result is due to the fact that, when fuel filters are out, they are bypassed in order to allow the transit of fuel toward the engine. Hence the fuel system after the filters receives impurities. Thus its behaviour was investigated through an analytical model (fig. 2); linear and quadratic fuel losses were reproduced (fig. 3), including sudden performance falls. This model aims at simulating the supply and measurement of fuel flow rate (FFR), which was identified as a good estimator of the health of the pump. In real applications, the FFR can be detected by monitoring the differential pressure across a restrictor positioned after the pump.

Moreover the industrial partner provided a dataset for gearbox fault analysis. This data consisted of six raw data values: four accelerometers, torque and pickup, all acquired during both healthy and faulty engine work. In order to acquire the vibration data, several types of accelerometers - piezoelectric, piezoelectric with internal electronics, piezoresistive and variable-capacitance, differing in performance, power requirements, uses and signal-conditioning characteristics - were considered. Accelerometers sense motion and produce an electrical output proportional to the magnitude, frequency and amplitude of the input. After the processing of electrical-based data, the first step was to extract features that are capable of capturing the differences between healthy and faulty system conditions and which can therefore be used for the



4 *Computation of the residual useful life of the pump (yellow line) during the mission*



5 *Accelerometer used to acquire* vibration data





6 Transducer used to monitor pressure difference among the fuel pomp

7 NPV sensitivity analysis on the MTBF of the prognostic unit taken as given the values of ATO and UER costs. The PU should increase its performance from 10'000 EFH to 16'500 EFH to reach the BEP

GENERATING A SOLUTION

On one hand, the differential pressure transducer (fig.6) selected to monitor pressure includes an all-welded stainless steel enclosure in order to avoid corrosion and harsh environmental contamination as well as external material damage and warranties a high Mean Time Between Failure rate. On the other hand, the data created by the analytical model of the fuel pump was used as input in a simple prognostic algorithm for the computation of the remaining useful life of the pump. This algorithm determines how many flight hours remain before the substitution of the component, reconstructing the FFR trend with the minimum square method (fig. 4). Moreover the computation starts after the FFR decreases under a tolerance value.

Extreme heat environments of gas-turbine engines have increased the choices for a piezoelectric accelerometer (fig. 5) which is a hugely rugged high temperature device for gearbox vibration acquisition. For this data, the diagnostic algorithm built followed the aim of adding some prognostic features. As a result, the classification algorithms were trained to distinguish four different



8 Main window of the software developed to simulate failures for an aircraft fleet

classes of gearbox health status: class 1: no failure, engine gearbox is healthy; class 2: failure present for less than 2 hours; class 3: failure present between 2 and 5 hours; class 4: failure present between 5 and 11 hours. While more experimental data would be necessary to improve the training process and to more accurately validate its performance, the resulting diagnostic algorithm showed high classification accuracy on the available data set. The model developed to evaluate the economic convenience of the prognostic system is a generic LCC that can be modified according to the nature of the data available. After developing the generic model, a specific application for data provided by Avio was developed.

The model can be divided into two parts: situation As-Is and situation To-Be. The first part consists in identifying the failure rates and accordingly the most suitable probability distribution. After that it is possible to calculate the average number of failures during the life cycle; this allows one to evaluate the total costs of failures and maintenance during the life cycle. The same reasoning holds for the second part where the prognostic unit is introduced.

classification. Two different types of feature extractions were considered: mean value and variance and Spectral analysis. The mean value, variance and spectral analysis were calculated in different time intervals and then combined with two different classification methods: Artificial Neural Networks and Fuzzy Logic. The different combinations of features and classification methods have been compared in order to choose the one with the best performance. To assess the economic evaluation, different models can be developed. The same LCC model is heavily dependant on the assumptions done on the failure rates. The model that can be applied to Avio data is based on constant failure rates. Nevertheless, this assumption may reveal some critical issues; an approach considering failure rates following a Weibull distribution may be more realistic. Moreover a LCC disregarding the change on the Maintenance and Logistic support policies reveals some shortcomings. Intervening on the maintenance and supply chain policy is a crucial point to improve the economic convenience of the prognostic unit through the introduction of predictive maintenance and a JIT logistic support system.



9 Scenario of expected planned flights for the fleet under analysis

This unit modifies the model through the addition of costs related to the unit itself but also because it decreases costs by converting serious failures into less expensive ones due to the ability to intervene in advance.

Finally – and in order to fully evaluate the profitability of the investment - the Net Present Value was calculated. Results obtained are heavily dependent on assumptions made on failures rates and costs, hence sensitivity analyses were completed in order to understand to which extent the prognostic unit has to improve its performance to be more confident on its convenience (fig 7). Finally, to investigate the economic impact of the prognostic unit in more depth for the case of an entire aircraft fleet, a dedicated software (fig 8) – capable of evaluating not only the average Life cycle cost but also its distribution - was developed (fig 9).



An Integrated Prognostic and Logistic Support System for the Engines of a Military Aircraft Fleet

TASKS & SKILLS

Federico Canova. As a management engineer, he is responsible for the Life Cycle Cost model. He calculated the total cost of a prognostic system implemented on a military aircraft.

Daniele Cavaglieri, Mattia Vismara. As mechanical engineers, they cooperated in order to develop a Bayesian prognostic algorithm for estimating the Residual Useful Life of mechanical components integrated with logistics and maintenance operations.

Francesca Licandro. As a management engineer, she is responsible for logistic aspects regarding the analysis of operations and maintenance activities.

Bojan Markovic. As an electronic engineer, he is responsible for the development of software capable of simulating a scenario concerning military aircraft fleet operations.

Giuseppe Randazzo. As an automotive engineer, he analysed the feasibility of the use of oil debris sensor for prognostic purpose and developed a diagnostic algorithm for gearbox failures detection.

ABSTRACT

The main purpose of IPROS project is to assess the feasibility of an information system that is capable of producing, gathering and elaborating plentiful information in order to lead military MRO (maintenance, repair and overhaul) activities and to obtain substantial savings in operations, logistics and overall LCC (life cycle cost). To achieve this goal, several methods were analyzed in order to determine the optimal approach to assess the RUL (remaining useful life) of an aircraft engine while focusing, more specifically, on engine gearbox components whose experimental data were provided by Avio. The project seeks to appraise whether the implementation of a gearbox prognostic system - developed by Avio and based on vibration analysis and in-line oil debris monitoring - will lead to a reduction of the engine life-cycle cost and thus worthy or not to be implemented.

To claim the feasibility of such a prognostic approach, an economical assessment is needed by developing an LCC model connected to the entire logistics support system. Specifically, the present study includes an analysis of the impact of the RUL estimate on maintenance and logistic activities. As a consequence, it is possible to define the number of spare parts needed and the location where the maintenance activities have to be performed and then eventually leveraging the inventory into a JIT approach. The economical analysis is based on the simulation of Eurofighter fleet operations.

The overall results show how costs related to MRO can decrease through an effective and efficient prognostic that is capable of turning unscheduled events into scheduled maintenance activities, which allows a better performance in the logistics operations standpoint and an increment of aircraft availability and safety.

UNDERSTANDING THE PROBLEM

The project is primarily based on data and information provided by Avio, hence more emphasis was given to the gearbox. In particular, the company asked the team to develop a LCC model to appraise the economical feasibility of implementing the EPU (engine prognostic unit) system on a military aircraft. Actually, this work is unique because there are no studies in literature which focus on such a multilayered issue involving both technical and economical aspects. However, the complexity of this project arose concurrently with the development of the LCC itself and led to a deeper understanding of the issue. Indeed, the reduction of the gearbox LCC involves not only the prognostic system but also the entire logistic support system. In other words, logistics operations should be manipulated on the basis of information on failure prediction. A research study was conducted in order to investigate current maintenance and logistic policies in order to figure out potential improvements regarding the art in aeronautical diagnostics and prognostics.

EXPLORING THE OPPORTUNITIES

Recently, military MRO policies have changed dramatically due to the new way of doing conflicts (humanitarian and nonlinear battle missions) and to Army's willingness to reduce the overall costs. Five overarching goals reflect this new scenario: high availability, high reliability, low maintenance costs, low LCC and effective supply support. A thorough study of these objectives illustrates the mutual interconnection between logistics, engineering, maintenance and operations and the relative links are extremely strict. Typically, logistics activities are primarily defined by operational goals but engineering and maintenance contribute consistently. Delays can be reduced through improved prediction of malfunction via diagnostic and prognostic tools in order to reduce unscheduled maintenance. Accordingly, the first goal was to identify a diagnostic algorithm that was capable of identifying and monitoring bearing failure conditions of a gearbox by using data collected by a specific oil debris monitoring system. Several detailed studies were conduct-



1 *System under study: AVIO accessory gearbox for military airplane engines*

2 Critical component addressed for the analysis: Gearbox Bearings



ed in order to evaluate, first of all, the influence of the oil system architecture and components characteristics on the data analysis method to be used and, secondly, the significant types of data capable of identifying the failure and thus defining the algorithm. The data experimentally collected and used for the analysis and the algorithm definition refer to both healthy and faulty system conditions. Raw data have been elaborated in order to extract signals features helpful for health monitoring. Various algorithms types have been evaluated in order to assess their capacity in performing such diagnostic task.

An efficient and effectiveness prognostic leads to proper maintenance and consequently it provides a reduction in LCC, whose estimation was the first goal assigned to the team. Consequently, a LCC model had to be developed with the aim of estimating costs associated with the faults and maintenance of a military aircraft gearbox in addition to evaluating the economical impact deriving from the introduction of PHM. In order to have a benchmark, former studies have been carried on to characterize the situation as-is, defining the most important input parameters and developing a sound LCC model. Subsequently, the impact of the introduc-

Introductor

Logistics



3 Oil debris sensor used for fault detection and health monitoring of bearings





4 Patterns of total ferrite particle mass for healthy and fault conditions

5 *Time progression of one of the features used for diagnostic purpose*

tion of a prognostic unit on LCC has been analysed by assessing which available cost data were to be taken into account as implementation costs and potential cost avoidances linked to PHM use. Another issue to be discussed was the role of uncertainty.

As mentioned, maintenance contributes significantly to the reduction of total costs; an appropriate maintenance concept must be tackled on a holistic standpoint that includes mutual relationships among all involved variables. Hence, the most challenging objective of the project was the definition of a fully integrated approach that could consider technical, economical and operational issues concerning the implementation of a predictive maintenance policy. In order to accomplish this task, an extensive preliminary literature review has been performed. As for technical issues, the review focused on understanding the typical failure modes of mechanical components and their related degradation patterns. Thereafter, the research objective shifted to the analysis and selection of the most suitable predictive algorithms which are commonly applied on the degradation patterns reviewed in the previous step. What is found from the literature review is that only a few attempts have been done in order to integrate all the issues mentioned before. Furthermore, those studies which focused on defining optimal scheduling in a predictive maintenance scenario failed to consider the dynamic aspect of RUL estimation and maintenance scheduling.

GENERATING A SOLUTION

The IPROS project for military applications came out with an overall solution involving all the aspects discussed until this point. In particular, a diagnostic algorithm based on the use of features thresholds and capable of detecting failure conditions was developed. In addition, a polynomial weighted equation which allows the merging of the data coming from the different features was used. The choice of developing this type of algorithm was due to its capacity to generate significant diagnostic results by using meager experimental failure data unlike what occurs with neural network-based and statistic-based algorithms. However, the algorithm thresholds and weights can be updated as more failure data become available; hence its performance can be compared with that of statistical based algorithms. This algorithm is easily adaptable to analyze other types of fault and can also distinguish between different system anomalies. As a consequence, its ability to detect failure conditions - several hours before catastrophic bearing failures - was demonstrated, thereby leading to potential reductions of its maintenance costs.

The previously described prognostic algorithm is an example of a common source of data for a LCC model since it provides information such as the remaining life of the component. The project proposes a LCC framework, which is a statistical model based on reparable systems' reliability theory. The resulting LCC gearbox



6 Military MRO Flow



11 RUL Probability Density Functions

has been refined through a DCF analysis which provides indications about the economical convenience of the PHM investment by means of a largely used index as NPV. Within this scenario, the role of uncertainty has been dealt with by performing sensitivity analyses on the most relevant parameters and assumptions used in the model and by developing a software solution which uses Monte Carlo methods. Finally, the LCC model has been applied to the Avio gearbox in order to compare the present LCC with the one deriving from the introduction of PHM. Although the developed LCC model is application-specific and not exhaustive, it provides a first conservative estimate of the economic impact of PHM and has a good degree of flexibility, making it easy to adapt to different business cases.

Finally, a broad solution capable of taking into account all the most important factors occurring in the MRO system was proposed. It is based on the physically and experimentally proved assumption that in every mechanical component subject to failure we can find a feature or an health index with a degradation pattern which evolves exponentially. Therefore, we created a set of exponentialshaped patterns with variable coefficients. This set was then used to determine a priori RUL probability function that is updated through a Bayesian algorithm which re-estimates the RUL probability density function as the exponential pattern evolves in time. An RUL prediction was completed in order to find optimal con-

IPROS AN INTEGRATED PROGNOSTICS AND LOGISTIC SUPPORT SYSTEM FOR THE ENGINES OF AN AIRCRAFT FLEET AN INTEGRATED PROGNOSTIC AND LOGISTIC SUPPORT SYSTEM FOR THE ENGINES OF A MILITARY AIRCRAFT FLEET



7 Maintenance as Part of



8 NPV probability distribution



9 Exponential Degradation Pattern



10 Mean RUL estimation by using Bayesian approach at different time steps



12 Maintenance Cost Function Components

ditions for scheduling and performing prognostic-based maintenance tasks through a cost function minimization. To assess the related potential benefits in case of a military aircraft operational scenario, we set up a discrete event simulation based on a Monte Carlo analysis. In realizing the simulation, a degradation pattern was associated with each aircraft and the Bayesian algorithm described above was iteratively run to simulate health sensor monitoring and real-time RUL estimation for optimal maintenance scheduling. Through the results of the simulation we obtained the LCC, availability, maintenance and fleet performance distributions in both scenarios.

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ORTHOROB



ORTHOPAEDIC SURGERY AND ROBOTICS



ORTHOROB **ORTHOpaedic Surgery and ROBotics**



ТЕАМ В

The project, in conjunction with Galeazzi hospital, aims developing *a robotic system for cutting masks alignment during total knee replacement surgery*

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PROJECT DESCRIPTION

The challenge In total knee arthroplasty (TKA) procedures, the surgeon is required to correctly orient the cutting guides to ensure the surgical operation outcome. Navigation systems and medical robotic systems are becoming part of surgical practice, but they are still not easily accepted in clinics due to their disadvantageous cost benefit ratio: they offer solutions which are too high-tech for the surgical requirements without meeting the safety and economic constraints. The Orthorob project is aimed at providing the surgeon with a robotic assistant which holds surgical tools in the correct position while surgical cuts are being performed. The idea is to totally reconfigure present robotic assistants in order to design a newly conceived system which could be smoothly integrated in the operating room and easily accepted by surgeons. As a result, the system has to be modular, flexible and adaptable to surgeons demands, not cumbersome but safe and reliable and, above all, should permit mini-invasive access to the surgical field.

The teams The project is divided in two sub-projects: A and B: project A is dealing with aspects related to the patient-robot relationship, while project B is dealing with the robot-surgeon interaction. In this framework, the know-how of the people involved in both the teams guaranteed that all the aspects related to: requirements and specifications collection (biomedical en-

- gineers)
- design and implementation (electronics, design and automotive)
- results dissemination (all)

 market analysis and products exploitation (all) can be accomplished in both the sub-projects (A and B) during the project duration.

The results The team working for project A designed an integrated system for patient limb immobilization during the surgery and for attaching the robotic arms bases. The arms, newly conceived light weight components, hold the surgical instru-



ment and the optical cameras for objects localization. In order to increase patient safety (in the patient-robot relationship field), the team also worked on a robust robot - optical system calibration routine and implemented a contact sensor that prevents the robot movement in case of impact with the patient. The sensor was tested in the laboratory and proved to be robust under minimum contact (estimated delay was accepted).

The team working for project B worked on a system which aimed to increase surgeon acceptance of the robotic device in the operating room. In order to do that, they developed an augmented reality environment where all Orthorob devices are simulated and can be used in a virtual room with a virtual patient. The surgeon is interactively taught how to perform robotic assisted interventions.

Further developments could be directed towards the application of the innovations proposed for other surgical fields in order to increase the exploitation of engineering technologies in clinical training and in therapies.



ROBERTO

TASKS & SKILLS

Simone Allazetta developed an innovative surgical table in which it is possible to integrate both the arms of a polyvalent robot as well as a system of immobilization for the leg during total knee replacement surgery.

Michele Bancale studied both surgeon and patients needs in-depth as well as the reasons why other robots fail in order to develop a truly innovative project. He developed the robot by making all innovative solutions work while considering ergonomics and feasibility.

Cesare Buffa was responsible for the introduction of a new sensor suitable for checking the forces applied to the robot in order to stop it if a specific threshold is reached. He realized and tested a prototype of this contact sensor.

Antonio Russo focused on the development of a calibration algorithm, suitable for guarantying safety and checking the robot position. He also studied the needs and requirements of stakeholders involved in the project.

Francesca Russo worked on a new mechanical approach for the robotic arm in order to reduce weight of the robot hardware and increase the safety and freedom of motion of the surgeon in the operating room.

ABSTRACT

Medical technologies and surgical improvements have developed so much during the last decades that a lot of treatments can be undergone easily; nowadays some highly risky operations have become routine owing to modernization and innovation in medical facilities. Computer Assisted Orthopaedic Surgery (CAOS) is a type of surgical procedure where computer technology, wireless or optical tracking and robotics are applied pre-, intra- and post-operatively to achieve the best possible outcome for the operation.

Our main aim was to focus on the relationship between the robot and patients: improving a robot's characteristics means that we would like to guarantee - at the same level - more safety for patients, a faster recovery and a more comfortable operation. The introduction of our innovative model can only be justified by obtaining a balance between costs (economical for the hospital, physical for patients) and real benefits achieved, in terms of space saving, easier work for the surgeon and a patient's condition which is really improved.

The team developed an innovative concept for an orthopaedic robot integrated into the basement of an operating table. Its name, ROBERTO, has been chosen in reference to our external tutor's name and it means "ROBotics with Enhanced and Renewed Technology for Orthosurgery". ROBERTO is the medium between the surgeon and patients so it can not fail. Patient's safety is such an important aspect in our vision that the entire project focused on the relationship between the robot and the patient. All its aspects will be discussed in more detail while highlighting why our idea may be applied as a winning strategy in the near future.

UNDERSTANDING THE PROBLEM

Robotic surgery is a growing field: from the latest statistics, more and more people are aging and for this reason they require surgical operations, particularly for bone problems. The task given to our group was to focus on the relationship between the robot and the patient in order to guarantee safety for the latter. The preliminary activities we took part in were dedicated to give us a brief but complete overview of the state of the art of the technology. We started by analyzing the current available robots (da Vinci, Robodoc, MakoPlasty) as well as their strengths and their limits: from several interviews with surgeons, we understood that in the surgical room there is a problem of lack of space. We have to consider that at least the surgeon, the anesthetist, and two or three assistants are required beyond, of course, the patient. The new robot should not be a hindrance for the surgeon; it should be easy to sterilize and, above all, easy to use. Surgeons are in fact quite lazy in understanding and applying new technologies unless it represents a real and equal advantage both for their work and for the patient's health. On the other hand, we must consider that there are a lot of costs associated with introduction of the new robot : first of all, the initial investment on the new technology. Secondly, costs for training both the surgeon and his medical equipment. Finally, maintenance costs for the new robot (sterilization, disposable). For this reason, a balance between costs and benefits must be attained in order to obtain the best result

EXPLORING THE OPPORTUNITIES

First of all, we analyzed the possibility to improve some already existing models. Starting from literature analysis, we understood that we had to guarantee more safety for patients while reducing at the same time both robot dimensions and the risks associated with its introduction. We initially focused on a robot suitable for industrial applications, available in our laboratory, to have an idea about how it really works. Our main difficulty was to think of something new and to apply it to a model that is not directly suitable for



1 Mechanical structure of Biorob project

a surgical operation. However, it was a good starting point, letting us become more familiar with the problem: we were able to perform some tests in terms of calibration as well as design and test a contact sensor in order to get an idea of the materials used while becoming conscious about how much space is required not only for the robot, but also for its relative control instruments (for example, the tracking system).

It was at this point that we understood something completely new was required: according to us, it was not useful, or at least quite trivial, to modify something already in existence. We would like to make a real innovation in terms of robot design, new operating table conception and space saving while making the surgeon's work easier but above all improving patients' conditions.

A new idea is in fact a successful idea when it can be applied, guaranteeing benefits that overcome costs. With this in mind, we tried to design a new model of surgical robot by making it not only smart in terms of its design, but above all functional in terms of safety for patients.

GENERATING A SOLUTION

By analyzing both the problems associated with the use of an industrial robot in an operating room and the requirements demanded by investors and stakeholders, we proposed an innovative solution in which the robot is fully integrated into the operating table.





2 Side view of Biorob structure

3 *A light weight structure: the tendon actuation approach*

The name of this system was chosen as "ROBERTO", meaning ROBotics with Enhanced and Renewed Technology for Orthosurgery, with the purpose of highlighting the most important concepts in our solution.

The specific requirement of having a system of immobilization to allow for registration during total knee replacement surgery demands system for fixturing the entire leg. Hence, the design of a system for fixing the hip, the knee and the ankle was performed in an innovative solution, integrated into the surgical table.

Particularly, knee fixing, the most critical one, is performed by inserting a legs section in the surgical table, thereby supplying the necessary mechanical stability. All these systems of immobilization were designed by considering the required movements during an operation of total knee replacement.

The different parts constituting the surgical table were also planned: the table-top and the support column. The latter becomes the most important element inside the entire structure because it is the seat for the arms of robots performing the surgical operation.

