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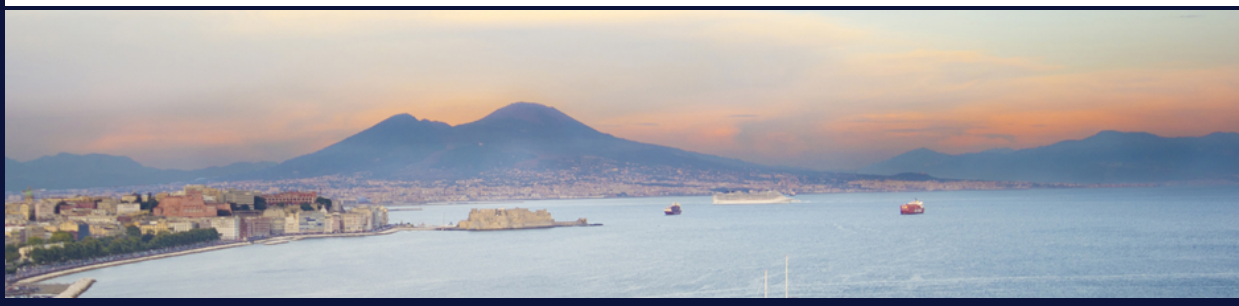

September 9th - 12th
2013 Naples (Italy)

Faculty of Engineering
University of Naples "Federico II"

Introduction and Welcome

It is our great pleasure to welcome you to XXII AIDAA Conference and to Naples.
In this booklet you will find the Technical Program and a collection of the abstracts together with several information, which we hope you will find useful. This is the 22th in the series, a well-established tradition in the aerospace Italian world.
It brings together people from universities, research institutes and industry working in the areas of aeronautics and astronautics *at large*, and considering also the closer engineering fields as automotive and railway.

The goal of the conference is to promote significant discussions and exchange of information both for academic and industrial needs. The emphasis of the conference will be also on the actual and critical economic situation in which the aerospace sector can be the answer more than a problem.

As in previous conferences, the technical program is centered around the Plenaries, which comprise 7 Keynote Lectures with two round-tables on specific topics. There are 141 contributed papers, selected by the AIDAA 2013 Peer Review Board (Organizing and Scientific Committees), the large majority of which also concern the forum themes. Authors from 10 countries and 3 continents make the conference truly international. The more represented sectors are those related to the Structures and Space but all the disciplines related to the aerospace will be represented.

The conference is few months after the celebrations of the Bicentennial of the engineering faculty of the University of Naples "Federico II".

The Organizing Committee would like to thank the Keynote Speakers, the Session Chairs and the Scientific Committee members for their invaluable contributions.

We hope you will enjoy the conference and we wish you a very pleasant stay in Napoli.

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Programme at a glance

Monday, Sept 9th

08:30 - 13:00	**Registration**	**Registration Desk**			
09:00 - 10:30	**Aula Magna**	**Welcome and Opening Cerimony (See Details on Conference Programme)**			
10:30 - 11:00	**Coffee Break**				
11:00 - 11:40	**Aula Magna Keynote**	**Prof. L. Pascale (title to be announced)**			
11:40 - 12:20	**Aula Magna Keynote**	**Ing. F.J. Rodriguez-Carrero (A350 XWB Assembly Boxes Integrator, AIRBUS Operations S. L.)** ***Composites on A350: a Challenge and a Step Ahead***			
12:30 - 13:30	**Lunch Time**	***II Floor, Historical Library***			
14:00 - 15:30	**Aula Magna Round Table**	**Round Table Clean Sky, Chairman : Giuseppe Pagnano (Clean Sky JU - Coordinating Project Officer):** ***The Role of the European Programs for Italy's Industry*** ***Speakers: Maurizio Fornaiuolo (AleniaAermacchi), Luigi Bottasso (AgustaWestland), Franco Tortarolo (AvioAero)***			
15:30 - 16:00	**Coffee Break**				
		Space Engineering and Technology	**Structures and Materials**	**Aircraft Technology**	**Aircraft Systems & Ops.**
16:00 - 18:20	**Technical Session 1**	Space Engineering and Technology 1	Structures - Methodologies	Aerodynamics and Wind Tunnel Testing	Subsystems and Integration 1
		Chairman:	Chairman:	Chairman:	Chairman:
18:30	**Welcome Cocktail**	***II Floor, Historical Library Terrace***			