With regards to the robot, we improved an existing industrial

robot in order to enable it to perform a total knee replacement. The most important requirement of the robot was the safety during the robot – patient interaction in an operating room. When designing the robot arms, the possibility of a polyvalent solution was taken into account. To attain this objective, the possibility of inserting different surgical tools on the different arms of the robot was evaluated, thereby enlarging its market. One of these specific arms was conceived to be the seat of a force sensor capable of detecting collisions between the robot and surgeon. We have chosen, for the robotic arm, a mechanical approach that is called 'tendon actuation approach'. This technology was used for the construction of the Light-weight robot. The concept has four arms that come out from the base following precise movements that do not unduly interfere with the surgeon or with themselves. We know that such a structure implies high production costs because of its totally innovative structure, and for this reason, we thought about the technical aspects that make it highly flexible.

The main elements that compose our ROBERTO are briefly described here.



4 Side view of our innovative robot; the fou arms are inside the basement



8 *Top view of the robot which is integrated* in the operating table

In order to perform a total knee operation some specific tools need to be used and stood by the four arms:

- the mask for the cuts
- a saw
- a stereo camera
- forceps or an aspirator

All these instruments could be used at the same time, according to what the surgeon requires. They should be conceived in terms of better fitting and adapting to the new arms. Of course, more instruments suggested by the surgeon may be added in the future. The idea developed is potentially innovative: as a future development, it could be possible to ask some manufacturing industries (MAKO Surgical Corp, Acrobot Company Ltd) about the possibility of large-scale production. It would represent the best possible conclusion for our project.

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5 The frame (skeleton) of the new operating table



9 *A* control console and a display are available on the operating table too



6 *Side view of our innovative robot. All the* arms are ready to start an operation



10 *Zoom on the arms of the robot which are* **11** *Another view of the operating table* ready to work on a patient's knee



7 *The four arms that stand the mask for the cuts,* a saw, a stereo camera, forceps or an aspirator



which includes the robot

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VirtoRob Project

TASKS & SKILLS

The team members work and interact in different phases of the project roadmap:

- Research on the state of the art: **all members**
- Surgical procedure and error modelling: Alberto Recalenda, Marco Diego Vittori
- Training process, human aspects and graphics: Keren Relin
- Augmented reality: Mauro Brenna, Marco Vergani

ABSTRACT

The primary objective of Team B has been to analyze the cooperation between the surgeon and the robot during a Total Knee Arthoplasty (TKA) surgical operation. The students of team B tried to detect some of the key issues of the human-machine interaction for this application as well as develop innovative solutions for these challenging problems.

In the context of the literature review, our team discovered that only a small percentage of orthopaedic surgeons all over the world use robotic systems to perform TKA while others simply choose to perform the classical manual operation. The principal reason for the lack of popularity of robotic systems in TKA surgery is trust: surgeons are more confident with traditional manual techniques. The robot is often only considered a machine, an advanced technological tool that does not fit in an operating room.

The solution proposed by team B concerns a virtual environment to perform simulated TKA with the aid of robotic systems. The simulated environment is independent from the robot used, making it possible to perform simulations and comparisons by using different systems.

This solution is based on a newly developed technology named augmented reality.

The basic concept behind augmented reality is straightforward: by equipping a surgeon with a webcam, it is possible to reconstruct the scene captured by it and to transfer this information to a PC. Moreover, by wearing head-mounted display, the surgeon can see the real scene with some virtual objects added by the PC. In particular, great attention is given on the training of novice surgeons.

For this application a simulated environment should provide different levels of abstraction, thereby allowing a learning-by-doing process. This approach ensures a soft learning curve by introducing in a step-by-step way all the complex issues of performing a surgery with a Computer Aided Orthopaedic Surgery system.

UNDERSTANDING THE PROBLEM

Research about Computer Aided Orthopaedic Surgery (CAOS) systems has experienced a huge expansion during the last ten years. From a merely technical point of view, a current standard robotic system can easily assure a level of accuracy and reliability which is fully compatible with the specific needs of orthopaedic surgery.

Orthorob Team B (in collaboration with team A) focused its research on the state of the art of Total Knee Replacement surgery with the aid of a robotic system. In the context of the literature review, our team discovered that only a small percentage of orthopaedic surgeons all over the world use robotic systems to perform TKR while others simply choose to perform the classical manual operation. The principal reason for the lack of popularity of robotic systems in TKR surgery is trust: surgeons are more confident with traditional manual techniques. In addition, the great majority of surgeons report that the use of a robotic system is a loss of time because it extends the duration of the operation without providing any advantage. In fact, results in the manual re-aligning of the mechanical axis of the leg are considered satisfactory. There is no clear evidence of improvements achievable through the use of robotic systems because of a lack of data due to the need to monitor the patient for a long period of time after the operation. Moreover, the use of a robotic system implies an additional loss of time because the system must compute a calibration step to fix the reference frames between the real world, the robot and the leg of the patient. The robot is often only considered a machine, an advanced tecnological tool that does not fit in an operating room.

EXPLORING THE OPPORTUNITIES

The team had the possibility to visit the operating theatre and to interview the surgeon Roberto D'Anchise. Some crucial points emerged from these meetings:

- The robotic operation should last at most 15 minutes more than the traditional one;
- The use of CAT (Computed Axial Tomography) should be



1 *The firewire Unibrain Fire-i digital camera used in the experiment*

avoided because of time limits, radiations, the need for reservations and budget constraints;

- Robotic precision should be demonstrated to be higher than a manual operation;
- The robot should only place the cutting mask correctly; no other tasks should be performed: in particular the robot is not allowed to perform any surgical operation;
- The choice of a robotic manipulator is preferable.

In particular, our team focused on the interactions between the surgeon and the robot by focusing on the surgeon and design a service that fits his needs.

In this view we investigate the possibility of the use of virtual reality in the surgical field. On the basis of the interviews we have learned that:

- it would be interesting to use virtual reality to learn how to perform the robotic operation;
- it could be a good idea to use virtual reality to help novice surgeons practice the robotic operation, without forgetting the importance of knowing how to perform manual operations;







2 An example of Augmented Reality. The 3D model of Kawasaki manipulation with the cutting mask is positioned on the table. During the motion the object remains fixed in that osition. All computation is done in real time



3 An example of Augmented Reality. A plane is detected in the image and the 3D model of the robot is placed consistently over it in real time

• it would be useful to train other members of the staff in the operational theatre as well.

GENERATING A SOLUTION

From these observations derives the solution proposed by team B, which concerns a virtual environment to perform simulated TKA with robotic systems.

The simulated environment is independent of the utilized robot used, making it possible to perform simulations and comparisons by using different systems.

This solution is based on a newly developed technology named augmented reality.

The basic concept behind augmented reality is straightforward: by equipping a surgeon with a webcam, it is possible to reconstruct the scene captured by it and to transfer this information to a PC. Moreover, by wearing head-mounted display, the surgeon can see the real scene with some virtual objects added by the PC.

Intra-operative use of augmented reality has been already reported in literature. Splechtna et al. (2002) developed a system which is capable of displaying CT images on the body of the patient with the aim of accurately locating pathological tissue before performing incisions.

By applying this technology, Orthorob Team B proposes the novel use of the simulation environment with coexistence of real and virtual objects.

Gloves can be used to improve the simulation by giving tactile feedback to the surgeon and by expanding his perception beyond the visual sphere. The technology of gloves for virtual reality is well established, and gloves suitable for this application can be easily found on the market.

Great attention is given to the training of novice surgeons. For this application a simulated environment should provide different levels of abstraction, allowing a learning-by-doing process:

• Theoretical presentation of CAOS systems in order to explain how a robot can improve the results of the surgical operation.



4,5 An example of Augmented Reality. The images captured by the webcam are reprojected on the monitor. Two eves are inserted consistently on a keyboard. During motion the object are fixed in that position. All computation is done in realtime

The aim of this phase is to make the surgeon aware that he can improve his technique and performance by using the robot; • First levels of simulation: in these phases the entire patient, robot and tracking system is virtual. In this way, the surgeon, by performing the operation in a controlled environment, can not be accidentally injured by the robot, and he begins to learn the practical fundamentals of TKA (Total Knee Arthroplasty); • Last levels of simulation: in these phases, the surgeon experiences a situation in which the patient is virtual, but all the other objects are real, even the robot.

This approach ensures a soft learning curve, introducing all the complex issues of performing a surgery with a CAOS system in a step-by-step manner.

Orthorob Team B strongly believes that a generation of surgeons trained with this kind of tools will be much more confident with the CAOS system and will be aware that robots represent an opportunity for improving their professional performances. This

would be a great improvement in the surgeon-robot relationship and represents the primary objective of Orthorob Team B.

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SHARITAGE



CREATING A PLANNED AND PARTICIPATORY FORM OF CULTURAL HERITAGE MANAGEMENT



Sharitage

Creating a planned and participatory form of cultural heritage management

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project

A conceptual proposal for a participated preservation of architectural heritage. Parties involved: Comune di Milano and Soprintendenza per i beni architettonici

ΤΕΑΜ Α

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PROJECT DESCRIPTION

The challenge In a new perspective of the value of the past, the preservation domain is being enlarged by a strong increase in the types of artifacts being considered worthy of protection and conservation: in addition to monumental high-style architecture (traditionally the preservation concern) many new categories of sites are now recognized as equally meritorious: cultural and natural landscapes, historic towns and villages, vernacular and industrial structures, etc. The urban and landscape preservation specificity is not only a matter of scale, but also of methodological approach: we must study our territory as a continuum of diffused cultural sites and not as a simple container of single buildings of historical interest isolated from their environmental context. The purpose of this research is focused on conservation and management of architectural heritage also when not protected by national laws for preservation (as historic town centers, modern districts, industrial architectures, rural buildings and landscapes, farms, factories, trails, gardens, etc..) with the goal to survey historic sites and features, read cultural and architectural values and analyze planning tools and conservation treatments in order to reach a proper approach to preserve, rehabilitate and manage the historic heritage defining specific plans. In this view the communication empowerment between the actors become a key challenge, facilitating knowledge and decisional flows, also increasing the awareness about cultural items. Also the involvement of common people become relevant in this perspective because their point of view results important to fully evaluate and manage preservation processes.

The team The work group has used its skill in the field of Cultural Heritage and in computing and management and has consulted the following stakeholders:

- Conservation and preservation bodies (Soprintendenze, Commissioni provinciali BBAA, Commissioni edilizie)
- Professional associations (Ordine Architetti)
- Owner/investors



- Private Associations (Italia Nostra, Do.co.mo.mo, etc.) Studied tools:
- Open GIS (Grass, quantum GIS, ArcGis)
- Open Maps (Openstreetmaps, ESRI maps)
- 3D integration with Sketch-Up models
- Photoshynt technology

Deep analysis of case study:

- SAFE METHOD Danmark
- GEOSYSTEM Benevento
- ARTPAST: ARISTOS, SICAR
- Social communication methods

The results The team has done the program planned and prepared a summary report outlining the theoretical and methodological issues addressed and defining the possible lines of research development. These could concern the improvement of the ministerial standard GIS tool SICAR with new features focused on programmed refurbishment as a way to put in practice theoretical principles faced during analysis. The team proposed solutions for present problems overcoming lacks of communication and lacks of important automations that could make the preservation process more effective and well-timed.

In addiction to these specific improvements the team studied a broader perspective of development suggesting more complex lines of research for long-time innovations.

To improve participation and awareness about cultural items the team suggested also new services, specific social actions and communication campaigns addressed to people and possible investors. The framework provided is intended both for Superintendance and architects (providing a more efficient tool to work) and also for the great part of stakeholders involved (municipalities, provinces, regions, owners and common people).


MANAGEMI HERITAGE CULTURAL Ч FORM

TASKS & SKILLS

Andrea Balestreri managed contacts with stakeholders and focused on theoretical framework. He supervised the implementation of the SICAR new functions mockup and the generation of the solution.

Alice Jasmine Crippa enriched the theoretical perspective, including that views of the general public and private investors.

She contributed to the main solution by subsequently focusing on communication campaigns.

Pedro Porto Barque De Gusmao provided a technical perspective to problem definition and solution development, subsequently focusing on the implementation of SICAR new functions mockup.

ABSTRACT

Starting from analysis regarding the evolution of cultural item concept itself, Sharitage explores the possibility to improve preservation process developing tools able to increase stakeholder participation.

Empowering communication is the most important goal of Sharitage: not only between Superintendance, Architects and Investors but giving also importance to the communication with the population.

The present lack of communication between actors involved in the process, could be ameliorated introducing internet based tools admitting to share a large quantity of information.

In order to reach this goal, Sharitage had been harmonized to an ambitious project of Italian Ministry of Culture called Risk Map that stresses an innovative conception of preservation that doesn't focus only on an artwork itself, but conceives it as a complex object constantly related to its environment.

After a large browsing of opportunities was chosen SICAR, an innovative tool developed in Pisa and Lucca superintendance, as the most suitable system on which base an innovation plan. The development program concentrates on a well defined mat-

ter: the programmed refurbishment practices.

It consists in the possibility of planning a well-timed maintenance calendar of steps, that could prevent not reversible deterioration, reduce costs amount and increase their predictability instead of thinking about urgent and isolated refurbishment activities.

The project focused on a new service for SICAR that, performing simple compilations makes the system able to notify the needed activities to the item supervisor and also to self-update a database of craftsman and maintenance products.

Second focus concerned the conception of "call for funds" campaigns designed for a more participative management of the cultural heritage.

UNDERSTANDING THE PROBLEM

The progress in understanding the scenario concerning Sharitage project followed two lines of research. The first one investigates the position that Sharitage had to take regarding MIBAC (Ministero dei beni artistici e culturali) fragmented asset.

Due to the problematic context, our task was implemented by responded to an acknowledgement phase for us with regards to harmonizing it to the most ambitious project intending to reortools that would be useful to our idea's implementation. der the way of working of this institution. The theorists of the Risk Map implemented their innovative This project, nowadays held by ICR (Istituto Centrale del Reidea in a GIS highlighting restoration needs but with tools today stauro, "Central Restoration Institute"), is called Risk Map and considered outdated because they are not internet based. The research field in GIS internet based technology grows stresses an innovative conception of preservation; it doesn't focus on an artwork itself, but conceives it as a complex object that quickly in this direction till today arriving to provide excellent is constantly related to its environment as a continuum. open source products and open source cartographies, optimal Cultural Heritage Bureaus and Regions are thought of as adin ministerial research because they are compulsory in the use ministrative and scientific supporters charged to safeguard and of open source software. This researching phase bring us to reflect about the invitation, enhance cultural heritage (as disposed by D.L.42/2004) and are as technology provider and collaborators, one of the best discovaided by innovative tools working in GIS environment. The second research line investigates the definition of Cultural Item. ered GIS implementers. The American ESRI, producers of the Until recently, it was the task of some MIBAC specialized peowell known arcGIS, or GOOGLE, as producers of EARTH well ple, holding the necessary cultural and political authority, to interfaced with the 3D representation of sketch-up. decide that something was a cultural Item or not in reason of a Probably choosing this expansive implementation line, if one of those companies decided to support our cause, would have uniform culture of the nation.

After the actual melting pot producing cosmopolitan and multicultural nations, the meaning shift in the national cultural item concept couldn't be underestimated. What is interesting in a growing multicultural society is the direct interrogation of the population in order to collect those items perceived as cultural value providers. New technologies 2.0 as some diffused social network could help in this purpose.

Another advantage is the disclosing of new points of view, therby expanding knowledge about an item, while also adding other peoples' personal experiences of use and their feelings about it. Our research method was structured upon the constant interaction with different type of stakeholders (public institutions, private associations, technicians, owners, investors and the gen-

eral public) in order to refine our ideas in relation to real stakeholder needs.

EXPLORING THE OPPORTUNITIES

The two previously described research lines had to pass through a period of effective technical feasibility evaluation which cor-

brought Sharitage to a technically driven innovation approach that scarcely would have reflected the Italian Cultural Heritage Bureau's conventional standards.

This exigency made us continue the research restricting the exploration through those case study facing our same focused problems.

After a strict selection we decided to deepen a system developed by the Scuola Normale di Pisa: SICAR.

This project is financed by MIBAC and is the only Italian case presenting a scientific team dedicated to the technological development.

SICAR is a framework merging a vector system for localizing building degradation, a product database and an basic forum.

The interaction between Sharitage research lines and the sci-







3 "Call for new item propositions" campaign: when people signal their beloved cultural items and why

1 "Call for funds" campaign: how to make the problem public and catching

2 "Call for memories" campaign: cultural items invites people to share personal old documents and memories

entific committee of SICAR was fruitful because it allows new ideas took rapidly shape and grow upon an already implemented architecture.

Sharitage research lines proposed to build new categories to be added to SICAR standard interface.

These innovations deal particularly with communication problems that are at the base of many project rejections as well as a significant amounts of time lost for architects, many halted investors initiatives and lost occasions.

Empowering communication was central in Sharitage goals but not only between Cultural Heritage Bureaus, Architects and Investors, but rather by also giving importance to communications with the population.

Its role in the bound process proposition or in "call for information" campaign permit to change the normal perception that historians or books gave to a Cultural Item.

Kantian theories of knowledge, in this case, fall slowly down because today is possible that the knowledge comes also out from the personal experience because when a social network is well managed the operation of multiplying points of view is possible. The letter of a lover, a childhood photo memory forgotten in a tray, could contain a partial description of the interested cultural item that could thus enlarge knowledge about it.

GENERATING A SOLUTION

When SICAR was recognized as the standard technical tool used by our primary stakeholder, a decision was made to focus on the potential technical development of the system which is already supported by existing technologies that are useful, fast implement and cheap.

A suggestion was then made to concentrate efforts on a well defined specific problem.

Programmed refurbishment was a concrete solution: instead of thinking about isolated refurbishment activities, carried on when an emergency occurs, it's possible to plan well-timed maintenance steps that could prevent uncontrolled rather than reversible deterioration.

Programmed refurbishment has also practical benefits regarding costs: routine activities are cheaper than major restoration processes and their costs are also predictable and well known. So it's possible to estimate a clear budget and plan activities during the most convenient period of the year.

The idea was to build a new dedicated service for SICAR that could be "generative" in the sense that an user - performing usual operations through SICAR and adding a few simple checks and time decay indications – would make the system itself capable of reporting the needed activities in advance to the respon-



sible party. With the same method the user also supports the constant updating of a craftsmen and maintenance products database through the compulsory fields required by the system. This is a concrete way to put in practice the "Manuale della manutenzione" (Maintenance Manual), but also adding the recommendations included in the "Libretto di utilizzo" (Usage Manual), often skipped or forgotten by restorators. Nevertheless there are some disadvantages. First of all Italy is a country highly sensitive to emergencies but not well adapted to a preventive attitude. In addition, the distribution of new standards is slow and greatly linked to legal provisions. SICAR is the ministerial standard but it is only "recommended" for now. This system also requires well trained people and the greatest benefits increase proportionally with the number of people that use it. These disadvantages could be faced thinking that the Cultural Heritage Bureau has the duty to manage cultural items and has a strong need for a new internet based tool to improve present practices. The Cultural Heritage Bureau evaluated this proposal as a good one also to promote the use of SICAR itself. But there is another big benefit that also has to be pointed out. For predictable costs it is possible to look for funds in advance, public or private. This point gave the idea to involve the general public and new private investors through a "call for funds" communication campaign, the second focus developed by this project.

Non-profit and public campaigns, in other countries, are some of the most effective examples of communication, also in light

4 The five actors that participate, with their actions and their information flows, to Sharitage



5 Different losses of original material due to traditional and programmed maintenance

of fundraising issues. In Italy only Pubblicità Progresso takes care of those themes but with low creativity and quality. So the Cultural Heritage Bureau and MIBAC, with low budget solutions, can start to take advantage of communications that are facilitated to perform their role.

In addition to a "call for funds" campaign, two others have been developed in order to facilitate a more participatory manner of conceiving cultural heritage management.

The first regards the possibility of collecting old useful documents from the general public both to build item memories, if they were get lost, and also to research new values. The second one invites people to suggest new cultural items, keeping this concept itself really up to date. For all of these conceptual proposals, a low street budget campaign, linked to dedicated websites or to preexistent tools (social networks, photosharing tools etc), is intended to raise interest around items at a high level by making their preservation simpler and promoting it to the public.

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SPACE HOTEL DESIGN SHD



Space Hotel Design

PRINCIPAL ACADEMIC TUTOR

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EXTERNAL INSTITUTION

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Aerospace Engineering

Giuseppe Cataldo

Aeronautical Engineering

Alessandro Gren

Management, Economics and Industrial Engineering

Andrea Paraboschi

Engineering for Cinema and Methods of Communications

project

The Space Hotel Design project performs a feasibility study for a space system targeted on bringing in common people for fun and relax

TEAM B

Andrea Minelli [Team controller] Space Engineering Maral Kinran

Industrial Design

Umberto Melia

Biomedical Engineering

Luca Milani

Management, Economics and Industrial

Engineering

Valentina Sumini

Architectural projects and management of constructive processes

PROJECT DESCRIPTION

In 2001, space tourism became a reality. Millionaire Dennis Tito was the first "fee-paying" space tourist: he flew to the International Space Station (ISS) and spent one week there. Since then, an additional six space tourists flew to the ISS, including one woman. At the moment, this adventure is only affordable to the very wealthy. However, space tourism offers a unique type of experience that might capture the interest of a larger percentage of the traveling population should costs be reduced due to improved technology. It is therefore forecasted that orbital accommodation for space tourists is going to develop into a big new market.

In this context, a preliminary assessment on the convenience and feasibility of a Space Hotel project is presented here. The study takes into account many different aspects and constraints deriving from the harsh space environment as well as the peculiar goal of the facility and the presence of humans which are not specifically trained to work in space but who just ask for relax and fun.

A multidisciplinary approach is maintained in order to simultaneously deal with the engineering and financial issues the application asks to solve. Although space technology and market solutions represent a strong heritage on the basis of which to propose a valid design for the Hotel, the novelty of the application forces the assumption of a new perspective focused on tourists' satisfaction; these new design drivers include cost limitations, a strong focus on ergonomics in order to respond to tourists' psychological and physical needs as well as on-board relaxation and recreational activities.

Moreover, some new technologies, such as inflatable modules currently studied by space companies, are suggested and placed side by side to classical engineering solutions, such as those realized for the International Space Station. The study proposes two different scenarios: an orbiting and a planetary surface hotel. The flying hotel orbits around the Earth, while the surface hotel stays on the Moon. Each of them



has to face different environmental constraints but responds to the same tourist needs.

A limited number of tourists – for a limited span of time and with appropriate prior training – will be hosted in the hotel and supported by astronauts who are already onsite in order to perform a specific scientific mission. This solution allows for the proposal of a project in the short-term time period due to the fact that the hotel becomes a limited part of an already feasible human space unit, designed for scientific purposes.

Both applications are technically feasible within the next decades although space holidays still remain a very expensive vacation.



Orbiting Space Hotel

TASKS & SKILLS

Alfonso Aragona. Studied the technologies for power production, investigated the effects of the space environment on the human body and focused on health risks for future space tourists.

Giuseppe Cataldo. Studied the influences of the external orbital environment on the space hotel, implemented a preliminary study to design its subsystems and main technical features and calculated the final mass budget.

Roberto Maffei. Studied the architecture for microgravity as well as pneumatic and inflatable technology for space, the hotel architectural layout and habitability in space.

Alessandro Gren. Studied a business plan for the space hotel focusing on the demand and main markets as well as the price-demand relationship, safety and risk standards accepted and the evaluation of the best time-to-market.

Andrea Paraboschi. Studied the space hotel guest profiling, developed the hotel 3D-model and studied both the entertainment technology on board and space hotel advertising.

ABSTRACT

In the last decade eight, people flew to space to spend an unusual holiday and experience the unique adventure of living in a microgravity environment while looking at the Earth from a different point of view. Space tourism is indeed a new reality that deserves being analyzed for the strong impact it is going to have on our society.

The main objective of the "Space Hotel Design" project is to provide future space tourists with a global experience that encompasses the means and the "to-dos" of this outstanding holiday. In order to attain this goal, the project focuses on an Earth-orbiting hotel and presents a feasibility study under several perspectives, such as the market, health related issues and the development of habitat concepts, technologies and services suited for sustaining human life in microgravity conditions.

Initially, people's expectations are analyzed in order to understand future market developments. Future generations' trends and attitudes are examined, with a focus on the luxury market and its generational-dependent trends. Secondly, existing or short-term planned concepts are examined and compared with each other so as to come up with innovative solutions from a structural and technical point of view. An assessment of these is implemented in order to choose the most suitable, i.e. the one which meets the users' requirements and satisfies the constraints imposed by the context.

Consequently, the final solution is conceived as a four-module structure with a scientific laboratory where a permanent twomember crew manage the six guests' journey. Tourists will undergo a two-week long training on Earth and will be allowed to spend one week in space. Each area in the hotel is designed for specific purposes and entertainment plays a key role. Ethical implications are taken into account in such a way that space tourism no longer means a waste of money if research is constantly performed in the laboratory incorporated within the facility. This poster will provide the reader with an overview of these issues and how the project analyzes them in detail while making recommendations for an integrated solution.



1 Space Hotel rendering - space module's window detail **2** Orbiting Space Hotel rendering

UNDERSTANDING THE PROBLEM

The main customers interested in this project provided us - directly or indirectly - with their targets, needs and requirements. In particular, we dealt with Thales Alenia Space Italy (TAS), our main stakeholder, and received direct feedback by or gathered information from:

- National and international space institutions (such as ASI, ESA and NASA) that might become potential partners of the project and, as governmental institutions, are aware of the current space policies
- Private investors or companies that would potentially invest in the project
- Future space hotel guests

During several meetings, TAS managers asked both teams to think of a possible space hotel model and to assess different feasibility options. Additionally, they invited us to focus on the entire experience rather than the technical complexity of the different subsystems and to leave a further in-depth technological analysis for future research studies. These requests were also confirmed during the mid-term review by the ASP Board, which strongly encouraged us to describe the whole "Space Hotel Tourism" experience. According to these suggestions, our attention gradually moved to the demand side of the equation, following a bottom-up approach.





3 *Space Hotel bottom view*

We started to analyze what people actually expect from space travel in order to understand how this market can evolve. In addition, we looked over future generations' trends and attitudes, with a focus on the luxury market and its generationaldependent evolutions.

Meanwhile, a global structural design was developed, starting from studying some competitors' solutions, in order to determine strengths and weaknesses of the existing or short-term planned concepts and to propose a possible solution by using pneumatic modules.

Furthermore, since safety plays a key role in any space project, our attention was concentrated on the space environment and all the factors that influence life in space. The training - being an important phase in this process - was defined to be half of the whole experience.

In conclusion, all user requirements can be summed up in these four categories:

- Experiential (demand-side needs): satisfying future guests' expectations, legitimating their expense
- Economic: feasibility, costs and revenue mechanisms
- Technical (structural design): materials and solutions
- **Safety**: guaranteeing the highest safety standards for both the guests and crew



In addition to these four main requirements, we dealt with some ethical implications which are strictly connected to each of them and ultimately to the success of the entire project. Actually, building an orbiting space hotel means spending a lot of money and time in research in order to satisfy the wishes of only a few and initially extremely rich people. In order to transform this elite activity into a useful activity for those people that will only see the orbiting hotel as a little spot in the sky, we agreed that something with social impact should be added to their experience, such as technical experiments.

EXPLORING THE OPPORTUNITIES

The current market of the aerospace industry has been dominated by space agencies such as NASA, ESA, JAXA or ROKCOS-MOS which, while trying to pursue political interests, have been unable to open themselves to the market and to cooperate with each other. They have monopolized this industry, thereby not allowing any private company to compete. This is partially due to the huge barriers needed to enter this sector, particularly in terms of fixed costs and knowledge, but also because space has never been considered a business.

The first movers in this race have already started their tourist space program and have ambitious plans to develop their business: for instance, Space Adventures, Space Exploration Technologies, Bigelow Aerospace and Virgin Galactic. Other smaller players are willing to take part in this race and many of them

have expressed plans to also compete in the orbital space tourism market, either with second generation vehicles built upon the suborbital craft or a totally new vehicle design.

The state of the art led us to analyze the International Space Station's features, for it is the most complex space station orbiting the Earth and hosting a crew of up to six astronauts. It is made of different subsystems capable of keeping the crew alive and allowing them to accomplish their mission. ISS's operation requires great effort in relation to the transportation of the astronauts, equipment, goods and data from and to Earth. The logistics and operational subsystems are relevant for determining ISS's orbit, its design and all of its peripheral systems, as well as integration and ground support. Most of the subsystems are linked or partially merged so that, in addition to the required subsystem functions, even higher objectives are achieved. As a matter of fact, various objectives result from implementing synergism in space system design.

The European COLUMBUS laboratory's characteristics have been considered in order to have an initial idea of what the Space Hotel may be looking like, especially in terms of dimensions and masses.

The space environment influences the condition and properties of used materials, as well as the onboard crew, the experiments and their operation. Therefore, health becomes a problem for two main reasons:



7,8,9 Perspective guests' survey - results pie chart results

- The microgravity effects on human body
- The space environment influences on both humans and structures

As for the first issue, adequate training is required before flying to space in order to adapt to the new conditions and minimize negative effects. As for the second, space structures are currently designed so that they can resist the impact of this harsh environment and guarantee safety for the whole crew.

As far as guest profiling is concerned, nowadays tycoons and very rich people are the main protagonists of space tourism: up to now, seven of them flew to space and the ISS. All individuals born between 1980 and 2000, the so-called "Generation Y", are expected to be the next future space tourists. They are thought to be Luxury Explorers, for they prefer the uniqueness of the experience rather than the luxury itself.

GENERATING A SOLUTION

After a careful comparison of all possibilities, a modular approach similar to the one used for the International Space Station was decided as the best design solution. As a matter of fact, it allows a clear definition of habitable spaces on the basis of their function and a simple construction of the hotel. The final concept consists of three modules for guests, a scientific laboratory, a common habitable module and a node for the connection of all the modules. Moreover the possibility to increase





the habitable volume by adding three further modules has also been taken into account and the employment of an innovative solution based on inflatable structures has been preferred.

The construction of the hotel will require four launches, if the Space Shuttle or a launch vehicle with a similar capacity is employed. It will orbit in Low Earth Orbit at an average distance of four hundred kilometres from the surface of our planet. A traditional solution based on six photovoltaic arrays has been considered as the best option for the power production system while innovative solutions have been proposed for the economic exploitation of the hotel.

The typical experience has been thought to be three weeks in length for a group of six tourists: two weeks would be required for training and preparatory activities on Earth, while about one week would be devoted to the real space experience, from the launch to the return on Earth. In orbit, tourists will be assisted by two professional astronauts and will be encouraged to live as such for the entire duration of their journey.

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MOOREA Moon Resort Architecture

SPACE HOTEL DESIGN

TASKS & SKILLS

Maral Kinran. Worked on guest accommodations. Study of the interior design of facilities. Responsible for product design. Collaborator on the interior design scheme.

Umberto Melia. Worked on psychological issues. Analyst of the physical implications of a low-gravity habitat on human beings. Study of the training phase.

Luca Milani. Responsible for logistical issues and the economic feasibility study. Mission costs and extravehicular activities analyst.

Andrea Minelli. Worked on subsystems design and sizing, requirements and constraints analysis. Responsible for environment analysis (site selection, radiation shielding), in situ resources utilization analysis and feasible implementation design. Responsible for the technical aspects of module configuration and of extravehicular activities.

Valentina Sumini worked on the development of the 3D model with technical and architectural constraint analysis. Responsible for the analysis of NASA standards and their influence on the overall project. Responsible for interior design configuration. Interior environment designer. Launch configuration analyst.

ABSTRACT

Space missions have always focused their interest on scientific and commercial goals to be exploited by humans, particularly on Earth. This study attempts to widen this point of view by developing a space program concept which visualizes humans moving into space, becoming themselves the payload and the goal of the space mission itself. The aim of the project is the analysis and the design of a Moon Space

Hotel. Studying this project's feasibility completely overturns classical space missions targets and requirements: in this case, comfort and users\customers' satisfaction are a must.

The analysis approach allows splitting such a huge design environment into three main correlated areas: infrastructure, transport and life support subsystems. Functional requirements and their interrelationship have been identified for each of the three.

Different factors play the role of exogenous constraints. The Lunar environment analysis leads to the hotel subsystems sizing and to settlement location selection. The hostile characteristics are linked with the development of shielding and protection systems and with in-situ resources utilization.

A mission cost analysis with the payload fairing volume constraint precedes the identification of the best modules layout in terms of number, size, shape and materials.

Module configuration, site location and logistics are all studied together in other to find the best feasible compromise of each of them. A hybrid rigid-inflatable configuration was presented with its modular scheme.

A logistical plan in order to transport all modules and freights is presented. An idea for a surface rover and a lunar lander (both permanent on the Moon) is also developed.

Psychological and physical aspects increase their importance and affect the entire project. This is due to the presence of "untrained" people from the general public. A small and closed community will be studied in order to define the main aspects of this micro society. To avoid or minimize psychological problems, countermeasures involve guest's selection, training, and in-flight support.

Entertainment is studied in order to highlight future guidelines and design drivers.



1 Modules external view

UNDERSTANDING THE PROBLEM When dealing with space missions, the most important aspects to be considered are: technology, safety, and costs. As an addiction to these ones, a hotel project can increase the relevance of other aspects such as ergonomics, psychological and physical problems and all the aspects related to human wellbeing in a hostile environment. These have to be analyzed starting from psychosocial or interpersonal stressors, associated with long-duration spaceflight, revealed by precedent long flight experiences. Lunar environment is characterized by vacuum, extreme temperatures, low gravity, radiations and meteorites. The settlement location is strictly related to the environmental analysis. Power sources, ISRU architecture, day and night transitions, Earth visibility depend on the lunar region selected. The absence of a natural radiation shielding (atmosphere) from galactic cosmic rays is one of the most relevant problems on the Moon. Radiation protection systems are studied also linked with the use of lunar resources.

Hotel subsystems must be sized and designed taking into account safety for the crew members. Redundant solutions and safety margin are considered in the definition of each subsystem. The economical feasibility is strictly linked with the market demand. The space tourism market appears to be limited but not without rich opportunities. Moreover, the sensible price-elasticity of the demand allows looking for an optimum-level in which a firm can maximize its revenues. The logistic situation is different from the one on Earth. A problem occurred may also shift the launch date of several days, so

2 *Dining and meeting module*

3 Fitness and training module internal view **4** Bedroom internal view

the safest and the least costly plan has to be developed in order to provide all the necessities for the people.

Ways to entertain people have to be studied in order to eliminate any sort of idleness.

EXPLORING THE OPPORTUNITIES

As soon as the location is identified, the configuration analysis and definition represents the second relevant step. Various alternatives have been proposed over the years such as mobile versus fixed habitat, integrated versus modular elements, in situ resource utilization versus transportation from Earth.

A first, important trade off to be managed involves the mobile habitats versus a permanent settlement. The first solution seems a temporary solution that implies less comfort and safety for the crew. A fixed ground base can satisfy the constraints in terms of safety (environmental protection), comfort, and optimal in situ resources utilization. The resources utilization is one of the main aspects in the operation phases. The fixed base solution does not imply constraints on the choices between a closed or a open cycle architecture, so both of the alternatives are considered, as well as a combination of them.

The logistic study has led to a plan which consists in three initial launches from the Earth to the Moon surface to transport all the facilities needed to install the Hotel. Then, several re-supply launches will be performed from the Earth to a hub/warehouse orbiting around the Moon, because it represents a less difficult solution. From there, the lunar lander is in charge to shuttle from the hub and the landing pad on lunar surface and v.v.



Form finding process

Physiological aspects regard the protection from radiation, the absence of natural time parameters, the adaptation of the body systems to microgravity/low-gravity, the sensory/perceptual deprivation of varied natural sources, Space Adaptation Sickness (SAS). It is evident that in a very small and closed "community", it is fundamentally important to know and to try to avoid the "negative" interpersonal relations, as well to pursue the "positive" ones. "Negative" interpersonal relations, if not promptly reduced, act as very powerful stressors as they are underhand. Interpersonal tensions linked to schemes, rules and group dynamics, have to be taken into account, making relation with psychological internal stressor, that includes the individual psychological factors.

GENERATING A SOLUTION

Concept

The concept for the Moon Space Hotel has begun with basic requirements: first and foremost, the habitat needs to be transported to the lunar surface. It is developed a modular system that combines ease of transportability and convenience of expansion. We assume that the scenario of 2030 on which we focus can change in a further future. So in case of any redesign process, new modules can easily be inserted for additional activities, accommodation units and life support systems.

The modules weight and geometry are constrained by the Ares V fairing. A study has been performed to evaluate habitat module shape, determining the optimal configuration and trying to transport more than one module in the same launch. A design driver is the maximization of the interfaces between different modules and permit the access to other habitat modules in case of habitat or airlock failure. Therefore, the resulting layout came out analyzing the

advantages of an "hive system" as hexagonal shape, which maximizes the number of connections between modules and minimizes the "dead zones". As a consequence, the final designed shape is an adaptation of this concept to the Ares V payload volume.

The module configuration has been also developed to reduce the payload fairing and to increase the organized habitation volume at the same time. Consequently, the habitat modules are composed by a rigid part (WORM system, stands for Wall Organizer Room Management) and an inflatable one. The shell is designed in order to satisfy the launcher fairing constraints, optimizing its internal volume. Therefore, two modules can be transported together inside Ares V payload fairing.

The choice to place the inflatable part of the structure under the ground level responds to the problem that surface-to-surface contact becomes very abrasive in absence of an air layer, such as in the lunar environment. The internal walls of the inflatable parts are obtained translating and rotating by omotety parts of the module floor. In this way, these walls can be compacted, during the launch, to the WORM, avoiding any lose of internal volume inside the launcher payload fairing.

The structure has to be shielded with a layer of regolith against solar and cosmic radiations that create grave harms on the lunar surface (radiations can damage DNA and increase the risks of cancer and other maladies) and against micrometeorites impacts. The transparent parts of the habitat are made up of two thin layers of aerogel filled up with water.

Moorea Layout

The hotel layout has been designed to host 16 people: 10 are members of the crew while the others are tourists. Numerous



2 Hotel layout scheme

factors like crew size, mission duration and function of the base, influence the habitat size. In this case, each tourist will spend a week in the Moon Space Hotel, while the crewmembers 5 weeks. The habitable volume per person considered for developing the project is 70 m³. There are 4 Sleeping Accomodation Modules, 3 Common Area Module, 2 Logistics Module and 1 Maintenance Module. In consequence, the hotel is composed by 10 rigid/ inflatable modules which have been transported by 5 Ares V launches. Furthermore an inflatable reception module is successively added.

The first module to arrive on the lunar surface is the Maintenance Module that is equipped to perform the functions of dust control/removal, maintenance, storage and hygiene. After the Maintenance Module, comes Logistics and Accommodation Modules which are a combination of rigid and inflatable units. In the Accommodation module 4 rooms are placed. This solution offers the tourists and the crew a private, modern, comfortable space. The rooms are designed as 2 floors. The bathroom and communication space are in the first floor while the bedroom is underground in the inflatable area. The sleeping unit is shaped according the inflated part's contour and is composed by a bed and a partially illuminated commode. The bathroom is one of the indispensable spaces of Moorea. It is equipped by a shower cabin, a washbasin, a toilet, mirror and circular shelves. The shower cabin has a special system, where its telescopic walls spread successively concentrated steam with shampoo and pure steam to minimize the water usage. The toilet is designed with handles for comfort of tourists who are not used to the low gravity. The shelves are halves spheres embedded inside the wall.

The hotel contains also other functional modules related to the different entertainment activities: Restaurant Module has all

the features required to have dinner and relax. It obtains a big circular window at the centre of ceiling illuminated around. Under the window takes place circular table divided in to let enter the crew member in charge inside and serve to tourists. The dining area is surrounded by relaxing area where are installed suspended armchairs that can move up and down thanks to a telescopic bar. On the other hand, Cinema Module allows tourist to spend amusing time watching movies or just looking outside thanks to a huge window; Fitness & Training Module is a space created to make people move and have fun.

The Fitness & Training module is made of an interior flexible membrane whose shape can actively be adjusted by the astronauts and tourists. Between inner and outer skin, a high resolution spaceframe is inserted; the spaceframe's individual members are pneumatic bars. The active data-driven structure works like a bundle of muscles. The interior skin is immersed with innumerable led and LCD panels that work together to form a large overall image or text. In this way, thank to these virtual windows, tourists would be able to experience the feeling of being on the lunar surface without having physical windows.































THE RETAIL BANK IN THE FUTURE: EMERGING BUSINESS MODELS AND NEW CUSTOMER RELATIONSHIP MANAGEMENT STRATEGIES

RBOF

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The retail bank in the future: emerging business models and new customer relationship management strategies

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project

The project aims to develop emerging concepts for retail bank branches and for electronic payments. Istituto Boella collaborates to the project

ТЕАМ В

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PROJECT DESCRIPTION

The challenge Significant changes are affecting the retail banking industry in the last few years. The risk of disintermediation coming from the rise of new models such as Financial Social Networks or direct banking players, changes in the regulatory framework about payments (i.e. SEPA) and the deployment of new Information and Communication Technologies are generating a profound transformation in retail bank business and operational models. Beyond this, the recent financial turmoil has increased the pressure on retail banks' goal of improving both their reputation and their operational efficiency. In this environment, banks are redesigning their frontoffice organizations to achieve full integration of three key channels: the Internet, the telephone and the physical branch. More specifically, banks are designing their Internet banking platforms in order to allow customers to not only perform all transactional services (i.e. managing an account, transferring money, trading securities, controlling returns on investments), but even more complicated services (i.e. underwriting a mortgage or a credit card). Branches will not disappear, but their role will change significantly: the physical branch will be still the last line of contact for customers and the location to organize the sale of more complicated (and profitable) products. In the same way, customers' trust will mainly be built inside the branch. In a similar way, banks will try to discourage the use of cash (whose logistics is complex and expensive) and will foster the use of electronic payments. This will have considerable implications for backoffice operations and the availability of data about customers that banks can use to understand their customers' financial habits.

The teams The project have been developed by two students' team. Team A was involved in designing a concept for a new branch. Team B worked on the development of a concept for mobile payments. Both teams worked in collaboration with the "Istituto Superiore Mario Boella".

The results Team A developed a branch concept based on more customer self-service and automation for transactional services, im-



proved customer flow, improved comfort, ergonomics and privacy for customers. Changes in lay-out, office furniture, covering, technology and organization of work were studied in order to maintain branches' operating costs and productivity at similar levels to the ones of current branches. The proposed concept represents a creative act in which the need for improving customer satisfaction on retail banking services, and the goal of banks to improve their operational efficiency and the efficacy of their sales activities, are combined. As such, it raised great interest at the Istituto Boella. Team B developed a concept based on the use of Near-Field-Communication technology. Students analyzed the critical factors that caused the failure of mobile payment services that were launched in the last few years (lack of investments in complementary assets such as POS networks, low usability of the device, low security in the transaction). Based on these results, and in order to foster the diffusion and the advantages of this technology, the team decided to combine the core mobile payment service with the typical recommendations functionalities that e-commerce players and social networks currently use. Evaluation of the potential diffusion of NFC-based mobile phones and payments performed through this type of device was also analyzed.



The Branch of the Future is Here Today

TASKS & SKILLS

Ilaria Cillo worked on the interior design of the branch, focusing on its technological equipment and on Multichannel communications. She also worked on the 3d renderings of the branch.

Valentina Colombo worked on the interior design of the branch, focusing on the materials and the organization of the spaces in relation to customer needs and the new roles. She also worked on the 3d renderings of the branch.

Marco Fiorini was appointed "team controller" and focused on the analysis of the organization of work and human resource management practices in the bank. He also compared business models as well as the size and level of use of the bank for different bank services at an international level. Finally, he studied the operating cost of the new branch in depth.

Emanuele Chirico focused his work on the development of the organizational model for the branch defining individual roles, positions and activities. He also worked on state of the art analysis, focus group activities and cost analysis.

Manuela Monti focused his attention on the development process of the concept of the branch and on project management. She also worked on the state of the art analysis, focus group activities and cost analysis.