Tuesday, Sept 10th

08:30 - 13:00	**Registration**	**Registration Desk**			
		Room "Bobbio"	**Room C**	**Room D**	**Room E**
		Space Engineering and Technology	**Structures and materials**	**Aircraft Technology**	**Aircraft Systems & Ops.**
09:00 - 11:00	**Technical Session 2**	Space Exploration	Structures - Composite Materials	Propulsion and Combustion, Gasdynamic, Heat Transfer 1	Subsystems and Integration 2, Aircraft Maintenance - Failure Analysis
		Chairman:	Chairman:	Chairman:	Chairman:
11:00 - 11:30	**Coffee Break**				
11:30 - 12:10	**Aula Magna Keynote**	**Prof. G. M. Carlomagno (University of Naples "Federico II", Italy)** ***Aerospace and Infrared Thermography***			
12:30 - 13:30	**Lunch Time**	***II Floor, Historical Library***			
		Room "Bobbio"	**Room C**	**Room D**	**Room E**
		Space Engineering and Technology	**Structures and materials**	**Aircraft Technology**	**Aircraft Technology**
13:30 - 15:30	**Technical session 3**	Space Tourism & Commercial Space Flight	Model Reduction and enhancement in Aerospace Structures	Aircraft Performance, Stability and Control	Aircraft Design - C
		Chairman:	Chairman:	Chairman:	Chairman:
15:30 - 16:00	**Coffee Break**	Coffee Break			
16:00 - 16:40	**Aula Magna Keynote**	**Prof. M. Napolitano (West-Virginia University, USA)** **Development, Manufacturing, Instrumentation and Flight Testing of Unmanned Vehicles as Research Platforms.**			
16:40 - 17:20	**Aula Magna Keynote**	**Mr. A. Bergweiler (Space Affairs, Germany)** **SPACE TOURISM - From an Early Childhood's Dream to Reality**			
20:30	**Gala Dinner**	***Cenacolo Belvedere, Via Aniello Falcone 122, 80127 Napoli (www.cenacolobelvedere.it)*** ***Guest star: Soprano Rosalba IULA***			

Wednesday, Sept 11th

08:30 - 13:00	**Registration**	**Registration Desk**			
		Room "Bobbio"	**Room C**	**Room D**	**Room E**
		Space Engineering and Technology	**Structures and materials**	**Aircraft Technology**	**Aircraft Systems & Ops.**
09:00 - 11:20	**Technical session 4**	Space Mission & Applications	Structures - Modeling	Aircraft Design - A	Air Traffic Control, Avionics
		Chairman:	Chairman:	Chairman:	Chairman:
11:20 - 11:50	**Coffee Break**				
11:50 - 12:30	**Aula Magna Keynote**	**Mr. G. Tumino, S. Mancuso (European Space Agency, Paris, France) Concrete Steps to Prepare the Future of Aerospace: From the Intermediate Experimental Vehicle to the Innovative Space Vehicle**			
12:30 - 13:30	**Lunch Time**	***II Floor, Historical Library***			
		Room "Bobbio"	**Room C**	**Room D**	**Room E**
13:30 - 15:30	**Technical session 5**	Space Simulation & Modeling	Materials	Aircr. Tech. Supp., Production, Non-conventional A/c	Aircraft Navigation, Aircraft Operations
		Chairman:	Chairman:	Chairman:	Chairman:
15:30 - 16:00	**Coffee Break**				
16:00 - 18:00	**AIDAA General Assembly**	**Room "Bobbio"**			
20:00	**Gala Concert (TbC)**				