ABSTRACT

The disintermediation process enabled by the Internet as well as new social and economic phenomena (such as the micro-credit diffusion, off-shoring trends for information-based services) and new Information and Communication Technologies (ICT) will produce a profound transformation in retail bank business models and in their customer relationship management approaches. The aim of the study is to express a vision for the trends which retail banks will face over the next 10 years. In particular, the work has the objective of understanding, in depth, the role of the physical bank branch and its evolution (or revolution) in relation to current trends. We propose both a new organization for physical layouts and of the work organization in the branch, particularly in reference to the lending of mortgage process. The project is aimed at defining the development retail banks must undertake in order to adapt to emerging trends in the technological and socio-economic context. So the principal objectives are:

- Develop a new concept for the role of the branch
- Hypothesize a possible evolution of the business model

In particular, we intend to define the concept of the branch in 2020. We observed that current branches are unsuitable or are becoming less and less useful for addressing the needs of some particular customers segments.

Our idea is to propose an innovative concept by not only re-organizing existing bank networks but by giving the branch a new strategic role so that the branch needs to be both virtual and real in addition to having flexible working hours and a specific location. We will also study the connections that the branch will have in the future (and it is currently having) with the Internet Banking and the telephone channels.

We have decided to approach the project woth a longer term view in order to be more free in developing innovative ideas and avoid being constrained by actual concept trends and hypes that characterize the main players in the retail banking industry.

UNDERSTANDING THE PROBLEM

The competitive environment in which the Italian banks are called upon to do their business has suffered, in recent years, a profound and radical transformation. Moreover, the financial crisis which largely invested banks all over the world forced them to rethink their role and their approach towards customers as well as reduce costs. Another critical problem banks are facing is the risk of being disintermediated in business lines like mortgages and investments by new focalized players such as financial social networks or direct banks that only operate on the web. In this context, the ICT assumes a key role, because it allows banks to cut costs in the back office and introduce a "multichannel" approach towards customers. The branch still maintains its key role as the main location where to contact clients and promote products, in particular in Italy, which has higher density in comparison with other European countries. Moreover, the number of branches in Italy has grown in the later years, as data about capillarity show.

However, banks need to rethink the branch's concept both in terms of layout and their approach towards the customer. As a result, the project's aim is to evaluate potential solutions and provide an efficient answer to this scenario.

EXPLORING THE OPPORTUNITIES

A new approach towards customers

The current scenario implies an evolution of the role of front office employees, from "tellers" to "sellers", in order to most effectively exploit physical contacts with customers in the branch which tend to decrease. Therefore, the new concepts emerging aim at transforming the branch into a more welcoming and comfortable place, where more attention is given to sales activities and customer experience.

Multichannel services and layout trends

The dream of a completely virtual bank is mainly abandoned. The multichannel approach, which allows customers to perform transactions anytime and anywhere, does not eliminate

the importance of the branch, which however needs to be conceptually re-thought.

To attain the above mentioned goal, banks not only need to change front office employees' approach, by focusing on a better re-organization of the staff, but also provide a self-service area at the entrance with advanced ATM's devoted to all transactional services. Moreover, it is necessary to change the layout of the branch by providing a more comfortable environment as well as lower "physical barriers" to entry, a better queue management system and an internal layout subdivided into different areas for different activities, with a particular attention to privacy.

The role of technology

A primary role is played by technologies supporting the transformation of banks - not only in the processes and in the organization of the branch, but also in its relationship with customers. To support innovative branch information technology can basically play three roles:

- 1. Enable clients to perform all traditional operations (request for information, provisions such as payments, deposits, transfers, etc.) without the intervention of the bank staff;
- 2. Promote the products of the bank, with information and advertisings customized on each customer;
- 3. Enable the client to make an appointment with his/her financial promoter by means of mobile systems or through the Internet and even to meet him in video conference, without being both present in the branch.

GENERATING A SOLUTION

Primary and secondary research

The first step in generating a solution was understanding customer needs with respect to the bank branch. For this purpose, we used the focus group, during which we aimed at creating a discussion instead of concentrating on individual responses in order to produce qualitative data (preferences and beliefs) that may be representative of the general population.



1 *The front office area and the tablet pc*



2 *The scheme plan of the branch, with the* description of the areas and their employees and the levels of services offered



3 *A* general view of the branch



4 *A view from the main entrance and the meeter* and greeter

At the same time, we attended an EFMA conference in Istanbul on this topic in which different banks proposed their solution for a "branch of the future"; we organized a focus group with ten industry experts from European banks in this primary research and the experts gave us practical suggestions and ideas to answer their needs.

The next step was to make use of a Quality Function Deployment to formulate the specifications needed to address the customers' and retail banks needs (emerged through the results of the two focus groups) in terms of the branch of the future. Technical requirements were obtained by comparing some solu-

tions which were adopted and illustrated by the banks present at the conference in Istanbul.

The trans-disciplinary approach of the team let us transform the needs of banks and customers into some tangible values and to think about what must be done to the product design in order to fulfill the necessary requirements. At the end of the process, we obtained a priority ranking for each product requirement; in this way we were able to understand where to intervene first.

Our solution

The physical branch responds to the questions and the necessities we found by trying to include all of our decisions into an interior design environment and connecting it to the new asset of the employees' roles. The project is a prototype of a medium largeness branch; it is designed in 2d in order to understand spaces and the human relations into them; we also propose a 3d model where the materials and the interior perception are shown to obtain a pleasant and interactive branch (interactions being between the customers, employees and the physical space).

The interior space we propose is composed of different areas visually separated by opaque and transparent glasses and the use of materials; at the same time all of the areas are in the same environment, in the way to create a unique space where the customer could understand the function of the zone he is acting in.

To create a more familiar environment, we eliminated the barriers between the exterior and the interior, and a "meeter and greeter" welcomes the customer at the entrance. There is also an area provided with kiosks, open 24 hours a day for 7 days,

where customers can perform every transactional service at an "advanced ATM". The waiting time due to queues is not passive, because customers can be informed about bank products in many ways, with a pull approach; in fact we provide three different solutions:

- 1. a relaxation area, in the centre of the branch, with magazines, newspapers and a LCD screen which provide information about bank services.
- 2. a tablet PC area, where the customer can be trained by bank's employees on how to use the internet services of the bank, read about promotional products and download informative materials on his mobile phone.
- 3. a retail area, where information about products promoted by the bank are provided.
- 4. with regards to branch services, the project plans three offices to perform counter services, one office for the financial promoter and one for the director; moreover there is an area devoted to small businesses. The number of employees is equal to 6, plus a promoter in the retail area, who may not be a bank's employee.

5 *A view of the relaxation area*



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Smart Money

TASKS & SKILLS

Matteo Ainardi, developed the concept with a main focus on functional and technological aspects.

Tiziano Barbagallo, focused his work on mobile payments diffusion analysis. He implemented some simulations in order to understand how banks could affect and provide incentive to facilitate the diffusion.

Jonathan D'Elia, developed the design concept and the technical feasibility, focusing on user experience.

Arianna Luna, concentrated on the economic feasibility of the project, evaluating its sustainability from both a social and an economic perspective.

Gabriella Negro, completed a stakeholder's analysis about requirements, needs and targets and also followed the economic aspects of the project as well as the diffusion analysis about NFC with Tiziano Barbagallo and Arianna Luna.

The team, supported by the Istituto Superiore Mario Boella, analyzed the current payment scenario in depth and formulated some preliminary concept proposals. Subsequently - in order to assess and improve the quality of the work - the team participated to the EFMA Conference in Paris by interviewing key experts and collecting feedback on the "Smart Money" concept.

ABSTRACT

The goal of the project is to aid retail banks in facing the threats and the opportunities offered by recent changes in technologies and regulations. The introduction of new regulations (i.e. the Single European Payment Area) could affect the traditional role of the bank by facilitating the creation of new payment institutions. Retail banks thus need to propose and foster innovative payment services in order to retain old customers and attract new ones. In Italy, cash is currently the most widespread form of payment: this situation does not bring any benefit to the bank because cash is not related to the customer's identity and does not provide any revenue. Furthermore cash is highly expensive due to complex logistics and security reasons. In our project, we focused on possibilities provided by mobile technologies in order to develop new payment services that are capable of gaining customer acceptance thus reducing the usage of cash. The project is developed from a technical, economic and social point of view. The starting point was the analysis of the different payment methodologies alternative to cash. Then we decided to exploit the mobile Near Field Communication (NFC) technology for all its advantages in speed, security, usability. The usage of the mobile phone as a payment device allows for the development of services with a real strong value proposition for both banks, customers and merchants. Smart Money is the service concept resulting from this initial study. It not only provides an innovative payment method but offers a deeper interaction between the customer and the shopping environment. This concept relies on RFID technology in order to establish communications between the shopping area and the customer's device: targeted offers and promotions are sent from the merchant through this channel. Furthermore, the customer can download additional contents about products on his mobile phone and can insert feedbacks about purchased items which then become accessible to other users. During the development of the concept, the team has considered costs and benefits provided to all the stakeholders. This activity has been driven by continuous feedbacks received by key experts that allowed a progressive functional validation. A diffusion analysis of the adopted technologies, together with an economic analysis, completes the feasibility study of the concept.

UNDERSTANDING THE PROBLEM

Banks are facing some challenges due to the new SEPA and PSD Regulations and due to the risk of being dis-intermediated by the entrance of new players in the payment market. The main issue of the project is to help retail banks in assessing the threats and opportunities offered by these recent changes. Furthermore, banks need to reduce cash, which is very expensive to manage (in Europe, in 2002, the total cost of cash was about 50 billion €). Currently, 85% of total transactions in Italy are made using cash, and 80% of cash transactions are of small amount (0-25€). Non-cash transactions in Italy now are made mainly by cards, direct debits and credit transfers, and are expected to grow in coming years (while cheques are expected to disappear after 2013): the number of non-cash transactions per inhabitant is expected to double in the next four years. So, after analyzing future payment trends, the team focused on the development of electronic based payment services. This work started by identifying bank needs and fears and by exploring the current payment scenario as well as the opportunities offered by new regulations and technologies. The mobile phone has been identified as the key device over which to build an innovative payment method; it could provide an enriched shopping experience to the customer, particularly for small amounts of money. This solution can help banks in renewing their image by offering an innovative service that can stimulate loyalty, attract new customers and moreover reduce the amount of cash transactions.

EXPLORING THE OPPORTUNITIES

The current scenario on payments systems has been analyzed in depth in the first phase of the RBOF project. A state of the art analysis clearly revealed that cash represents the main cost for banks; this is mainly due to opportunity costs as well as security and logistics reasons. So we have considered the reduction of cash usage as the main objective to be pursued in this project. In recent years, the use of credit/debit cards has grown significantly all over the world. However, especially in Italy, card payments still represent a tiny percentage of the total payments value, approximately 2%. Nevertheless the usage of non-cash payments instruments is increasing and cards are slowly replacing cash, even for low-value payments.

We focused our analysis on identifying possible solutions that could provide incentives for the use of electronic payment systems. The challenge in identifying a reasonable solution was to provide enough advantages to every stakeholder involved in the payment process. In particular we are talking about clients, merchants and banks. Each of these stakeholders requires the new payment system to offer an added value with respect to cash, in order to be willing to switch from the old to the new payment method.

The most interesting solution that has been identified consists in promoting the use of the mobile phone as a new payment instrument. Nowadays about half of the global population has a mobile phone and in Europe the number of mobiles per person is even greater than one. We therefore considered exploiting the widespread distribution of mobile systems and also using them for payments using NFC as the enabling technology. We decided to promote the use of mobile systems as payment instruments through the implementation of a social network which is able to connect groups of customers. In this way customers are able to see the recommendations of friends in their network and to see comments and ratings about products which they may be interested in. Moreover, they are able to release feedbacks on the product they have bought, thereby providing useful information to other customers. In addition, for every payment done through mobile systems customers receive bonuses which can be used to have access to promotions and discounts and which in turn have been conceived as an additional way of incentivizing the use of this new payment instrument. Respect to the use of cash, merchants can collect information about their clients and, by processing it, are able to offer targeted promotions to their clients. With regards to banks, the expected result is to significantly reduce the usage of cash with a strong and positive impact on the bank's operational costs. Furthermore – by proposing an inno-



1 The web page we designed to communicate the service



vative and attractive service - banks may increase their capability to retain customers and to attract new ones.

In conclusion, switching from cash or cards payments to mobile payments does not simply mean changing the payment instrument but offering great added value to customers, merchants and banks.

GENERATING A SOLUTION

Smart Money is an enriched payment service that integrates the payment functionality into mobile phones, thus allowing for deeper interaction in the customer and the shopping environment.

The concept focuses on multimedia/books/music/movies stores (e.g. FNAC, Mediaworld...) and aims at implementing interactive features of e-commerce portals into the physical space of the shop. These shops have different features that can enhance the diffusion and the adoption of an innovative payment service:

- 1. the average customer is a relatively young person interested in technology;
- 2. multimedia, books, music and movies incentivize the users to give feedbacks, opinions and reviews: this factor can be exploited, through integration with social networks, to give to the user the access to trusted opinions and reviews;
- 3. these stores are divided into specific thematic areas: this al-

lows to place different interactive advertisement devices which display promotions related to the thematic area;

4. event ticketing is often offered by these stores: downloading an e-ticket through the mobile phone can be a very attractive alternative with respect to the traditional paper ticketing.

The concept stakeholders are customers, retail banks, merchants and mobile phone operators. The idea is developed by primarily focusing on the need of retail banks to retain customers, attract new ones and, moreover, reduce the expensive usage of cash payments. For these reasons the aim of Smart Money concept is to propose an attractive application that can incentivize the distribution and adoption of mobile payments. The usage of smart phones as payment devices allows for the development of interactive functionalities which are typical of online shops:

- 1. for each book/disc/dvd it is possible to download, directly from the shelves, additional information, as well as other customers' feedbacks and reviews:
- 2. the user can buy preview tickets for events directly from his mobile phone, selecting the desired seat;
- 3. possibility to book and buy in advance brand new cd/books/ dvd, to attend special events with the authors/musicians/artists and to win backstage tickets for concerts.

4. targeted offers and promotions that can be downloaded from LCD/RFID panels to the mobile;

From the technological point of view, four main device are considered:

- 1. Customer's NFC mobile phone.
- 2. Merchant's NFC POS (which can be a NFC mobile too).
- 3. LCD panels with RFID tags in order to show interactive advertisements to customers in the shop.
- 4. Web portal that allows the user to manage his account, check his expenses, write feedbacks and reviews on purchased items and read feedbacks and reviews produced by other users (friends \rightarrow integration with major social networks).

NFC mobile phones are considered the core device on which the concept is built. This technology is selected since it can provide a secure, fast and channel without physical contacts through which the payment information can be exchanged. Furthermore, it is assumed that customer's mobile phones have a flatrate connection to the Internet in order to interact and access the online contents offered by the service. The concept is based on the strong assumption that NFC will gain massive distribution in the next years. This assumption reflects the common opinion of key retail banking experts: NFC has the potential to be a complementary technology of magnetic cards in the case of micro-payments. The project evaluates some realistic perspectives about the evolution of this payment method, during the period from 2009 to 2030, by applying the Bass diffusion model and by creating some scenarios that combine different significant variables (i.e. transaction volumes, learning curves, diffusion of contactless POS and NFC phones) Smart Money service is developed by a retail bank in partnership with the multimedia retail company. The bank must implement an electronic wallet mechanism which can be accessed and used from the NFC mobile phone and can be recharged through the customer's bank account or through a credit card payment from the customer's personal page on the website.



3 *A* scheme of the main benefits the stakeholders will have using the service

The data coming from the merchant about customers purchases and interests can be used by the bank and by the merchant in order to profile customers and offer attractive targeted promotions through the customer's personal page as well as through messages on the user's mobile phone.

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NEWSOLAR



A NEW GENERATION OF SOLAR CELLS



NEWSOLAR A new generation of solar cells

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Architectural projects and management

of constructive processes

Angel Trifonov

Management, Economics and Industrial Engineering

roject

Product design and comprehension of key industrial criteria in order to *enable better developments of new* kinds of efficient and low-cost solar cells

ТЕАМ В

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Chemical Engineering

Marco Ticozzi

Environmental Engineering

Francesco Torre

Industrial Design

Matteo Villa

Materials Engineering

PROJECT DESCRIPTION

The challenge

- To create a world free of carbon emissions, where power is plentiful, safe and truly green and where even the most remote village has Internet access and with light in every home, including aesthetic solutions for buildings.
- To mimic the energy production in plant leaves, creating artificial photosynthesis in a new kind of solar cells - dye sensitized solar cells (DSSC) - which are not yet in the market but which could represent a cost-effective alternative to silicon and thin film-based systems.
- To explore solutions aimed at improving competitiveness by implementing new production processes and by suggesting potential applications and new business opportunities, thereby creating the highest level of design flexibility without compromising between aesthetics and functionality.

The teams

- Two teams, one focused on solar energy conversion in buildings, roofs and facades; the other studying flexible cells for portable electronic devices.
- A multidisciplinary composition, taking into account the fact that technical, economic and management skills are fundamental for understanding the main advantages and drawbacks of this promising technology, while design competencies are more important for creating innovative products.
- An engineering approach, adopted separately for each team, with the aim of formulating new ideas and designing some prototypes of DSSC cells and modules, both on rigid and flexible supports.

The results

- Analysis of the predictable performances of the dye sensitized solar cells, and comparison with those of current solar photovoltaic technologies.
- Identification of possible compromises between best performances and cost; proposal of process implementations to im-



prove DSSC technology in order to take advantage of a faster entrance in the market.

Design of DSSC-based objects and structures, related to the idea of being "green", generating electricity even indoors and in low light conditions, without a tradeoff between aesthetics and functionality.



Building Integrated Photovoltaics

TASKS & SKILLS

Stefania Butera, analyzed the environmental performances of DSSC modules as well as their sustainability and suggested many potential innovative applications in addition to contributing to the analysis of their technical aspects and environmental impacts. She also coordinated the team's work and contributions to the project.

Paolo Grassi, investigated the properties and the cost of DSSCs, carrying out a systematic comparison with other standard photovoltaic technologies. He also coped with some technical issues of the proposed applications, particularly the electric configurations.

Filippo Marchione, studied the state of the art of DSSCs, their functioning, their processing technologies and critical points.

Elena Scripelliti, strongly contributed towards the identification of building integrated applications of DSSC modules; in particular, she addressed the issue of the indoor and outdoor architectural integration of panels, both from a conceptual and graphical perspective.

Angel Trifonov, carried out the marketability analysis of DSSC technology and thoroughly investigated the needs of all relevant stakeholders and the potential customers. He also gave a fundamental contribution to the brainstorming session by proposing innovative and groundbreaking solutions.

ABSTRACT

Energy plays a role of primary importance in our society, but the constraint of fossil fuels reserves along with issues related to pollution are resulting in an effort to enhance the efficiency of energy processes in addition to reducing their losses and promoting renewable energy sources.

One of the most interesting renewable energy forms is Photovoltaics. Solar radiation, widely available all over the world, free and inexhaustible, is used to produce electricity. However, despite its relatively high power density, the related cost of energy production is significantly higher compared to traditional energy sources. As a result, research is focused on the development of cheaper PV cells, such as DSSCs - very promising electrochemical devices where the process of conversion of solar energy into electricity is promoted by dye molecules linked to a nanocrystalline TiO2 layer.

DSSC are characterized by a low cost of raw materials and production, moderate efficiency, partial transparency, and related aesthetic qualities, light weight, flexibility, in addition to being capable of working in the absence of direct light. Although the principle of functioning is not completely clear yet, DSSC might represent a very competitive technology.

The objective of the present work is to investigate the strengths and weaknesses of DSSC in order to find out innovative and competitive applications linked to the integration of solar modules in buildings.

A scientific study on the principles of functioning of these cells and an in-depth analysis on materials and processes are carried out as a basis for the definition of their properties.

After that, the general trends and needs of potential customers have been investigated in order to suggest innovative architectural applications; two were selected among these, and analysed in detail: the first one is feasible in the short term, while the second one is more futuristic and creative, yet not completely feasible at the current state of development.



1 Interior rendering: parametric wall and sliding doors

UNDERSTANDING THE PROBLEM

Technological development of society has resulted in increasing energy demands. However, progressive depletion of fossil energy reserves, on the one hand, along with the environmental consequences of their combustion, on the other hand, have been matter of concern lately. As a result, increasing interest has focused on renewable energy sources, solar energy representing their primary form. Nevertheless, photovoltaic energy still has significantly higher costs with respect to other energy sources, and efforts have focused on the development of a new generation of low costs PV cells.

Furthermore, some general trends have emerged from society in the last years which could also affect its relationship with energy supply and that should therefore serve as a basis for the identification of appropriate solutions. The tendency of people to travel more and more and to change locations frequently, with the relevant problems of moving their lifestyle items with them, calls for a first key issue: flexibility. A second major trend is the use of energy while in motion, and the related problems of recharging portable electronic devices.

Finally, another important issue that is gaining importance in modern society is sustainability and equity, given that energy



2 Interior rendering: standard configuration with desk and abstract picture

and food independency in poor regions are key factors in implementing development strategies.

Hence the necessity of developing a solution that is capable of coupling low costs for renewable energy production with the required flexibility and mobility and in a sustainable and equitable manner. DSSC technology, if properly implemented, might represent a good solution to such requirements. The purpose of the present work is to identify suitable applications, particularly those related to the architectural integration of such devices.

EXPLORING THE OPPORTUNITIES

The term "photovoltaics" indicates a wide group of different technologies which have been organised into three categories: first, second and third generation.

The 1st generation solar cells are silicon-based. This technology is quite mature and efficiencies have been measured higher than 20%. Its main drawback is the substantial impossibility to reduce production costs.

The 2nd generation of solar cells was developed to reduce production costs and is based on the use of a thin film of PV material. Despite efforts to reduce costs, their commercialisation has not yet reached the desired results yet.





4 Most important issues in developing and designing the Interior Walls solution

common devices

The 3^{rd} generation was developed to achieve a strongly competitive cost/efficiency ratio, either with very high efficiencies but high costs, or with moderate efficiency but cheap devices (η =15-20%). Dye Sensitised Solar Cells, invented by Grätzel and O'Regan in 1991, belong to the latter category.

DSSCs have many interesting features; first of all, they are able to produce energy even in absence of direct incident solar radiation. As a consequence, although their efficiency (a value of 8% was assumed from scientific literature) is actually lower than traditional PVs, the overall amount of energy collected is comparable. Furthermore, the costs for materials and processes are low, and the assembling of the modules is relatively easy. Another strength point of these cells is that they are aesthetically enjoyable, partially transparent and can be realised in different colours. Finally, they have a low weight and can be either rigid or flexible, depending on the substrate. All these features make DSSCs rather interesting for building integrated applications, and indoor uses may be considered as well.

On the other hand, the long-term stability of DSSC is quite a debated issue. The cells' degradation mechanisms are not fully understood yet. A lifetime of 10 years is assumed in the present work for outdoor applications, which are doubled in the case of indoor uses. A second weak point is the optimization of an adequate production processing for flexible DSSCs. Other critical points are environmental performances, in particular relating to greenhouse gases emissions during processing. End of life disposal also raises concerns, mainly due to the presence of toxic compounds, though promising achievements are expected in future on these matters due to the employment of more environmental friendly molecules.

GENERATIG A SOLUTION

The objective of conceiving and designing innovative, buildingintegrated applications for DSSCs is achieved through a series of analyses aimed at identifying the most suitable directions for work and preparing an effective brainstorming session. The expectations of the project's stakeholders were considered, as well as the requirements of potential DSSC users. Several applications were therefore proposed, both indoor and outdoor. Regarding indoor ones, all domestic surfaces could be theoretically converted into energy harvesting surfaces if realized with DSSCs: interior walls and panels, pieces of furniture or curtains. With regards to outdoor building integrated applications, DSSC panels could be utilized in windows, external sun-louvres, claddings and roof-



5 *Exploded assonometric view and front view*

ings, city advertisements, gazebos and greenhouses. The two most interesting applications are then selected from amongst these proposals, while adopting decisional criteria based on the assessment of their technical feasibility and innovativeness. The first chosen solution aims to completely re-define the current perspective about solar panels: DSSCs are no more a simple device to produce electricity, but an eco-chic product designed to please both the aesthetic and environmentally friendly feelings of users. The aesthetic features of DSSCs were coupled with a brand new technology which allows one to wirelessly recharge electronic devices in order to design an outstanding and completely innovative product and which is completely technically feasible at the present state of development. Decorated interior walls, jointed and movable, low cost and easy to self-assemble, would be useful to create, move, renew, change or personalize domestic environments while also producing electricity which is then wirelessly delivered to portable electronic devices through special pads. The second proposal is on the contrary futuristic and innovative, and its practical realization still requires significant research efforts to overcome long term stability problems: aeroponic greenhouses in desert areas, whose energy demands are fully supported

6 Section and structural grid

7 Image of logo and advertisement in top view

by DSSC panels, in a closed cycle of energy and materials. The new paradigm is to consider greenhouses as not only farming buildings but architectural elements integrated within the landscape and that could be used for advertising or promoting the territory. In addition, desert land can be exploited twice, both for energy generation and as a food production surface due to the cell transparency. Although further work is still required to overcome the technical limitation of DSSC, this solution represents an important link between innovation and sustainability!

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DSSC technology for portable devices

aevice

NEWSOLAR_A NEW GENERATION OF SOLAR CELLS

TASKS & SKILLS

Paola Calcagnile was responsible for proposing innovative applications.

Antonio Mazzitelli checked the overall progress of the work while reinforcing it with reported scientific literature.

Marco Ticozzi focused his analysis on environmental aspects in relation to both the actual state of the art and to the opportunities for DSSC. Moreover he has been responsible for internal reporting data.

Francesco Torre's responsibility has been to generate new design concepts and frames for DSSC.

Paolo Vicino acted as team leader and was responsible for scheduling and internal coordination. Moreover, he performed cost and feasibility studies of different business opportunities and potential applications.

Matteo Villa was responsible for driving the general work, introducing PV technologies to other team members, exploring new concepts and opportunities and developing technical and business solutions.

ABSTRACT

The aim of this work is to analyze organic photovoltaic technologies by focusing, in particular, on dye sensitized solar cells (DSSCs), in addition to studying their potential as an energy supply system for portable devices. A multidisciplinary approach is necessary in order to handle the complexity of the subject (Luzzi for Dyesol, 2nd International Conference on the Industrialization of DSC, St. Gallen, 13-09-2007), making DSSC perfect for an ASP project.

Complexity in DSSC technology arises primarily from the fact that the technology is still not well defined: thousands of materials are referred to in the literature and many of them are not well characterized yet (Schubert for IOLITEC, DSC Industrialization Conference, 2007); moreover, a standard device has still to be settled and procedures for certification are not ready as well (Hinsch for Fraunhofer ISE, 2nd International Conference on the Industrialization of DSC, St. Gallen 11-09-2007).

The first part of our work is focused on describing the characteristics of the main photovoltaic technologies. Subsequently, the team performed a more in-depth study of DSSC technology in order to present nowadays state of the art, both in terms of technological principles and characteristics of the cells.

In the following chapter, the weaknesses and strengths of DSSC technology are discussed from the perspective of addressing the right field of application; within this analysis, the team has carried out a comparison with other thin-film technologies that represent the most likely competitors on the market.

In the last chapters, the team proposes potential solutions on two different levels. From a technical point of view, the suggestions aim at improving DSSC competitiveness by implementing new production processes and by testing and eventually adopting new materials. From a market perspective, the team suggests potential applications and new business opportunities, ranging from the solar umbrella to a solar modular fabric to be sold as a B2B product.



UNDERSTANDING THE PROBLEM

The team has performed an investigation of most of the photovoltaic technologies nowadays existing, both at the industrial and at the researching level. The target was to understand the role that DSSC technology could play in the future, considering the competition with other photovoltaic systems. Among all the technologies currently developed or in phase of developing, the following have been identified as possible DSSC competitors: thin film amorphous silicon solar cells, printed CIGS (Copper, Indium, Gallium, Selenide) and fully organic photovoltaic (OPV) systems. As a matter of fact, all the four considered technologies, offer the opportunity of satisfying costumer needs: the photovoltaic market is nowadays looking for lower production costs and environmental impact, both of which are primarily caused by production processes and utilized materials . Finally, it is worth remembering the importance of integration opportunities within existing technologies and devices; all these aspects have been considered in the analysis.

The actual state of the art presents DSSC as very promising for the future, but some problems are still unsolved and are the subject of ongoing research. Durability and stability have not, until now, reached the level required by the market and materials with better performances are being tested, in particular those concerning electrolyte, still generating sealing and corrosion problems. Efficiency is still considered to be quite low.





1,2,3 The charging of devices at seaside will be the emblem of a turnaround in the conception of energy, no more as a centralized service, but as a delocalized and near to consumer product

Moreover, industrial processes able to manufacture low costs cells and modules are achievable but implementation is still ongoing. Finally, the competitiveness of DSSC technology seems to be strictly related to situations and conditions they are applied to; finding applications where their intrinsic characteristics of lightness, transparency, flexibility, diffused light conversion and design opportunities can represent an added value is the ultimate goal this project is focused on.

EXPLORING THE OPPORTUNITIES

Two different aspects have been considered in analyzing opportunities; from the technical point of view, the possibility for a continuous process that is capable of meeting market needs is already reported in the literature. On the other hand, the team suggests particular situations and applications in which the characteristics of DSSC make it more suitable to outperform competitors.

Low costs, EPBT, and environmental impact can be enhanced by using polymers instead of glass as substrates and by applying a roll-to-roll continuous production process. Today, this is technically possible, due to new techniques that allow titanium dioxide deposition without the use of high temperature sintering, a step usually performed on glass substrates, but incompatible with plastic materials.

Given these conditions, research on efficiency and durability makes sense for direct industrial application, but only if focused on systems that can be implemented in a continuous, integrated



4,5 A portable and fashionable energy producer. The Solar Bag can easily integrate DSSC solar cells by stimulating, through fashion, the idea of a green energy revolution



roll-to-roll process. A second promising field for applied research concerns biocompatible electrolytes and biodegradable materials which can substitute plastics. These steps are needed in the future in order to further reduce environmental impact and to create a opportunity for new fields of application, for instance in the medical industry.

In addition to this, a roll to roll process can be implemented for the production of integrated devices; integration of different functionalities in a singular device is possible in biosensors, screens, batteries, scanners, electronic newspapers, medical disposables, labels, RFID tags, etc. Integration is nowadays considered the main driver for technology implementation and flexibility and conformability assumes a central role in setting innovation opportunities.

With regards to applications, the transparency, lightness and opportunity of colorful frames, obtainable through the utilization of different dyes, are all positive features for designing DSSC-based items related to the idea of being "green". Indeed, if appearance and transmitted concepts are considered as the drivers for innovation, design becomes central for exploiting new market opportunities: in this case popularity of the technology is favored by diffusion of fashionable and appealing objects and brands. Technical aspects only assume a secondary position in this scenario: it doesn't matter how the device itself works, but the message it communicates.

However, the realization of fashionable design items is related to the feasibility of ad-hoc productions that still have to be implemented for continuous processes. Industrial facilities and knowhow become central in defining winners and losers.

Finally, new opportunities that are not directly connected to cell production or utilization, like the development of companies specialized in implementing industrial facilities or in designing new integrated systems are made possible by cheap solar cells availability.

GENERATING A SOLUTION

Technical solutions

Since complexity in dealing with DSSC technology arises from the large amount of different state of the art solutions reported, the introduction of new materials was not the main focus of the work; however, the team has found the introduction of many alternative solutions to be promising, including carbon nanotubes, fluorinated polymers and biocompatible materials.

Process implementation was also considered to improve DSSC

technology. In particular, available techniques were preferred to futuristic solutions in order to take advantage of a faster entrance in the market.

A roll-to-roll-process is proposed for the production of scalable, light, transparent DSSC devices with low environmental cost. PET is suggested as substrate; PL passages for the production of a metal grid, capable of granting scalability, are inserted at the beginning of the process, and followed by ITO deposition in vacuum; afterwards, TiO_2 is deposited and an UV irradiation step is considered to grant sintering. Ink-jet printing for dye deposition is then suggested. Finally, electrolyte deposition and sealing steps, determined by the electrolyte chosen, were not univocally indicated. In dealing with integration in electronic devices, NIL processes are considered as a potential solution; the section includes basic principles, opportunities and a general production process.

Business solutions

Tackling the problem from a business perspective, the team identified two main opportunities that deserve to be analyzed in more depth.

6 The integration of DSSC is feasible in every kind of day-to-day item. The novel design of this four-poster bed is an emblematic solution posted by the group





7 DSSC as solar cloth: solar tent can be manufactured by using a DSSC cloth like a normal plastic film. In the reported example, semitransparency grants the opportunity for all day sun exposure without reducing too much luminosity of internal spaces

First, a new firm could try to enter the market as a futuristic cloth supplier. This means producing modular frames that could later be used to manufacture clothes or fashion objects, but which are also able to perform specific solutions: abandoning the idea of modularity improves devices esthetical appearance.

DSSC technology for advertisement is the second proposal. The substitution of PV silicon panels in urban integrated systems is already feasible: companies can be interested in committing personalized frames for some billboards made of DSSC, thereby generating public awareness. Market entrance of cheap plastic DSSC or OPV systems, potentially integrated with an OLED display, can push opportunities even further forward.

Applications and design

Finally, applications are considered and new design ideas are generated. Due to their versatility in term of flexibility as well as a fashionable aesthetic impact, achievable through the proper modulation of dyes, DSSCs can be generally implemented in many devices and used either in common life or luxury items. This feature could foster a revolutionary change in the conception of energy: from a centralized service to a delocalized and product that is closer to the consumer.





















ADMIRE 2

ADVANCED MOBILE INTELLIGENCE AND REACTIVE ENVIRONMENTS



AdMIRE 2 Advanced Mobile Intelligence and Reactive Environments

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ADMIRE combines the "presence everywhere" of ICT and the relevance of the mobile devices, thereby becoming the "personal" technology tool

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PROJECT DESCRIPTION

The challenge AdMIRE, Advanced Mobile Intelligence and Reactive Environments, presents a revolutionary vision in which the "intelligence" is placed on the mobile device. "Mobile" as "personal", always available in the hands of the user, able to hold all his/her knowledge. The environment is perceived as "reactive": equipped with ICT sensors and controls it "reacts" to user requests, providing timely and effective answers. The environment (a living room, a square, a bathroom, an info-point, ...) is a place for content and a place for physical actions. Multimedia content can be found and "downloaded", "played" or also "uploaded" from the mobile for other users. It is in the environment that physical control happens: controlling lights, playing devices, appliances and more. The challenge is to make the AdMIRE vision real in several senses: defining user experiences, designing the environment, the interfaces, the protocols, implementing the necessary pieces of software and interfaces, making the necessary economic assessment.

The teams The goals for both teams were to *sharpen the AdMIRE* vision and build a prototype which places a mobile device at center stage, for TEAM B, of an environment rich in content and, for TEAM A, in terms of *physical control over the environment*. More in detail, the assignment for both teams meant the following: • Designing the user experience and visualizing the physical appearance of the environment, for different places and situations. The specific assignments for TEAM B were:

- Defining mobile interfaces for different functionalities, including "download", "upload", "playing" and "down-streaming".
- Defining and implementing an *architecture* for the project vision.
- Developing all the necessary SW components for the mobile devices. The specific assignments for TEAM A were:
- Designing the user experience and visualizing the physical appearance of the environment, for different places and situations.
- Defining the mobile interfaces for the different functionalities, including both direct control over individual appliances, or overall control of the global environment.



- Defining the overall architecture, the high level protocol interpreting user requests, and the low level protocol, interfacing the devices.
- Developing *drivers* and low level protocol for real devices.

The results TEAM B has achieved a number of interesting results:

- A conceptualization of a new "user experience" for using the mobile device during the *shopping experience*.
- A new business idea and the planning of a start up company providing applications for Apple iPhone, related to made in Italy's shopping experiences (food, fashion, design).
- The complete interface for a new application related to food shopping and services named i-Eat.
- A suitable architecture supporting all the functionalities of the new application.
- A functioning prototype of the application, integrated with wireless and data networks of supermarkets.

TEAM A has achieved a number of interesting results as well:

- A conceptualization of the "user experience" in providing innovative features, based on mobile devices, in different environments, specifically home and public spaces.
- Defining the "concept" for interactive installation.
- Defining and prototyping interfaces for the new functionalities of the mobile devices.
- Defining a suitable architecture supporting the functionalities.
- Layering the solution in different protocols: from user level, to an intermediate generic level, to a (device specific) low level protocol.

There is elevated potential for serious industrial exploitation of this new technology. A leading industrial company producing expensive idromassage-bathtubs (with electronic control over bubble, temperature, etc.) and advanced lighting, has already requested a working prototype that could become the basis for an innovative line of products.



I-Domo Pervasive immersions in sensible flows

TASKS & SKILLS

Daniele Casulli & Alejandro Repetto solved all technological challenges ranging from the low level infrastructure to the high level communication protocol and computing system architecture.

Chiara Doglione & Federica Pecoraro explored new solutions for reinterpreting the emotional experience of the user in a domestic environment, focusing on the personalization of the design inspirational elements. They projected the user interactions with the environment from both a technical and graphical point of view.

Paolo Patelli, his most important contributions include the formation of *user experience* concepts and proposals, the production of interweaved visions as well as actual architectural solutions.

Daniela di Rienzo contributed towards defining the elements that restyle and interpret the wellness environment. She analyzed existing solutions for lighting, displays, and smart materials.

ABSTRACT

AdMIRE research project aims at putting smart mobile devices at the center of a new concept of User Experience by creating a natural and immediate interaction between people and their environment, taking place everywhere and at every time [1]. Namely the main goal of this project is the creation of an immersive experience where control over the physical environment is actualized through the mobile phone and by means of a pervasive computing approach. In our vision the mobile phone is not only a universal remote controller but it also hosts the artificial intelligence capable of controlling the elements of the environment through both a profile-based and real-time approach. The complexity is hidden from the end users and the information processing dissolves in behavior.

The team explored a wide spectrum of domotic functionalities, home automation appliances and services covering environmental, security and safety controls as well as entertainment and communications; then the focus shifted to the design of a multi-sensorial experience in an immersive atmosphere involving a dynamic composition of elements, such as sounds, lights, colors, aromas, water and vapor, that we refer to as the hard, soft and digital realms of space. In order to coordinate these situations and transitions we developed the I-Domo application.

The technological approach adopted is based on a service-oriented architecture. This choice provides unlimited flexibility: it allows for the use of different technologies on the server side, without any constraints on the client side.

I-Domo's results involve the building of an intuitive, userfriendly and elegant interface; a flexible rich interior design and a ubiquitous technological paradigm.

Research is currently focused on innovative solutions applied to private or semiprivate environments, but the I-Domo paradigm can be extended also to public spaces, being the customization of a shared environment a major challenge for future developments.



1 Three-tier I-Domo architecture

UNDERSTANDING THE PROBLEM

In the last few years ubiquitous computing has grown in popularity. From PDA to mobile phones, from GPS applications to domestic appliances, technology is silently permeating our daily routines [2]. In this scenery, the work site, the home, the avenue are transformed into locations where information is processed and gathered. In particular, all habits of daily life (as the way to manage the electrical appliances, purchase groceries or watch TV) turn into a chance to interact with technological devices in a spontaneous and ordinary manner. Nowadays, buildings have intelligence distributed everywhere (air conditioning, electrical appliances, televisions, home theatre, computers) which - combined with the ever-increasing popularity of wireless technologies - allows for complete control of the domestic environment. The mobile phone is the ideal interface to manage an environment: it is portable, always on, and allows for access to the home's functionalities regardless of the user's position (at home or away). This extreme versatility permits the use to easily interact with the house while allowing for flexible use of systems like surveillance, entertainment, energy consumption and so on.

EXPLORING THE OPPORTUNITIES

The I-Domo proposal involves remodelling our lives around a noninvasive paradigm where people would interact with a responsive environment fluently and naturally.

2 *All high level functionalities are managed by the iPhone*

3 *I*-Domo Communication Framework

A lot has been written about reactive environments [3] and mobile technology; however, very few previous works exist on the combination of these two concepts. In I-Domo, the iPhone device becomes a wearable universal control tool which offers the consumers "anywhere-anytime" access to their house while keeping track of the user's state, needs, preferences and options available at any precise moment. All information becomes accessible from "anywhere-anytime" and delivered in an way which is appropriate for the user's location and environment.

One of the major challenges faced by the team was putting together existing technological modules. In fact, considering the fact that single intelligent blocks are already available in the house market, the challenge was to eliminate all remote controllers, all user interfaces and different access terminals to easily manage a "domotic house". Furthermore, the intelligent systems of today are very expensive for the mass market; they are not scalable and not accessible remotely.

I-Domo proposes to build the basic architecture for implementing smart controllers operating in reactive environments. Compared to traditional domotic schemes, intelligence does not reside in a single central computer but on a distributed system. The mobile device becomes the centre of our lives and it is used as a controller of the global environment as well as a "content repository" of the information exchanged with other people or



4 *Example from the hierarchical menu; I-Domo interface*



5 *Example from the tag cloud menu; I-Domo interface*



6 *Controlling the environment settings; I-Domo bathroom* **7** *Topological connections; I-Domo bathroom*

devices and as an intelligent system keeping trace of the user's history. In these home control scenarios, interoperability and communication between devices play a fundamental role. Although a single standard would be strongly desirable, the actual coexistence of multiple communication strategies had to be managed, considering that each of them meets specific unique demands. However, I-Domo's approach to a reactive environment goes beyond standard control functionalities: the ideal home should be able to understand the habits of its hosts, foreseeing actions or even hazardous situations while fully exploiting the technological possibilities of the environment.

GENERATING A SOLUTION

The research team attempted to find a still unexplored area of study that could consider a partnership with Teuco company. The choice of working on the concept of a "bathroom of the future" resulted as the most appropriate. We imagined a highly technological, exciting and extremely customizable space where the edges between public and private spaces are blurred.

We have faced social and behavioral challenges in our reinterpretation of the bathroom environment from a functional connotation to a housing and living space, used for relax, wellness, body care, but also for content fruition and social interaction; a radical design, both visionary and factual at the same time, makes this vision tangible and becomes a key point for the I-Domo project. In order to accomplish our goals we have defined some strictly interdependent sub-tasks:

- implementation of a pervasive, ubiquitous technology,
- development of a multi-sensorial experience in an immersive atmosphere,
- definition of a hybrid functional program,
- design of the architectural features,
- design of the user interface.

From the technical point of view the solution has three levels and each level defines a protocol: the user level interface, the high level interface and the low level interface.

The user level interface mainly refers to human computer interaction (HCI) design; the intermediate level plays the role of middleware, acting as a broker between mobile devices messages (using SOA) and low level messages (using bit-level communication) sent to the domotic devices; the low level protocol defines an electronic communication standard for managing sensors and controllers. The greatest advantage of this model is its ability to easily mix and integrate different services, combined with its scalability properties. This flexibility has allowed us to manage a wide range of domotic devices without changing the proposed architecture. Simple client-server architecture would need extensive adjustments each time a device is added to the environment. Furthermore, the integration between new and old devices would be very complex. With respect to the factual technology, the team selected the Apple iPhone as a smart controller due to its forecasted growth in market-share, as suggested by international research. Moreover, its usability has been considered a good start to develop new experiences; its multi-level touch screen would offer interesting interface opportunities and should enhance our idea of effortless and natural interaction with technology.

The I-Domo experience has two levels of complexity. First, the I-Domo application is used to manage, automatically or remotely, the basic functionalities of the house, such as light controls, the security and intercom system, room temperature, energy savings, the tub temperature and spa with efficient controls and easily handled devices. Then I-Domo allows the user to recreate an immersive environment displaying multimedia content on the off-white surfaces of the bathroom.

8 Functional areas; I-Domo bathroom

Graphical patterns are generated, manipulated and synthesized as images and animations on the basis of daily iPhone-related activities carried out by the user: received and the missed calls, dialed numbers, the content in the agenda and in the notepad are the source material of suggestive graphs that, even if are not immediately recognized by the user as concrete and significant information, bring a great aesthetic value, always different and personal at a selected degree. It is then possible to orchestrate a multisensory rhapsody involving sounds, lights, colors, aromas, water and abstract figures tuning the atmosphere of the environment to the mood and the habits of the user, linking hard, soft and digital space.