Thursday, Sept 12th

08:30 - 13:00	**Registration**	**Registration Desk**			
		Room "Bobbio"	**Room C**	**Room D**	**Room E**
		Space Engineering and Technology	**Structures and materials**	**Aircraft Technology**	**Aircraft Technology**
09:00 - 11:00	**Technical session 6**	Space Systems	Structures - Crack and Damage tolerance	Aircraft Design - B	Propulsion and Combustion, Gasdynamic, Heat Transfer 2
		Chairman:	Chairman:	Chairman:	Chairman:
11:00 - 11:30	**Coffee Break**				
11:30 - 12:10	**Aula Magna Keynote**	**Keynote: Dr. J. N. Kudva (President and CEO, NextGen Aeronautics Inc., Torrance, CA, USA)** ***Twenty-five Years of Adaptive and Morphing Structures - A Subjective Retrospective***			
12:10 - 12:50	**Aula Magna Keynote**	**Prof. John Halpin** ***Requirements for Certification of Composite Airframes: Historical Evolution***			
13:00 - 14:00	**Lunch Time**	***II Floor, Historical Library***			
		Room "Bobbio"	**Room C**	**Room D**	**Room E**
14:00 - 16:00	**Technical session 7**	Space Engineering and Technology 2	Structures Engineering	Rotary Wing Systems	Structures - Morphing structures
		Chairman:	Chairman:	Chairman:	Chairman:
16:00 - 16:30	**Coffee Break**				
16:30 - 17:30	**Aula Magna**	**Closing ceremony and awarding of prizes**			

KEYNOTES

SPACE TOURISM - from an early childhood's dream to reality

A. Bergweiler

SPACE AFFAIRS - Germany

The era of space tourism is about to start or has just started decades ago. It is matter of fact that the very first space tourist was the US citizen Dennis Tito who reached the International Space Station on board the Soyuz capsule on 28 April 2001, spending some 20 million USD. He was the first who paid this trip out of his own pocket. In general, there were "space flight participants" (this description is most used by those who flown to space on their own amusement) before Tito. E.g. Helen Sharman was the first british citizen in space and flown to the MIR space station mission JUNO, paid by a broadcasting company.

With the advent of SpaceShipOne by Scaled Composites that won the Ansari X-Prize in 2004, the commercial suborbital flights became feasible first at the relatively low cost of $200k per person person. Virgin Galactic and other companies are presently completing the qualification of their rockets and other spacecrafts, and some of them will soon start their commercial space tourism flights.

But it is not only the technology what is a challenge, legal and insurance issues are popping up each day beside. The idea of enjoying the Space aside its use for exploration and scientific experimentation is very old and ancestral. Most of the people are attracted by the extraordinary meaning of making a Space experience! Not anybody, but those who were "born with stardust in the eyes." want to be involved more.

It is matter of fact that many dreams come first to reality in books and movies and expressed in the years in different ways to influence the development of real engineering systems and invented totally new technology what is used nowadays without knowing, where it originally come from.
Thanks to the multimedia approach used for its presentation, the paper tries to stimulate those ancestral elements everyone has inside the human body.

How science fiction influenced reality: (multimedia presentation part "from the past to the present into the future:

- From Jule Verne's "From the Eath to the Moon", from Heinlein's "The Man who sold the Moon", Kubrik's "Odyssey 2001 and "Star Trek" to the Space Ship II and the Lynx what will carry commercial spaceflight participants on private wings to space. Some technical illustration to underline differences and similarities
- Suborbital space tourism in relationship to education & outreach
- Space Tourism is starting on Earth. Get involved as business start-ups in space business.
- The "Solar System" as a settlement target. Cruises to the Moon, to Mars and beyond.
- 16 years of doing commercial space business. Real experience with "space tourism participants" as jet-flyers, zeroG participants, expedition participants, investors for spacecraft systems and more.
- Already available opportunities for people to have a real experience.
- The "I was there and touched it" factor – psychological influence of space tourism on life in general.

Aerospace and infrared thermography

G.M. Carlomagno* and C. Meola

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Infrared Thermography (IRT) allows for remote detection of electromagnetic energy radiated from objects in the infrared band. After detection, this energy is converted into a video signal which practically leads to the object surface temperature map. The technique constitutes a great potentiality to be exploited in a number of technical areas but then, in particular, in aerospace for several different purposes. On the one side, when heat transfer by conduction is involved, an infrared imaging system is the right solution for production processes, maintenance purposes and non-destructive evaluation (NDE) of materials. On the other side, IRT has also proved to be suitable for the measurement of convective heat fluxes in complex fluid flows and for investigation, through the Reynolds analogy, of the flow field behaviour over complicated body shapes. Scope of this lecture is to review some of the most relevant experimental results obtained over the past several years by the authors, and the research team they belong to, in the exploitation and the application of infrared thermography to both thermo-fluid-dynamic studies as well as non-destructive testing.