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iEat An innovative shopping experience using mobile phone

TASKS & SKILLS

Luca Ricci, Laura Brunet, Elsa Gabriela Emery Gaona. As design team, they investigated virtual and physical food shops, associations for food promotion and culture. The analysis focused on specific trends, like organic and high quality food, and on the customers' interactions with it. With this background, they came up with the concept for the iEat application and the design of the scenarios of interaction in the daily life of the users. Finally, comprehensive research on iPhone led to the design of the user interface and of the look-and-feel of the application.

Stefano Crespi, Mostafa Sharaf. As technology team, they analyzed the current state of the art, exploring existing solutions in the market and options for the system architecture; they also performed the Requirements & Design analysis for the actual iEat Application in strict collaboration with the designers in addition to working on the implementation of iEat Prototype. They concluded with the testing phase, both to assure correctness and satisfactory user experience.

Donato Pietragalla, **Elena Pelizza**. As business team, they performed the decision making process to choose the appropriate mobile device and technology. Moreover, they completed the business analysis, exploring the appeal and feasibility of the application, in order to create a business plan of iEat and MADit, a start-up to provide mobile applications related to "made in Italy" shopping experiences.

ABSTRACT

The project developed by Team B is related to the creation of a startup, MADit, whose mission is to combine the quality of "made in Italy" with technology, using a single device. The company presents three strongly interconnected working areas: the business, technology and design team.

A first concrete application deriving from MADit vision is the "iEat" system: based on the Apple iPhone, it changes the way to experience shopping. With a simple application the buyer becomes an interactive user of the supermarket: he can get detailed product information, scan the products and pay them directly via mobile, he can leave and read comments on his purchases, in a 2.0 socialnetwork view; he can receive suggestions and other contents from the supermarket system in order to discover new products and useful information.

The business team conducted a detailed analysis of the market, considering both supermarket and mobile state of the art, as well as existing points of overlap; moreover, considering the direct and indirect competitors, the device and the strategy to enter the market were chosen after evaluating opportunities and risks.

The technology team concretely implemented indications and inputs: iPhone was chosen as a device and the technology to realize the vision was also defined; the products' scan is obtained using the iPhone camera and the RedLaser Software Devolpment Kit (SDK). The payment is not concretely developed, but the system is designed to obtain it by using highly widespread SIM cards.

The design team initially investigated different potential applications of AdMIRE technology and then focused on the thematic area of food promotions and sales. Scenarios of use were elaborated, with different levels of detail, in order to visualize the user experiences enhanced by iEat, and to structure the user interface. All the sub-teams worked in strict cooperation and contribution, with a continuous exchange of inputs and observations. The final result is the prototype of iEat Application, intended as a starting point to show its potential and the main features that integrate the scan phase of a product within the mobile application.

Food shopping and technology

As a matter of fact, the food-technology relationship has become closer and closer in the last years. Looking at already existing solutions and newly arising trends, it was realized that many experiments were carried out in recent years on new ways of interaction using technology directly with customers in order to improve the shopping experience in stores for food and other products. The team focused its attention and researches on such trends in order to provide innovative solutions.

UNDERSTANDING THE PROBLEM

The AdMIRE Project features interactive, rich contents and mobile technology. They are the means which transform a mobile device into an intelligent access point for the sake of hi-tech services and contents forming the frontier of reactive environments. Based on this concept, the food shop scenario was developed. In addition, the team was inspired by looking at current examples of ad-hoc applications dealing with user experiences, even though they did not satisfy most of the key principles of interactivity, user-friendliness, richness of contents, community and information quality. The research has consequently focused on two parallel paths: AdMIRE's System architecture and AdMIRE's mobile application. This involved adapting and integrating the first into the chosen scenario and developing the second on one of the latest mobile technologies as well as on the most successful mobile device, the "iPhone".

GENERATING A SOLUTION

The goal of the project is to improve shopping experiences by making them more pleasant and full of interactivity with the help of an innovative application which can unify available forthcoming services and technologies. In fact, the iEat application allows users to get continuous information about food, both outside and inside the shop by providing information about products, making shopping easier and more convenient as well as by allowing interaction with other users and controlling recipes. After considering the global vision more in detail, the team decid-



1 *Storyboard: a customer shopping with the iEat and iPhone*



2 *Storyboard: due to the information by iEat on his iPhone, the customers can choose the best rice to suite his needs*

ed to develop the concept of iEat application to be used inside and outside the shop, overcoming the ordinary "shelf exhibitor" with the use of iPhone monitors as access points for additional services; through a centralized wi-fi communication, users can have internet access and "on place" interactive and highly customizable board, enjoying an enriched experience of familiar activities.

The main features implemented in the prototype are as follows:

- Shopping list: the possibility to create, manage, check personal shopping lists in real time related to a wide library of recipes, as also suggested by users themselves;
- Direct shopping: through the use of iPhone-built in cam, the iEat application allows users to scan product barcodes directly, creating a virtual order ticket which is better for the customers than common cart-pushing walks among the shelves;
- **Community**: the user has a personal profile and can interact with friends and with the system by sharing comments, preferences, recipes, interesting events, etc, or can interface with already existing social networks like Facebook or Twitter;
- **Payment**: the payment functionality is still in form of prototype which should allow the user to check out by simply using his/her iPhone device.





3 *iEat: the mobile* shopping experience in the supermarket

4 A world and a community around the product: suggested recipes about the food to purchase

5 Product information displav. Each type of information is identified by intuitive icons *iEat user interface*

As already mentioned the bridging between the two levels is done through wi-fi communication, either with direct access to the internet for services like YouTube videos, general contents or maps, or consuming ad-hoc services developed (e.g. web-services). The implementation has been performed by following Apple directives for iPhone apps development as much as possible in terms of architecture design (MVC and delegation patterns), user experience (simple and friendly interfaces), performance (reactivity, memory management and graphical optimizations), accessibility and general standards.

The user interface combines the user-friendliness of iPhone and touch-screen input with a simple and elegant graphics style made of basic elements that exalt the numerous pictures of food products to purchase and the results of suggested recipes.

EXPLORING THE OPPORTUNITIES

AdMIRE exploits the technology through mobile devices, particularly iPhones devices, since it is widespread and users are already familiar with it.

The shopping experience will change due to the innovative style of shopping with iEat which involves choosing products and mobile payments, enhancing the shopping experience and strengthening the relationship with products and brands.

iPhone was chosen due to its widespread distribution, the success of the touch screen experience, its enormous potential in

terms of the smart-phone and the rumors about future upgrades. iTunes can already provide different applications related to our field of interest but one thing we notice is that they are too specific or focused on only one individual aspect of the shopping experience; there are many apps devoted to the creation and easy management of a shopping list; others exploit the GPS functionality to locate particular shops and some deal with barcode reading and there are also ideas regarding apps for new forms of "mobile enabled" payment. iEat starts from all these feature to build an application which accompanies the user in the whole shopping experience, and together with the new concept of shop already presented grants user satisfaction and pleasure in usage.

iEat business

As pointed out, iEat is based on iPhone, and the mission of this application is to allow the user to communicate with a supermarket environment. In fact, after analyzing the two markets, it was noted that supermarkets are more and more interested in mobiles and in the introduction of new ways of payment ("Passabene" of Coop). iEat offers more than a way to pay via mobile: it creates a service that puts the user in the center of the environment, allowing him/her to receive personalized information. iEat application has been thought for a Business to Business (B2B) context: iEat may be attractive for a certain niche of stake-



6 MADit Business model: MADit considers a B2B structure, selling the application to the *supermarket that then provides it to the customers*

holders as big chain supermarkets (COOP Switzerland or Carrefour) and food groceries in general. The decision of the technology has been conducted after an analysis of market trends: direct and indirect competitors in smart-phones - and not only - were considered. In fact, there are several customized technologies that allow the payment of the products in a supermarket, but none of them has vet imposed itself as the optimal solution related to the shopping experience. This was either due to their cost (considering the tech-cart with new devices integrated) or because of the traditional experience that the costumers have in the supermarkets.

MADit startup

MADit is the start up that has to combine "made in Italy" quality and technology in the real world. It is a company where the business runs around the development of services as a mean to address advertisements and other innovative services based on the typology of the firm: the idea is to be efficient and not invasive in order to create an enjoyable application. Its core philosophy is that supplied services must change the user experience of everyday life by introducing the paradigm of the *communication continuum*. The core business is to create synergism amongst markets that usually have been considered far from each other in a B2B (Business To Business) structure.

nore pleasant shopp more offers relax and social cos

In particular, it was noted that the mobile market produces devices which are fully able to communicate and interact with a physical environment. This key point allows for the creation of synergism between distant worlds by using the unexploited "intelligence" of the mobiles to create new business.

7 *The stakeholders' relations and benefit within iEat system*

MADit is created by a group of young and motivated people who are enthusiastic to enter the market with an innovative start-up. The originality of the team is the variety of backgrounds of the singular person. In fact, the members belong to several technical areas (design, informatics and media). Moreover, the members of the group have an international vocation: the team is composed of people coming from different part of the world and which have worked in several countries (Mexico, U.S.A., Switzerland, Egypt and Japan). This also implies an opportunity to run the company with a global vision.

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WIFI-4-ENERGY WE



WiFi-4-Energy

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Wifi-4-Energy aims at identifying strategies for the energy retrofitting of buildings (e.g. Politecnici) by exploiting WSNs for environmental *monitoring and control*

ТЕАМ В

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PROJECT DESCRIPTION

The challenge Energy efficiency and green buildings are an important challenge for developed countries in order to achieve the commitments of the Kyoto Protocol. In this field, the WF4E project's aim was to identify and define solutions for energy retrofitting, environmental monitoring, as well as controls and energy savings in large and complex buildings. Moreover, the goal was to determine strategies by using multidisciplinary techniques and, in particular, by exploiting wireless sensor networks (WSNs).

From this perspective, it is necessary to perform an overall analysis evaluating the energy inflows and outflows of a system in order to identify factors that affect energy consumption and waste. To obtain a simple and effective sensor system, only the most influential among these factors are taken into account and used to determine the most significant variables that need to be monitored. Finally, an effective user interface has to be defined to display the data gathered by the sensors and to highlight anomalies and wastes as well as to solve critical situations and increase energy consciousness in users with the general goal of energy saving in a comfortable environment.

The teams Team A focused on the analysis and implementation of the wireless sensors network. They carried out a technical feasibility analysis of a monitoring system, defined an appropriate ICT technology, designed a proper topology for the network and chose an effective communication protocol. Economic matters have also been taken into account in order to perform a feasibility analysis with respect to costs and savings associated with the designed system. Team B focused on the analysis of a suitable human-data interface, capable of providing real-time environmental monitoring and controls as well as displaying the real-time situation of a given environment in addition to providing future forecasts. Implementations and feasibility studies have been carried out in order to validate the results. In addition, specific attention has been paid to communication solutions capable of increasing energy awareness in users.



The results The innovative idea that has driven both teams was based on a different approach concerning energy management. Based on evidence, the comfort of users has always been considered during the design phase of modern buildings. However, it has never been monitored nor controlled during the operative life cycle and the focus in energy management is mainly devoted to energy saving.

The general idea was therefore to develop an ongoing commissioning system composed of a suitable network of sensors capable of detecting the most significant parameters, and a strong and powerful control interface. This system focused on the importance of controlling both energy consumption and the comfort situation of the given environment.

The project demonstrated the feasibility of the WSN technology for energy applications.

Moreover, it explored different potential future developments. On the one hand, the introduction of additional features (e.g., integrating monitoring with automatic control of plants, so that anomalies revealed by sensors can be rapidly adjusted) has been considered. On the other hand, the teams conceived particular innovative applications of their commissioning system. With only a few corrections, it could be applied in different scenarios ranging from large and complex buildings (e.g., private residences) to even transportation. In general, all environments where energy saving and comfort represent a twofold objective may be eligible for such applications.



WIFI-4-ENERGY

WINES & Co. WIreless Networks for Energy Savings & Comfort

TASKS & SKILLS

Paolo Andreazza explored the state of the art in the field of sensor networks and contributed to his team through his know-how about protocols and topologies.

Daniela Dazzi considered the topic of energy savings in buildings by working on energy analysis and investigating strategies that are currently available in the state of art. Benedetta Gaglioppa brought her experience in the field of energy by focusing on the audit theme and the development of an innovative solution based on Fanger Theory. **Paulin Kitieu Nanfack** was involved in understanding the project's computer science issues, collaborating in the development of the proof of concept of our solution. Marco Torello, the team controller, focused his attention on WSNs aspects, thereby proving the technical feasibility of the solution and implementing a prototype.

ABSTRACT

The starting point of this project's work is the awareness of some limits that affect current approaches to the topic of improving energetic performance of complex buildings, an issue that has become essential nowadays given the significant role that the building sector has in energy consumption and CO₂ emissions. Currently available solutions are mainly concerned with the efficiency of plants and materials, in accordance with limitations imposed by laws and standards (whether mandatory or not). These kind of actions, however, do not ensure that people who live in the building perceive a comfortable environment. Moreover, if no *ad hoc* measures are taken to check if the energy performance is maintained over time, the building operation will likely result in being far from the energetic/economic optimum.

For this reason, our innovative idea consists in an ongoing commissioning system that - by making use of wireless sensor networks (WSNs) - merges, in the framework of energy saving in buildings, two other fundamental objectives: the maximization of user comfort, and the guarantee of savings over time obtained with appropriately implemented actions.

To reach this objective, we mainly focused on the thermal energy demand of a building since we found that in this sector a sensor/actuator system can offer significant advantages. To obtain a cost-effective solution it is necessary to give precedence to simplicity and identify a limited set of parameters to monitor. Following the approach of the Fanger thermal comfort model, we only selected temperature, humidity and air velocity.

The proposed work represents a novel idea for energy savings, with interesting future potential developments: for example, we suggest the integration of our commissioning WSN in prefabricated modules for ceilings and floors, whose connection automatically provides electrical current to the nodes. In such a way, it is possible to make the system less invasive and solve the energy problem, while keeping the wireless channel for data exchange.





UNDERSTANDING THE PROBLEM

The building sector (tertiary and residential) plays a crucial role in the field of energy savings. As shown by official statistics it is responsible for approximately 40% of European final energy consumption (source: European Environment Agency). For this reason, energetic performance of buildings is the topic of extensive research nowadays, particularly with reference to the targets established by international commitments and standards. To deepen our knowledge of this problem we initially carried out an energy analysis in order to understand the system at issue in terms of the inflows that should be considered in an assessment of the energetic performance. Such an analysis brought to a division of the system's energy needs into four classes: thermal energy, light, electric power and venting. Under the supervision of Ingenia s.r.l. - which works on innovative systems in the field of building automation and energy efficiency - it has been possible to identify within these classes the main influencing factors that affect energy consumption and waste: efficiency, use and status. The main aim of this procedure was to find guidelines for the development of a system that is capable of reducing energy waste, but costing less than the potential savings. For this purpose, the

1 *Schematic view of the architecture* chosen for the whole system



3 General scheme of Energy Audit

2 Energy analysis graph of a general system, showing energy demand, divided into classes, and the natural and artificial vectors which convey each kind of energy from the outside

> analysis results were compared with the needs of the Energy Managers of complex buildings. We exploited the outcomes of interviews we had with them for the definition of a weight function according to which we evaluated all energy classes and factors. We finally concluded to focus our work on the use of energy in the thermal and venting sectors, which offer the most relevant and cost-effective saving opportunities.

EXPLORING THE OPPORTUNITIES

An in-depth study of the state of the art revealed that different saving opportunities have already been implemented for buildings. In the energy field, the tools of Energy Audit, Energy Certification and Continuous Commissioning are adopted with the aim respectively of estimating, certifying and ensuring the energy performance of buildings and plants over time, in terms of insulation, efficiency, control and regulation. All these tools are based on the energy balance of the system under consideration, in reference to the theoretical notion of the first law of thermodynamics, which states that "energy can be neither created nor destroyed, but only transformed". This principle is applied to buildings with the purpose of monitoring and then reducing





4 Main factors involved in Fanger's theory of thermal comfort

5 An inside view of one of the network

consumption through calculations of the energy supply and the heating and cooling load.

From the sole perspective of energy savings, current approaches are surely effective and well designed to reach their aim. However, they are mainly focused on reducing consumption in accordance with the limitations that come from laws and standards without taking into account the comfort of people who live inside buildings: this is a limit we wanted to overcome with our innovative solution.

A great opportunity that we exploited was represented by Wireless Sensor Networks (WSNs) which we adopted for a non-invasive monitoring of environmental parameters connected to thermohygrometric sector. The main experimental activities of our team are connected to this topic, particularly with reference to topologies, protocols and synchronisation procedures. With more in-depth theoretical understanding of the state of the art followed by some practical tests, we explored available solutions in the perspective of finding the most energy efficient ones amongst them: actually a very demanding issue in WSNs design is the limited life of batteries which imposes to reduce as much as possible power consumptions.

GENERATING A SOLUTION

The innovative solution we propose consists in a WSN-based sensor/actuator system for thermohygrometric quantities in buildings. It aims at being a supporting tool for Energy Manage-

ment, Energy Audit and Ongoing Commissioning but also aims to ensure the thermal comfort of the user. The novel characteristic of our idea is that we return to comfort the importance it deserves, considering it explicitly even when talking about energy consumption and waste; in other words, we wanted to guarantee the most energy efficient way to satisfy people comfort needs. In order to obtain a cost-effective solution, it is necessary to privilege simplicity and monitor only a limited set of parameters. To identify them we followed the approach of Fanger thermal comfort model, that is adopted as a reference in standards (ISO 7730:2005), according to which we selected temperature, humidity and air velocity. If compared to the model based on energy balance, our choice surely results simpler because it doesn't require the measurement and estimation of lots of parameters. Here lies the strength of our solution: this system is cost-effective, easy to implement and avoids the risk of making mistakes if some data are not available for the analysis. Moreover the different uses of the environment are implicit in the theory and do not need to be evaluated *a priori*, but are indirectly assessed through other physical properties. For example, if the number of people in a room increases too much this phenomenon is revealed via an increase in temperature and a change in the index of thermal comfort that moves out of the acceptable range.

Besides the identification of the model we also concentrated on the method to measure the required parameters. After exploring available opportunities and considering aspects like cost, performance, standards and programming ease, we came up with a network based on a multi star topology. This choice is particularly energy-efficient for nodes given that, in this case, they are only in charge of transmitting, so it's possible to minimize the working time of the antenna (the most energy-wasting component). The selected protocol is 802.15.4, mainly for compatibility with other applications.

The main features of the proposed solution are listed below:

• out-of-the-box and easy to use, but also open: the solution doesn't require any further configuration or hardware modification, so it can be easily installed, used and also maintained



6 *Integration of a network node in prefabricated modules*

by a non technical user. At the same time it is non-proprietary and if necessary can be customized;

- versatile: it applies to every kind of building, but it may also fit different scenarios, such as public means of transport, by just scaling the number of nodes;
- fault tolerant: the designed solution enables continuous operation, rather than complete failure, when some parts of the system fails:
- scalable: the number of nodes can vary without any modification in the software and hardware configuration of the system:
- interface free: the data saved and stored in the database can be easily accessed and integrated with a wide range of different applications.

In order to demonstrate the technical feasibility of the system and validate our mathematical model, we created a prototype of the network and installed it in different environments in order to acquire data, test the system's reliability and check its lifecycle. We also had the possibility of verifying the installation ease of our system by having it tested by a group of future energy managers. The result was positive, since it showed that the only difficult part is the identification of the best installation areas. A system improvement can be proposed for new buildings: by

WI.N.E.S & Co.

7 The proposed network topology

integrating sensors and sink node in prefabricated modules we will make the solution non-invasive, thereby effectively requiring no modification in the installation environment. Another important feature we have conceived for these panels is the ability to conduct current, if powered on, when they are connected. In this way we drastically increase the system life-cycle, that can be considered unlimited.

An interesting future development of this network could be represented by the integration of the three elements that compose a gateway (sink node, PC and LAN router) in a single package: this solution will not only reduce the hardware cost of the system but also the energy budget.

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Comfort Modelling and Easy Energy Management

WIFI-4-ENERGY

TASKS & SKILLS

Marco Leogrande was the team controller, responsible for keeping the agenda of the project and related submissions and deadlines.

Ju Liu developed the software and the basic features of the graphical user interface. In addition, he analysed the framework of current regulations.

Matteo Minola implemented research on innovative solutions and future developments. In addition, he reviewed the internal consistency of the work.

Filippo Pizzocchero worked on energy analysis and on the logical path towards the solution. He also developed the mathematical model and collaborated in the development of the software.

Diego Tonelli performed the energy analysis in more depth and investigated both the state of art and the possible opportunities. His work also concerned feasibility studies and project implementation.

ABSTRACT

Increasing awareness on the issues of energy savings has helped to consistently improve the environmental quality of the buildings where we live in. The main point of interest of most energy saving projects literally consists in how to save energy and, particularly, in how to improve energy efficiency and the performance of a system, while minimizing costs. On the other hand, the comfort of the people living inside the environments is frequently underestimated and is only considered a side effect.

The main goal of our team was the development of a system aimed at assuring the comfort of those people. While the theoretical basis of our research is well-known and composed of several standardized documents (amongst others, ISO 7730 and ISO 8996), the framework that we have designed is completely new and offers an innovative approach to the problem. By means of a wireless sensor network (WSN) and an intuitive management system, we built a highly-flexible ongoing commissioning system: the main difference between our solution and current solutions is the capability of quickly adapting to dynamic situations. In fact, it is possible to monitor the comfort situation of the observed environments in real-time through the management system and take effective measures to face eventual critical events. This is performed by analyzing information gathered by sensors networks and by applying a mathematical model in order to understand the current situation. The target of our system therefore includes energy managers and more generally the people involved in the energy management process of a big and complex building. In order to accomplish a reasonable proposal, we have carefully studied and analyzed the feasibility of the project. These studies have been performed on several test cases and have motivated the belief that the chosen approach is capable of improving the environmental comfort situation while managing to save considerable amounts of energy.