Requirements for certification of composite airframes: historical evolution

J.C. Halpin

JCH Consultants Inc.,
Dayton, OH
USA

The certification of composite structures for CIVIL and MIL aircraft has been evolving for about 40 years. The technology for the certification process is now mature enough to support the process for major CIVIL airframes. Tailoring the "Building Block" approach for substantion is a challenge to obtain a proper balance between safety, cost and schedule. Specific examples of current interest will be discussed illustrating the need for an understanding of the underlying material engineering and structural topics and the different operational usage for different classes of airframes (large long haul versus regional).

25 Years of Adaptive Structures – A Subjective Perspective

J.N. Kudva

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While 'smart materials,' particularly piezoelectrics, have been known and used by the scientific community for more than a century, the term 'smart structures' came into vogue in the 1980s. The impetus for the research at that time was sparked by the initial demonstration of embedded fiber optic sensors in a composite laminate. Since then, hundreds of millions of dollars of R&D investment has been made in the broad area of smart or multi-functional materials and structures. This presentation traces the historical development of this field, starting from about the mid-80s to the present, in three areas:

1. Health monitoring, mainly for structures, wherein sensors are attached or embedded in the structures to monitor its (internal) health. The goal is to increase safety, reliability and possibly increase the flight envelope and reduce maintenance costs by implementing condition-based-maintenance rather than the current practice of schedule-based-maintenance.
2. Integration of antennas and other sensors to provide multi-function capabilities at the component level – for instance provide optimal structural and antenna performance, enhancing overall system capability;
3. Adaptive structures where sensors and actuators are integrated in the structure or the overall system to change shape or state to optimize its performance for differing external conditions such as loads and flight regimes. The rationale in this case is to provide multi-point optimization at the system level, for example to realize wing shapes which could be optimal across a wide speed range, resulting in multi-mission capabilities.

While much fundamental and applied research has been conducted in all three areas, transition of the developed technologies with demonstrated performance improvements has been limited. The reasons for this are many and varied; the presentation provides a broad brush, subjective assessment of the overall R&D commercialization efforts in the field and a speculative vision of the future of smart structures.

The talk will also address the joys and challenges of a starting and running a small R&D business.

Development, Instrumentation, and Flight Testing of UAVs as Research Platforms for Flight Control Systems Research

M.R. Napolitano

Flight Control System Laboratory, Director
Department of Mechanical and Aerospace Engineering
West Virginia University, Morgantown, WV 26506-6106, USA

Among several other civilian and military applications, UAVs are becoming very important tools as research platforms for testing research flight control laws, especially for specific classes of "high risk" flight control laws, such as fault tolerant flight control laws and formation flight control laws. This trend has been made possible by the decreasing costs and the miniaturization of all the components of the on-board avionics, the increased reliability of small propulsion systems, as well as the introduction of mini jet turbines allowing reaching speed in excess of 150 mph. Researchers at the Flight Control Systems Laboratory (FCSL) at the Department of Mechanical and Aerospace Engineering (MAE) at West Virginia University have a 20 years' experience in designing, manufacturing, instrumenting, and flight testing UAVs as research platforms or testing a variety of specific flight control laws. Over the years the FCSL team has developed 13 different UAV platforms ranging from rotary wing UAVs to jet-powered UAVs with 5 generations of avionic payloads with a total of 700+ research fights. This paper highlights some of the research accomplishments of the WVU FCSL team in the area of formation flight and fault tolerant schemes.

Keywords: Flight Control Laws, Unmanned Aerial Vehicles, Fault Tolerant Systems

Concrete Steps to Prepare the Future of Aerospace: from the Intermediate eXperimental Vehicle to the Innovative Space Vehicle

G. Tumino

IXV and ISV Programme Manager
European Space Agency, Paris (France)

Looking at 10 to 50 years from today, with the ever increasing number of orbiting satellites, the natural progress of space activities will lead to a growing need to access orbit for their servicing, extending their life, limiting their replacement, and controlling their disposal.

The availability of a miniature robotic reusable space-plane, with a multi-purpose cargo-bay capable to perform multiple in-orbit operations ranging from future generation cooperative satellites servicing and controlled disposal, to earth observation, micro-gravity experimentation, high altitude atmospheric research, and so on, returning to Earth from orbit by braking through the atmosphere and landing on a conventional runway, opens to scenarios where access to space may be performed routinely and competitively in comparison to today's expendable solutions.

Considering the extensive efforts on the subject already on-going in several space-faring nations, including the latest developments of mystery space-planes such as the X-37 in United States and the Shenlong in China, the consolidation of an affordable roadmap to prepare the future is of strategic importance for Europe.

The development of the IXV and the definition of the ISV are the two most concrete European steps in this direction, and their up-to-date status and perspectives will be presented at the XXII AIDAA Conference.

ABSTRACTS

Polarimetric data for soil moisture retrieval. Preliminary results on the capability of SAR data for landslides monitoring

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Soil moisture content has a great importance in different environmental and land activities, such as hydrology, agriculture, meteorology, and forestry. In particular the information about the behaviour of the soil moisture is the basis for prediction of river floods, rainfalls, avalanches and landslides, that are the 42% of natural disasters[1].
The new generation of high-resolution Syntethic Aperture Radar (SAR) satellite systems, play an important role in the damage assessment and post-disaster monitoring. Radar remote sensing with its sensitivity to the dielectric and geometric properties of soils, its ability to operate independently of weather or light conditions, and its capability to reach inaccessible corner to ground measurements, is one of the most promising approaches for surface parameter estimation. Moreover polarimetric data play a significant role in soil moisture retrieval because they allow direct parameterisation of scattering problem.
In the framework of a PhD course in Aerospace Engineering, are used some Cosmo-SkyMed polarimetric data (provided by courtesy of the Italian Space Agency) acquired in the area of Naples to demonstrate the ability of Synthetic Aperture Radar satellites for predicting and monitoring landslides events.

References

1. G. Metternicht, L. Hurni, R. Gogu, Remote Sensing of Environment (2005), 98.

Development of a Fault-Tolerant Electro-Mechanical Actuator for MALE UAVs

R. Galatolo[1], G. Di Rito[1], F. Schettini[1], E. Denti[1], P.S.Guinzio[2], G. Vinelli[2] and S. Palazzo[2]

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The technological applicability of electrically-powered actuators for Unmanned Aerial Vehicle (UAV) primary flight controls is nowadays quite proved in terms of performances. Both Electro-Hydrostatic Actuators and Electro-Mechanical Actuators (EMAs) allow to attain the load, speed and dynamic response objectives, but several concerns are still open in terms of reliability. In particular, the use of EMAs (which, thanks to the elimination of hydraulic fluids, imply less maintainability constraints) requires a cautious approach to the safety assessment analysis, mainly for the lack of a statistical database about component fault modes. An effective counteraction can be provided by using actuator electronics that implement health-monitoring functions, so that the EMA could be compensated in case of faults (fail-operative actuator) or reverted in a safe mode in case of a complete failure (fail-safe actuator). Clearly, the fault-tolerance characteristics of the single EMA depend on the whole flight control system architecture.

This paper describes the research activities carried out by AleniaAermacchi and Pisa University for the development of a fault-tolerant EMA for a Medium Altitude Long Endurance (MALE) UAV application. The attention is focused on the EMA failure analysis and the EMA architecture definition, aiming to point out via fault tree analysis the effects on EMA safety levels of different architectural solutions. The EMA is basically composed of a digital Actuator Control Unit (ACU) performing closed-loop functions and health-monitoring algorithms, a brushless motor, and a mechanical power train. The EMA is developed in order to be fail-operative in case of some electrical/electronic faults (e.g. power switch fault, motor phase fault) and fail-safe in case of other faults.