UNDERSTANDING THE PROBLEM

"Wi-Fi 4 Energy" had a tough objective. We had to monitor and correct the energy conditions inside buildings by exploiting wireless technology.

Since the best strategy to find solutions to new complex problems is to reduce them to their essentials, we used this 'Systems Engineering' approach, which is also one of the strong point of Ingenia (the external institution involved in the project). This approach allowed us to increase our knowledge and critique about energy management by understanding deeply the problem as a whole. It is important to stress that this fact does not mean ignoring some factors. It helps, on the other hand, to go deeply into the core of the problem and to only focus attention on the few elements really necessary for its solutions. The energy analysis we managed with Ingenia was the starting point for developing our own ideas and was driven by both our stakeholders as well as our potential customers. They provided us with useful information about the actual state of the art in relation to their main needs.

We therefore decided to think of an innovative and cheap solution for correct energy management. Firstly, we had to choose the most appropriate approach for our goal and the degree of generality. We defined two parameters for this purpose: the generality and the *depth*. With generality we mean a scale to define the level of definition of the analyzed building. A low level of generality corresponds with analyzing a specific kind of building, for example an office. With depth we instead mean the richness of details and parameters of the analysis. It is clear how the two parameters are strongly correlated. Certain configurations of these "settings" are very hardly reachable (highest generality and highest depth), whilst others are not so interesting for our purposes (lowest generality and highest depth) and may conduct to a product applicable only for a very specific building. We chose to assume the highest degree of generality and the lowest degree of depth.

The vastness of this attempt is represented by the huge numbers of variables. We overcame this impasse by exploiting the Sys-

tems Engineering approach. In fact, we were able to agglomerate the numerous variables in few important energy factors. Furthermore, we created a *weight-function* with the scope to calculate the importance of each parameter in order to understand the right strategy to follow. Evaluations of the factors inside the weight-function were based on researches and averages of the found values. We also contacted a statistical meaningful number of energy managers from all over Italy in order to listen to their requirements and we included their answers in the weightfunction.

At the end of this intellectual process, we found that the most important variables in energy management are *heating* and ventilation.

EXPLORING THE OPPORTUNITIES

Once the problem was clearly stated and the analysis methodology chosen, we had to explore opportunities and choose the main goal we wanted to achieve.

Firstly, we thought of a set of solutions capable of reducing energy consumption from the perspective of pure energy and money savings. There is a large variety of this kind of products available on the market and many big research projects related to the topic has been activated in some of the major enterprises and Universities all around the World. The Politecnico di Milano and Politecnico di Torino are also involved in this kind of research.

The main disadvantages of this approach include high costs of research and implementation and in-depth training of users (non-intuitive controls and huge number of details). Moreover, the achievable solutions can only be applied to specific environments.

We decided therefore to investigate and explore a completely new approach to energy management.

We moved our attention from pure energy savings to better energy quality. As a consequence, we considered the comfort of the users as the core objective of our project and our major issue to face with.

Even if comfort is not easy to define nor measure in a direct way, there are sets of national and international regulations on





2 General overview of the energy management

in buildings, setting short-term and long-term targets



3 Schematic representation of the generic application of our model in 2D. It is possible to perform instantaneous comparisons of different environments

1 *Results obtained from the energy analysis: values of the* weight function for each parameter affecting different energy

the topic, defining parameters, standards and suggestions in order to assure a better quality of energy demand. These regulations are very often employed during the designing phase of environments. However, after in-depth research on the actual framework, we pointed out that they are not taken into account anymore after that process. Comfort is usually considered as a side effect of energy saving policies, arising from defined control strategies and eventually reported by complains of users.

Afterwards, we had to develop a deep consciousness on the topic as well as collect and exploit results of existing researches in a new context and set the competitive advantages of our solutions. All these activities were aimed at satisfying the needs of stakeholders and customers, thereby minimizing energy consumption and guaranteeing comfort of users in a given environment.

We pursued long and careful trade-offs among different alternatives in order to define the main features of what we think being one of the best solutions for future development of energy management tools.

GENERATING A SOLUTION

As we have already stated, our solutions aimed to create a situation of comfort with optimal energy consumption. First of all, we needed a formal definition of *comfort* and we

found it in the ISO standard 7730 "Ergonomics of the Thermal Environment" and in the research done by Fanger. The sensation of comfort experienced by a person is assumed as a function of the physiological strain imposed on him/her by the environment. This strain is proportional to the difference between internal heat production and heat losses on the actual environment. Fanger created an equation to calculate this strain on the basis of environmental and personal factors; as a result, he was able to predict the percentage of people satisfied or dissatisfied for certain environmental conditions.

We decided to collect information on environmental factors by means of a suitable network of sensors. Wireless sensors were chosen as a reference, since they do not require high costs and are applicable everywhere in a non-invasive way.

Furthermore, we developed a mathematical model in order to calculate comfort votes in a complex environment, according to regulations guidelines. This model was therefore implemented in a tool which is responsible for monitoring and controlling real-time situations, thereby also generating future forecasts. The interface that we developed provides a clear visual representation of the comfort situation, a key feature for Energy Managers. The main features of our tool are:

• User-friendly interface: it is simple, clear and comprehensible,



4 Virtual representation of the results obtained by applying the model. Only areas of interest are shown

and provides information on energy consumption at any level. • Wide applicability: it is not defined for any particular environment; in fact the model has the possibility to be applied

- everywhere.
- Accessibility: the way data are gathered and processed exploits availability of different networks as intranet, Internet or wireless connections, leading to faster and more effective decisional processes.

As a verification, we applied our model to real environments and we obtained very interesting results, with proof of lack of comfort in certain environments as well as explanations and suggestions for possible remedies. To conclude, our tool succeeds in monitoring comfort, revealing situations of unease and, at the same time, allows for the achievement of significant energy savings of up to 10% or even more. We have also had the opportunity of thinking of potential future developments of the project, such as the application of the idea in public transportation. This last aspect is very promising due to the high applicability of our solution as well as the possibility of significantly raising the quality of the public service.

5 *Virtual representation of sensors* deployment in a reference environment. The tool is capable of monitoring and controlling the real-time comfort situation by collecting data from a suitable network of sensors

6 *Parameters affecting thermal energy consumption in buildings. They are merged* in three major factors, which are efficiency, use and status



7 Parameters affecting ventilation in buildings

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HOME EMERGENCY

home emergency sheltering feeding developing



Home Emergency

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project

A project on the recovery and reuse of farmhouses owned by the city council which are transformed into cores in a system of spaces dedicated to housing

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PROJECT DESCRIPTION

ASP students participated in a project sponsored by multiplicity.lab regarding the re-use and development of farmhouses owned by the City of Milan. The first phase involved the installation of the exhibition "la vita nuda" edited by Aldo Bonomi at the Triennale of Milan. The subject of the installation was a possible guide for the "Municipi dell'abitare", a network of sites devoted to social housing within the Milanese public farmshouses. The second phase consisted in the project "Cascine Expo 2015" developed by students in different ways, according to the framework outlined by the Expo conceptual masterplan guidelines. The work was splitted into two different themes: housing, and nutrition/ agriculture.

In Milan there are 58 farmhouses owned by the Municipality. They are located radially at the borders of the municipality, mostly within the major parks of Milan or in agricultural areas near waterways. Some of these farmhouses, initially at the borders of the city, are now surrounded by new development. They are in different conditions, used or partially-used, abandoned and in a state of decay.

Historically, the identity of farmhouses in Milan is linked to agriculture. Today only 14 farm houses are still family-run farms. Some of them combine agricultural production with new services: commercial (direct selling of products), education (educational farms), tourism (restaurants, bed&breakfast) or cultural (concerts, exhibition areas, conferences spaces) services. In the majority of cases just a little part of the spaces and areas belonging to the farmhouse are used for the primal activities.

In recent years, the agricultural vocation of the farms hosted another specific activity, which was developed intertwined with the original one, or replacing it. Many farms were in fact recovered and kept alive by NGO's and citizens' associations. The associations have found spaces that are available and flexible



in order to accommodate different kind of social and cultural activities like: housing and care areas, community centers, cultural places, art, music, teaching and leisure spaces. These farms have become laboratories of integration and citizenship and important social guards of the territory.

Despite the fact that the farmhouses owned by the Municipality of Milan are places of great value, due to their historical, architectural and environmental qualities, there is no specific policy for the their recovery and their development.

The project "Cascine Expo 2015" promotes the recovery and development of Milan-owned farmhouses and the activities hosted by the buildings. The framework considers a sustainable model of open spaces dedicated to agriculture, food, housing. The Expo 2015 theme - "Feeding the Planet, Energy for Life" – could be brought in the very texture of the city due to the farmhouses, thereby helping Milan in becoming a laboratory of sustainability and citizenship.



EMERGENCY

HOME

sustainable city farMIng

Feeding, Feeling more than Filling

Chiara Cannavicci, worked on the urban analysis of the areas, helping in the mapping of the services in the neighborhood in addition to implementing the analysis of different solutions for the network model.

Matteo Ferranti, focused his attention on the primary technical and economic feasibility of the market model while paying attention to the cost-benefits analysis of the project.

Francesco Franci, analyzed the actual issues that faces Milan focused on the context of the Expo 2015 extrapolating useful data for the project development.

Roberto García & **Chiara Geroldi**, focused on the development and management of the project based on the prior analysis and realization of a network model for communication exchanges between the farmsteads and the territory. They developed a model for the farmsteads market from a territorial scale to the local one.

Davide Passini, evaluated the food distribution system of Milan, interviewing potential stakeholders and the entities involved in the project.

All the team actively participated to the survey in site (farmsteads, farms, parks, institutions and markets) and to the interviewing of the people involved in the project.

ABSTRACT

In the city of Milan there are almost sixty municipal owned farmsteads in abandoned or semi-abandoned conditions. Even though these structures represent an example of traditional Lombardy agrarian architecture, they have completely lost their potential and function inside the city. Milan was chosen to host the Expo of 2015, whose theme is "Feeding the planet, Energy for life", and which focuses on the promotion of sustainable feeding. Taking under consideration the great opportunity given by the Expo, the city has the chance to renovate its appearance by developing and rediscovering its rural side. In order to follow this path, our project "sustainable city farMIng" aims to reestablish the agrarian role of the farmsteads by reactivating their functions and promoting their integration in the community.

The network of the farmsteads will act as a filter between the territorial scale and the urban one, linking the countryside (a channel of continuous production) with the city that, by contrast, is characterized by its needs of consumption, making both realities to work in synergy. By enhancing the feeding and agricultural traditions of Milan's farmsteads, the project intends to explore three possible models: the first considers the farmsteads as places of *production*, the second as places for *distribution*, while the third one will comprehend a *hybrid* model.

The project response is the creation of a network model with a complex system of collaboration that provides farmsteads with the possibility to exchange: products, tools, know-how and labour. Using as a reference pole of 21 farmsteads linked to nearby farms, the production system will be associated to a new distribution structure of marketplaces. The farmstead will become a place of social sharing, an educational entity capable of transmitting knowledge about the agrarian traditions of Milan under a model of farmstead community markets, thereby encouraging a multicultural exchange.



UNDERSTANDING THE PROBLEM

The "sustainable city farMIng" project involves a group of Milan's municipally owned and abandoned farmsteads and their surroundings. A significant reflexion about the actual time context of the city has facilitated a better comprehension of the issue. Nowadays, the valorisation of the agricultural reality of the farmsteads has become a main issue for Milan due to the Expo 2015. Historically, the most famous Expo's were the ones that communicated - in their urban structure - the topic of the event. Milano should proudly express its agriculture vocations given by its geographical positioning inside the Po Valley. The recovery of the farmsteads forms part of this program that aims to promote the feeding and agricultural traditions of Milan, thereby endorsing typical Lombardy products manufactured in the city.

The Expo is an important framework for the "sustainable city farMIng" project, as well as the study initiated by multiplicity. lab, a research laboratory of the Politecnico di Milano, which served as an introductory work for the development of the project. The project developed by the Home Emergency Teams



1 *The farmsteads as a filter between the countryside and the city*

2 Network map of the 21 farmsteads subdivided by production and distribution

(A and B), in fact, resumes the work started by multiplicity.lab which started working on the topic of farmsteads in the year 2006. At the year 2007 the Alta Scuola Politecnica (ASP) research group of students began to work in the theme. The path followed for the solution comprehends an in-depth research and analysis of the farmsteads in order to understand their conditions. The research gave us the possibility to talk with potential final users, defining all the possible stakeholders, facing their needs and extracting the project requirements. The results of this first common work were shown during an exhibition "Vita Nuda", held in the Triennale di Milano during the months of May - September 2008. This gave us the chance to show the project for the first time to the public and receive feedback from citizens. The information collected in the exhibition helped us to understand the multiple problems we faced in the project.

The two groups developed different paths for an in-depth analysis of each theme. The topic developed by Team A, "sustainable city farMIng", followed a feeding and agricultural approach, while Team B's topic, "Contemporary sheltering for sustainable communities", looks for a solution to the sheltering problem that





faces Milan today. All the steps have been precious to help define the strategies and guidelines that our project tries to reach.

EXPLORING THE OPPORTUNITIES

By identifying the main objectives of the project we find some topics relevant for successful development: production, distribution and education.

Regarding production, the continuous increase of urbanized land and the gradual reduction of cultivated areas is part of today's problem in the city urban environment. After thirty years of incorrect farmstead maintenance policies, our project together with Expo connected activities, looks forward to restore this abandoned architectonical heritage. An in-depth analysis of the agricultural data of Milan reveals that cultivation is mostly extensive monoculture and the main problem is the absence of biodiversity. This will be one of the issues faced in the project: integrating the farmsteads and their territory by stimulating biodiversity.

The distribution system of goods produced in the city under our model will take into consideration three examples of organizations: farmers' market, rete GAS (Gruppi d'acquisto solidale/ Solidarity Purchasing Group) and open market. The Farmers' market aim is to reconnect citizens and countryside while the

GAS tries to establish channels between customers and sellers based on values while the open markets are a capillary and distributed entity where exchanges between players still exist.

The education factor considers several players in Italy that are using food as a promotional system to renovate the state of mind about sustainability and environmental issues. Some profitable solutions have been found in their organizations and which could be applied to the project, for instance tasting events (such as "Salone del Gusto" in Turin), education on food quality (promoted by Eataly and Slowfood) and the guided tours in the agrarian places of production (Parco Agricolo Sud di Milano, Fattorie Didattiche).

In our model, the biggest challenge is to reconnect the city to its rural roots. Finally, it is important to consider that the farmsteads have diverse features (tools, land, specific know how, and so on) and, as a result, the only viable model to ensure their survival is one based on a mutual collaboration and exchange program.

GENERATING A SOLUTION

The project "sustainable city farMIng" presents several innovations with respect to the role of Milan farmsteads. The project classified the 21 farmsteads by dividing them into three categories, starting from their features: production, distribution, and hybrid. The farmstead as a place of production will dedicate the land to host practices relative to the production and processing of agricultural products. They will become places to experiment sustainable farming practices by looking forward to improve food quality. The farmstead as a place of distribution will promote a km0 agriculture by becoming filters of the rural production, mainly coming from Parco Sud, into Milan. Farmsteads will host an agricultural trade in their courtyards with self-produced goods and products from the network of nearby farms. A hybrid model of farmsteads will be able to distribute and produce food. The subdivision of the network is an innovative way to think about the farmsteads as a system, instead of single entities.



The farmsteads will host open markets and tasting events. The weekly farmstead markets will host spaces dedicated to Expo info points as well as the commercialization of products coming from: countryside farms, agrarian companies and the farmstead itself. The distributed products will follow the guidelines of a km0 production. To differentiate our market from others already existing in Milan, most of the products on sale would be grown organically and locally (fresh or transformed). During the tasting events that will take place on a monthly basis, ethnic restaurants and other institutions will be invited to participate. An important innovation is represented by the chance, for the temporary users of the farmsteads (immigrants, people of low resources and homeless) to be more involved in society. This model looks to develop a place where foreigners can express their culture through food. This process will help to create a multicultural exchange through a "Food Education Program", i.e. workshops and jobs related to the time that the people accommodated in the farmsteads intend to spend in the facilities.

In order to test and verify the feasibility of the concept we have just described, we developed a prototype of the network model. The study began west of Milan because of its proximity to the site of the Expo 2015; in particular, we worked on Sella Nuova Farmstead and its surroundings, taking under consideration public and private farms. Building the prototype has meant under-

5 Timeline map of the 21 farmsteads and their activation order



6 Advertising campaign

standing the requirements and the needs of every stakeholder. From this point of view, our team made surveys and interviews with three main stakeholder types: public players, institutional players and final users (sheltering project beneficiaries, citizens, agricultural companies and farmsteads actual residents).

The project studied a specific program linked to agricultural and feeding issues for each farmstead. It provided a hypothetical network model involving the farmsteads by identifying in which ones a production or distribution model could be developed. The farmsteads, by following the project guidelines, will hopefully become a social condenser in the neighbourhood, thereby stimulating the cohesion of the multicultural population of Milan.

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Contemporary sheltering for sustainable housing models

HOME EMERGENCY TASKS TOP

TASKS & SKILLS

Tommaso Brambati: collaborated in surveying and studying existing sheltering models in the Milanese region. He contributed to the project by finding technological solutions for its economic feasibility and energetic sustainability while focusing on governmental policies and environmental assessments.

Murilo Gomes Nagato: implemented specific research on external sheltering models applied to the cases of Barcelona, South America and United States (New York). He offered theoretical inputs to draw a model based on the principles detected from the American Pathway to Housing model while also managing economic and construction requirements.

Raffaele Pe: contributed to the collection of on-site material related to the state of the art of the Milanese sheltering models, paying particular attention to the anthropological implications of such a condition. He developed also architectural solutions and economic assets for the preliminary project for Cascina Casenuove.

Angela Maria Potenza: implemented a comprehensive screening of governmental supports for housing available in the area of Milan. She structured three model distributions with architectural and social devices while specifying financial strategies and timing schedules for the construction of the project.

ABSTRACT

A contemporary metropolis like Milan is oppressed by a constantly increasing demand for social housing solutions and flexible sheltering systems due to continuous internal and external immigration flows.

The project is a pilot shelter in a former farm, set in the Western part of Milan (San Siro district). The building nowadays is surrounded by a building environment and it is property of the Municipality of Milan, left in state of total abandon. The refurbishment of the building serves, at the same time, as house for temporary and permanent residents as well as individuals and families in addition to being a service supplier of integration of guests and of those who are in social and economical difficulties or in need of a place to stay. This system avoids great concentrations and offers new functions and services to the inhabitants of the neighbourhoods (sports camps, libraries, workshops for professional training, places for entertainment, etc.), and which can be paired with already active social networks in the territory (most importantly the school network). The project creates housing opportunities for people in need of special rental or environmental conditions and a new centrality with services for the whole neighbourhood. In order to get this goal, we have defined three models, based on three different approaches to homelessness and housing problems: a "Traditional model", which reflects the traditional way of facing homelessness in Italy; a "Co-housing model", which is inspired by the American Supportive Housing approach; and a "Hybrid model", which tries to mix different elements from both of the two other projects and which focuses on a more heterogeneous and integrated sheltering system. Each model develops a spatial concept, which describes different kinds of offeredhousing opportunities and services, and an economic feasibility study, which entails expenses and revenues of the model in order to provide a number of different outcomes and assets for the neighbourhood and the whole city scale.

UNDERSTANDING THE PROBLEM

One of the main problem of the contemporary metropolis is the difficulty in meeting a high demand for housing and sheltering solutions from a variegated population that is constantly increasing due to internal and external immigrations and their demographic development.

The social policies of the Milanese administration relative to the problems related to individuals in deepest poverty, people suffering social segregation caused by mental or socio-economic problems, and also refugees and the latest arrivals of migration flows, involve temporary solutions which concentrate the masses - without distinction between individuals or families - into large camps (for the Roma community), or shelter them only overnight in public dormitories, or through public policies, which force those without home to mimetize and disperse in the folds of invisibility and marginality of the contemporary city. These policies provide inadequate responses to the problem because they have been unable to face such a large number of requirements and different sociological issues. In recent times, the urgency to find a quick solution to this home emergency has provoked the building of lots of individual variations to the established way of sheltering by paying attention to the psychological and social implications of the service offered; many of these are run by NGOs and Catholic organizations. Although sheltering and housing problems in Milan are related to the entire region of the city, a partial solution could be provided by exploiting a network of abandoned farms spread out in the rural belt or in a peripheral urban context, an important historical and architectural heritage and property of the city council. The focus on one farm-case study offers the chance to deepen the problem by providing feasible pilot solutions that can also become re-activation propellers for other Milanese districts or for the whole conurbation.

Cascina Casenuove is an abandoned farm set in the 7th district of Milan surrounded by a residential area with few different events and urban emergencies such as the Meazza Stadium and the historical social housing development Quartiere Baracca. By



1 Cascina Casenuove: plan of the co-housing model

exploring the site through surveys, interviews and readings, the main detected critical aspects are related to the low functional variety of the blocks and the presence of a large number of foreigners and refugees, most of them boarded out in the social dwellings of Quartiere Baracca. The number of services for the population is very low and the absence of a cultural and historical centre at the level of the neighbourhood – which can promote the district as a place with a recognizable identity – is evident. Sometimes the international character of the community provoke instability in relationships between different groups. The Cascina Casenuove project wishes to renovate the surroundings introducing in the abandoned farm a new civic centre, with a highly mixed functional proposal: housing opportunities, social and community services and commercial spaces.

EXPLORING THE OPPORTUNITIES

The project aims at overcoming the evident failure of some traditional policies of the Milanese administration by individualizing different urban and socio-political models of hospitality and integration of populations who are excluded from the general urban housing market.

The varied community of the S.Siro district represents the number of stakeholders involved in the project, their needs rep-



2 Conceptual scheme of the project

resent the main challenges and project directories. The area is characterized by a population of Italian and foreigners people living in a neighbourhood in need of a civic centre with services and public spaces, occasional tourists who come to Milan especially for the events of the stadium looking for a temporary accommodation, special families, individuals, or relatives of hospitalised people and students who are looking for permanent or temporary housing settlement with low rental conditions, local NGOs in search for a place to set up their activities enlarging the offer of social and cultural services, and homeless of evicted people from Quartiere Baracca who may be looking for a place to stay for a few nights.

The refurbishment of the farm will then respond to all these issues, particularly by focusing on the possibility to re-activate the S.Siro neighbourhood through the rehabilitation of an old building in the suburban context, introducing a sustainable community with lots of services and cultural features with small and medium scale spaces, capable to temporarily host a moderate number of users. The project approaches the old building as an historical trace of the rural identity of this urban context whose restoration becomes a necessity in order to re-build a new centeredness in a suburb without a collective memory of the place, without symbols and icons in which it is possible to identify the characters of the community itself. GENERATING A SOLUTION

The team has developed three functional solutions for a feasible refurbishment of Cascina Casenuove. Each solution refers to a different housing and sheltering model inspired by existing models detected in the Milanese area or external models deepened through research studies and direct interviews.

Traditional Model

This shelter system for the homeless is based on the current principles of housing support in Italy and, in particular, in Milan. The model renews the old building by placing new functions in the structure for the neighbourhood such as social services and temporary shelters for homeless, thereby transforming the former rural building into a civic centre and a residential development. The model provides an emergency shelter, a flat for 6 people, and two social operators with a kitchen, a bathroom and a talking room. In the central patio of the farm are located a kindergarten and a cultural centre with community gardens and playgrounds. The South wing of the building will be re-used as a house for poor families: 13 flats (max 30 people) with kitchens and services in common. The East wing of the building is a Hostel for tourists and students, while the North wing is a residence for relatives of hospitalised people with 12 beds + living room. The model also presents commercial spaces and association headquarters in which all the operators and administrators of the shelter system are based. Economically the model works on the idea that all the functions should pay back the costs of the system; in this case, the majority of the incomes should be gained from the commercial activities related to the hostel - i.e. accommodations - to the internet café, to the laundry service.

Co-housing Model

This development is conceived on the principles introduced in US in 1992 by Doc. Samuel Tsemberis through the *Pathway to Housing Association and the Supportive Housing Programme*. This programme provides a permanent accomodation to selected individuals with economic problems or disabilities. These

cases capable of living in a community with surrounding families and children, for them the co-habitation with normal people is highly suggested. The model would transform the abandoned Cascina into a residential dwelling with 16 flats with special renting conditions and common services for all the residents, 5 supportive housing shelters in a sort of co-housing development. The central part of the development is reserved for a kindergarten and cultural centre for the community and for the rest of the neighbourhood, with tenants gardens and a playground for the kids. The model also includes an emergency shelter for six people, a space reserved to the housing agency and other NGOs and a commercial space. From the point of view of the economic feasibility, the majority of the incomes will be deducted from the rent of the apartments and of the commercial spaces.

Hybrid Model

This model strives to unify - in one project - the positive outcomes deriving from the assets of the other two models. The number of co-housing flats and supportive housing is here reduced in order to locate a hostel in the North and East wings. The hostel is one of the most lucrative activities in the community together with the commercial activities. The model preserves an emergency shelter for six people and a housing agency. A bigger space is given to other NGOs with special attention to the economic potential of G.A.S. organizations and organizations that work on sustainability and energy selling and production (Solare Collettivo, Orti urbani etc.). In the two buildings in the middle of the square of the farm there are a kindergarten and a cultural centre for the neighbourhood, with a playground for the kids and some private tenant gardens. By comparing the three models, economically, they all should start building their own business in thirty years (time dedicated to pay back the renovation costs). The traditional model offers the largest variety of activities and services that the whole neighbourhood could exploit while the co-housing model – although it stimulates the construction of a sustainable community – risks imploding on itself by attracting a smaller number of external



3 Typical patologies and necessary operations for the requalification of a Cascina



4 *Cascina Casenuove: plan of the hybrid model*



5 Section of the Cascina

users. The hybrid model blends the positive effects of the first two models including a bigger number of services for the community and for the neighbourhood.

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PREMEMB



PREFABRICATED MODULES FOR ENERGY MANAGEMENT IN BUILDINGS



PreMEMB

Prefabricated modules for energy management in buildings

broject

Developed with ENEL Research Center (Catania), this project aims at developing highly energy-efficient building envelope components for Mediterranean countries

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PROJECT DESCRIPTION

The challenge In the last decades, it's becoming more and more clear everyday that the rational use and production of Energy will be a crucial issue for the development of our civilization. Big efforts are being done to find new exploitable energy resources and to improve the performance and efficiency of the existing conversion technologies. To make these efforts useful, it's easy to understand that a parallel line of action involves decreasing of energy demand. In dealing with this problem, the target of the project is to develop architectural concepts and design prototypes that may lead to scalable, low-energy, cost effective buildings for European and Mediterranean climates. Starting from a case-study building localized near Catania, the students were asked to propose innovative solutions both for the facades and the roof, including active and passive components and exploiting all the possible advantages given by modularity and by prefabrication. A solution that could work with free and clean sources and with sustainable materials, never neglecting the requests of the final users and the aesthetic of the building.

The teams Considering that the project aims at two different modules for the façade and the roof, it has been natural to split the group in two teams. The characteristics of the work of the two teams are however similar and both teams include architects, civil engineers and industrial engineers in order to allow for a multi-disciplinary approach to the problem. Team A has developed its work by focusing on the façade module. It has been studied how to integrate energy-production and energy-saving systems in a vertical wall. The different skills of the members of the team have allowed for a work approach from many points of view, ranging from technical aspects related to energy production to the interaction with lights and shades and the relation with current legislation. In order to completely rethink the building, team B has worked on a new concept of roof. It has conducted a feasibility study in order to create a "water roof" that could be used as a pas-



sive way to reduce energy consumption and as an active way to produce energy. Having different skills inside the team has created a stimulating environment and has permitted to discuss several aspects as energy management, external look and links with other facilities. Heterogeneity has permitted to find different solutions that come from different fields.

The results Both teams, after a first phase of analysis of the problem, the stakeholders and the state of art of the sector, have proposed a solution that involves different innovative technologies and have justified the choices by performing economic and energy simulations. To do these, commercial software and appropriate models written by the students have been used and merged. ENEL, the main stakeholder of the project, has expressed satisfaction about the methodology which was adopted in approaching this complex and multidisciplinary problem, enlightening also the innovative skills of both teams.

The proposed solutions can give an interesting contribution for increasing the energy efficiency of buildings, and this could represent an interesting issue, particularly for Public Administrations that have to deal with a lot of structures for offices, schools, hospitals and other. In a period of economic crisis, this renewal could also be a key point for stimulating, in a sustainable way, the production and the markets.

Smart façade module

PreM project 12A

TASKS & SKILLS

Lorenza Bianco studied the optimization of the photovoltaic device integrated in the shading system by developing a model to analyze the intensity and direction of solar radiation during the year. She then defined the best graphic and architectural shape of the module.

Filippo Colzi analyzed the energetic and economic aspects of the module by developing appropriate models and using commercial software too. In addition, he studied the behavior and the performances of the layer of Phase Change Materials inserted in the wall.

Alessandro Scandiffio focused his attention on the study and integration of fiber optic collectors in the module. He also developed the model for the tracking sun photovoltaic system in depth and studied the advantages given by the new shading system.

Each problem met during the development of the project has anyway always been faced by all members of the group. All members have also actively participated to the initial brainstorming phase.

ABSTRACT

Energy efficiency in buildings is nowadays one of the most debated topics in the field of architecture and engineering. Yet in the latest 80's, in Sicily, ENEL, the most important energy firm in Italy, started a project involving the design and testing of "smart" modules for a research center building named Conphoebus. The aim of this work was therefore to imagine and design an innovative solution that could be integrated in external walls of buildings to decrease their energy consumption. When talking about energy as "primary energy", an effective solution has to consider at the same time different features:

- deal with both thermal and electrical energy
- deal with both energy production and energy saving
- improve the wellness of final users
- exploit cheap, clean and renewable sources
- exploit sustainable technologies

The well known advantages of "big-scale" industrial production and of prefabrication are also non-negligible and extremely interesting features in generating a feasible solution.

Working in this direction and after a first phase of analysis of the case-study Conphoebus building and of the state-of-the-art, the team has developed the design of a module that can properly fit the above mentioned requirements. Different technologies have been used, merged and integrated in the same module. A photovoltaic mono axial tracking brise-soleil, an optic fiber collector and a layer of Phase Change Materials inside the wall, allow the users gain all the advantages provided by Sun radiation while not being affected by the disadvantages. The use of appropriate layers in the wall, moreover, allows the internal temperature be within the limits of comfort with low energy consumption. The use of a standard basic structure on which to assemble different components as a function of the desired features, will indeed join together the economic advantages of prefabrication and big-scale production and the advantages of developing an "on-demand" solution.



1 Case study: Conphoebus building

UNDERSTANDING THE PROBLEM

Eleven years after the Kyoto Protocol, in December 2008, the European Council approved another extremely important document which assessed the targets commonly known as 20-20-20. In the year 2020, the electrical energy production should be covered for at least 20% from renewable energies while CO2 emissions should decrease by 20% and the energy efficiency in buildings should rise by 20%. It's exactly at this last point, considered as important of the two others, that the project wants to intervene. In Italy in 2008 the civil sector has been responsible for almost the 33% of the consumption of primary energy. It has been calculated that an intervention on the energy efficiency of public buildings in Italy could lead to savings from 200 to 600 millions of Euro per year, and from 28,000 to 84,000 tons of CO₂. At present, several interventions are possible, but no one has represented a turning point of the situation. A correct energy management in buildings, indeed, is related to the use of technologies and materials with proper characteristics which difficult to obtain and therefore expensive. In the construction phase, when the requirements are often to keep the costs as low as possible, the energy efficiency tends to be neglected. The challenge is so to design a system that could be at the same time efficient, feasible and easy to introduce as well as capable of stimulating the market so to create a virtuous circle.



2 Schematic building section with the main technologies

The constant contact with Enel, main stakeholder of the project, and the analysis and visit of a case-study building, the Conphoebus research center in Catania, have let to a better definition of the problem. In particular, the needs of final users have clearly emerged:

- decrease the direct lightening of offices exposed to south. The direct radiation heats the ambient and creates an uncomfort-able environment for the eyes.
- decrease the mean temperature of the offices during the summer
- have a glazed part to watch outside.

To these requirements, the more technical ones have to be added:

- introduce an active component for the electrical energy production from a clean and free source.
- decrease the heat flows through the wall.

The efforts of the Team have been focused on giving an answer to all these problems, with the target being to obtain a higher efficiency grade in the Building Energy Label while always trying to maintain economical feasibility.

EXPLORING THE OPPORTUNITIES

The field of energy production and savings presents a huge amount of ideas and proposals, from the most elementary to highly technical ones, ranging from artistic, futuristic and creative ones. Introducing novelties in this context means to try to think in different



3 *External panel of the building*



ways; what has been done is a contemporary analysis of the stateof-the-art and large-scale brainstorming while being completely unconstrained by physical or chemical laws. By "exploiting" the small experience in this field, the Team has so freely discussed about possible solutions to tackle the proposed problem, enlightening how things that are normally considered dangerous or, at least, useless could be theoretically converted in interesting opportunities. In that sense, proposals have been done, such as to absorb and convert noise, annoying and dangerous, or to exploit the energy connected to the movements of tectonic plates, always present, but considered only when it dramatically appears during earthquakes phenomena. But technical and physical problems obviously exist, and it has been so understood that the real opportunity could have been to integrate and link together different and already existing technologies.

din-mo-mo-ma

Among these, the Italian climate situation fosters the adoption of Photovoltaic modules, nowadays reliable and affordable due to public funding. In addition, small wind turbines are now interesting solutions for energy production, but, after a first phase of study and analysis, it has been evaluated that they don't fit with a façade device.



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or to exploitFinally, from a less technical point of view, a big opportunity is
to involve in the project the Public Administrations; to intro-
duce an innovative and efficient solution in public buildings,
would indeed represent, against initial investments, a remark-
able level of money savings, an important contribution to save
sources and reduce emissions and a positive stimulus to the
local and national economy.

GENERATING A SOLUTION

The results of the requirements and opportunities analysis have resulted in a solution that integrates different technologies and components in a single prefabricated module. A photovoltaic mono axial tracking brise-soleil has been designed. Composed of three Silicon modules with a variable tilt, it has been optimized from different points of view, in terms of the choice of the kind of Silicon, the definition of the supports position and the effect of the tracking system on the amount of energy produced.

Accurately designed, this component allows at the same time to



6 Façade module axonometry

exploit the advantages of the solar radiation, converted in electrical energy, and to avoid its disadvantages, preventing it from entering in the working environment, heating it and making it uncomfortable.

Above the brise-soleil, an optic fiber collector has been positioned. This is capable of transporting natural light inside the building that is free and which, if correctly diffused, is extremely pleasant in a working environment. For the case study building, the optical fiber is an interesting solution in order to enlighten the central corridor, lacking in windows. It is, another time, a way to exploit a positive aspect of the sun radiation. The thermal energy aspect has been considered through an appropriate design of the wall layers. Expanded clay and wood fiber guarantee the required characteristics in terms of structural resistance and thermal insulation, being moreover ecologically harmless. To increase the thermal inertia, a layer of Phase Change Materials has been inserted in the wall; during the day these innovative materials, melting at a temperature quite near to the comfort one, are able to absorb a big amount of thermal energy as latent heat. If properly managed, this behavior can result in a remarkable level of cooling energy savings.



7 Production comparison between photovoltaic tracking system and fixed system

The performance of the proposed components has been evaluated by means of different models, both commercial and properly written by the team. The economic aspects have not been neglected. The choice and analysis of the proposed components should not live down that the module proposed wants to be flexible; the idea is so that only the basic structure of the module has to be fixed, while it will be a choice of the user as to what kind of components insert. A potential future development of the work could then be the definition of alternative components and a table that could help users choose the right combination as a function of the desired features. In this way, there will be the simultaneous attainment of the advantages of big scale production (production of standard components) and the ones of on-demand design.

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REnBRA Renewable Energy for Buildings – Roof Applications

TASKS & SKILLS

Leandro Candido: focused on the design of the roof structure and the related calculations. He worked on scenario definition and market investigation in the first phase in addition to contributing to the definition of the modular concept.

Achille lannazzone and Stefano Petrucci: worked on the study of roof energy balances and on its energy performance. They also worked on prices, performances and sustainability of different auxiliary components which are necessary for the solution and contributed to the definition of modular concept and its market assessment.

Erica Pilotto: dealt with module design, roof structure, comparisons among different roof typologies as well as the study of rain water applications. She examined the evolution of the house under the perspective of the passive houses.

Liliane Tonet Rensi: analyzed the application of lightening globes, studied comparisons among different types of roofs and the application of rain water. She worked as system engineer, studying the multidisciplinary aspects such as the state of the art.

Antonio Russo: focused his work on information gathering, researching products in the market and bibliographic research. He also evaluated the adoption of a trigenerative solution

ABSTRACT

This work aims at considering all global project guidelines with direct application to the roof. In other words, the work consists of the design of a modular roof with energy saving/production functions which are required to be appropriate both for residential and commercial/industrial applications. In particular, the team studied the application of the final solution on the Conphoebus building, at Enel's Resarch Center on Renewable Energy in Catania, Sicily. With the aim of creating an innovative project, the team – from

the beginning - chose to work on a solution that would introduce a close interaction between the use of technological devices and the roof. As a result of this intention, the proposed solution is not any type of common device installed on the roof, but is the roof itself. Furthermore, in addition to the main technology, whose goals are energy savings and energy production, the project also takes into consideration two auxiliary technologies, one focused on exploiting the capacity of the roof to collect rain water of the roof, and the other on optimizing the use of sunlight.

After an initial brainstorming process, the research was carried out with the aim of studying the real applicability of the chosen solution through the achievement of energy saving goals. Such goals represent a necessary condition since the final solution still lacks implemented models that would enable effective application. The following sections contain further information concerning the development of the modular roof project, with all the related considerations on structural analysis and performances. The reader may also find highlighted results and conclusions concerning this new technology.





air gap

UNDERSTANDING THE PROBLEM

The global climate issue has forced us to focus on environmental causes in order to search for alternatives to the current way of life and which could result in a more sustainable environment. Considering that buildings represent 33% of total primary energy consumption, the focus of this project is to interact with this reality by strongly renewing the concept of renewable energy applied to buildings.

The first step of the project involved analyzing the appliance of a modular roof component to Enel's Conphoebus building, located in Catania. This component must be suitable to the Mediterranean micro-climate but should also apply to a wide range of applications in residential and commercial buildings. The following steps were the analysis of the climate conditions in Catania and the characteristics of buildings. The team selected the following targets:

- creating an innovative solution;
- totally integrated with the roof structure;
- modular structure;
- suitable with Catania's climate, but also with a wide range of applicability;

1 The image shows a 3 dimensional view of the roof module pointing out the different lavers

2 The image shows a 3 dimensional view of the roof module pointing out the different layers





4 This is a scheme to represent the idea for the LGs

- satisfying insulation requirements during all seasons;
- providing conditioning solutions;
- providing energy recovery solutions;

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• implementing integrated technologies, in order to take advantage of different positive aspects.

The team subsequently calculated energy consumption of the entire building and in order to validate the chosen solution we decided that it had to achieve the minimum goal of at least 10% of energy saving.

EXPLORING THE OPPORTUNITIES

The starting point for choosing technological solutions to adopt consisted in an initial brainstorming, integrated with a phase of research/study, followed by a comparison of potential solutions. As a result of this initial analysis, we found out that all common solutions, such as a green roof and cooled roofs, are only suitable for one climate condition. Generally these devices are placed over the roofing, and this means that they are not well integrated with the roof structure. Furthermore, almost all of these solutions exploit well-known technology, and are anything but innovative.

With this general vision, we concluded that the solution that better fits our targets was the Solar Water Collector. Since this is a brand new technology, there is not enough documentation concerning the modeling of this structure and its real performance. So, at this point, the aim of our project was no longer just centred on the economical analysis of the results in terms of costs and energy savings but also aimed to verify if this solution could be truly applicable or not.

Another important aspect of the chosen technology is that it allows for the application of auxiliary technologies. Since the main technology works with water, we decided to integrate the project with a Rain Water Collector, due to the potentiality of rain water recovery in Catania and the possibility of having such a wide roof area on the Conphoebus building.

Finally, as our solution concerns a roof technology, we decided to study a device that allows the usage of daylight to enlighten the internal corridor located on the 3rd floor of the Conphoebus building. We decided to draw inspiration from a new alternative solution that is currently being used in the Brasilian favelas for low cost lighting.

This alternative solution consists of a PET bottle full of water that is inserted in the roof through a hole. The bottle in this way works as a concentrator of sunlight and helps supply internal lighting for houses. Here the water concentrator consists of a glass globe integrated with the roof structure, thereby simultaneously representing a strongly innovative and cost-effective solution.

GENERATING A SOLUTION

Solar Water Collector

The core idea of the solution that we present involves a Solar Water Collector. As previously mentioned, this technology is not a device installed on the roof, but is the roof itself. Its structure is divided into:

- A first metallic sheet;
- A chamber that can be filled with water or air;
- A first glass layer;



5 The image shows the actual situation of the Conphoebus roof

- An air gap for insulation;
- A second glass layer;
- A scrollable curtain.

In a brief description, the possible configurations according to climate conditions are as follows:

Summer daytime: the water fills the main chamber in order to provide indoor cooling by free convection, and the scrolled curtain is open in order to protect the roof from solar radiation; Summer night time: the water is sent to the upper glass, in open air. Here it evaporates, and due to thermal radiation emitted to the sky, water should cool the glass for day use;

Winter daytime: the water fills the main chamber to collect solar energy and warm up the indoors by radiation. Warm water can be also channeled into the heating system;

Winter night time: water is sent to the insulated storage tank in order to maintain the temperature reached during daytime. It is also sent to the heating system to maintain the inside temperature.

The first issue for the design of this roof configuration is to settle on its modular composition. Analyzing the maximum industrial dimensions for each component, the team identified a "small size" module that is capable of adapting our technology



to the needs of different kinds of consumers. All energy simulations have been developed both for the total roof area and for the single module.

Another topic concerning the modularity of the roof to be analyzed is the joint method which should avoid any water leakage inside the building and maintain the air gap between the two glass layers. Problems have been solved by attaching one corrugated metal sheet to another by welding, and in the second case an omega profile provides the necessary support to both glass layers, thereby preserving the air gap. The next step was the calculation of structural loads in order to ensure the security of the roof. The maximum load that glass layers can stand in the case of adverse climate conditions and maintenance was also considered. To validate our choice, we made a comparison between the efficiency of our roof model with the existing one and also with other alternatives (cooled roof). This simulation was performed with a program named "Summer Thermal Environmental Performance" (STEP) that simulates the inside temperature of a non-cooled environment in a summer day according to the national Standard UNI 10375.

As a result and through the adoption of the SWC a lower inside temperature can be achieved ($\Delta T \approx 2^{\circ}C$) in comparison with the actual roof. Then, by comparing the SWC with a traditional roof containing cool roof materials, results show that the latter is equivalent to the first one in terms of indoor temperature. But

6 The image shows how the lightening globes work inside our water roof



7 This is a schema of the winter-day working of WSC

our solution not only aims at insulating but also energy production. In this way we can conclude that the SWC is a valid solution.

Rain Water Collector

The Rain Water Collector is an auxiliary solution which aims, first of all, at making the core idea feasible in order to satisfy the water needs. Nevertheless, the total amount of recovery water is bigger than the amount required by the WSC for working. So, taking advantage of this, exceed water can be used to integrate water needs for the garden watering.

Lightening Globes

As this device is totally innovative, all design methodology was defined by the team members. In particular, we studied possible formulas to determine LGs performances and to estimate how many LGs were required by the case study. Finally, computation of energy savings and comparisons with normal lighting devices were made.

Conclusions

As previously exposed, our solution introduces several innovative elements: first of all, the replacement of the traditional roof structure and a brand new daylight lighting device. Furthermore, it seems to satisfy our initial target in terms of energy savings. In addition, our project aims at fostering eco-sustainable building technologies. For this reason, we decided to only adopt eco-friendly materials which could be integrally recycled in case of demolition.