The work starts from the AleniaAermacchi experience on *Sky X* and *Sky Y* UAV demonstrators, in which analogue ACUs were used to close the position, speed and current control loops of each EMA. Such solution was sufficient to meet the performance needs for a UAV demonstrator, but has some limits that need to be addressed to be compliant with STANAG 4671 or AER-P.6 safety requirements. The goal of the ongoing research program is thus to develop a demonstrator EMA with high technological readiness level, capable to be qualified and certified for a new vehicle.

Low Speed Wind Tunnel Test of a Morphing Leading Edge

M. Kintscher[1], T. Kühn[2], H.P. Monner[1], M. Wiedemann[1]

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Because of the large potential of drag reduction natural laminar flow is one of the challenging aims of the current international aerospace research. For the achievement of the absolutely essential surface quality new concepts for the high lift system at the leading edge are required. Five years ago DLR started a new morphing activity aiming at a smart leading edge device [1]. The concept incorporates a flexible glass fibre structure of the leading edge which is actuated by conventional actuators and kinematic stations. The glass fibre structure is especially tailored to achieve a desired aerodynamic target shape and fully closed so that there are not steps and gaps for a high quality surface. In a first step a functional demonstrator was realized and tested in a ground test which is able to continuously alter the shape of a leading wing edge under wing bending loads. As a second step a European consortium of leading research groups and European aeronautic industry started the common project SADE in 2008 which aims to demonstrate the functionality of smart high lift devices in low speed wind tunnel tests. A functional full-scale demonstrator of 5m span and 3m chord is planned in the project. The paper gives a survey on the concept of the smart leading edge, the design of the wind tunnel demonstrator and on the recent results from the wind tunnel tests. The paper will focus on the validation of finite element calculations with the comparison of stress/strain data and the predicted deformations under aerodynamic loading.

Figure 1: Wind Tunnel Model in the Wind Tunnel T-101 at TsAGI, Moscow.

References

1. Monner, Hans Peter und Riemenschneider, Johannes und Kintscher, Markus (2012) Groundtest of a Composite Smart Droop Nose. . AIAA/ASMR/ASCE/AHS/ASC 2012, 23.-26.04.2012, Honolulu, Hawaii.

AleniaAermacchi Production System

A. Vergani[1], D. Ainardi[2], D. Tricarico[3]

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Abstract (Topic: Production)

AleniaAermacchi Production System (APS) is one of the Alenia's biggest challenge nowadays. Its purpose is to definitely drive the change to a new production system based on Lean principles and combat wastes. The industrial benefit of introducing a lean system is to gain the capability of increasing product quality and level of service for Customer, reducing costs at the same time.

APS Project started in January 2012 in Pomigliano and Nola plants with the collaboration of Porsche Consulting. The APS'six-principles helix, defined by a multi-functional and inter hierarchical team at the very beginning of the project, represents the foundation for all current and future activities:

Figure 1. 6-Principles APS logo: Flow, Pull, Takt, Zero-Defects, Responsibility, Zero-Shortages

Flow, Pull, Takt, Zero-Defects, Responsibility and Zero-Shortages are the 6 APS pillars. According to "*Inside to Outside*" rule, the implementation strategy of APS began in the core transformation area: the Shopfloor. First two areas engaged by the APS change were the assembly lines of ATR-72 in Pomigliano and Airbus A380 in Nola. Each work-center involved has been deeply analysed and its manufacturing and logistic processes have been re-designed applying a standard methodology of Value Stream Analysis, Value Stream Design and Cost Deployment. Main tools used by APS team to start the substantial change are Workflow, Kamishibai. Workflow is the best operations 'sequence accounting customer demand, technical constraints, ergonomic issues and balancing available manpower. The elementary unit is a 3.75 hrs Job Card called Kamishibai. Combination of these two items reduces WIP and lead time (*e.g.ATR-72: -38% of lead time in 2012 and 700 K€/year of saving for WIP reduction*) and achieves to intercept earlier problems. In APS operators are like Surgeons in operating room. So they must be served with all parts required right on the assembly line, at the right time and in the right quantity.

Plasma effect on Radio-Frequency communications for lifting re-entry vehicles

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The present work investigates plasma formation around two lifting hypersonic vehicles and its implications on the Radio-Frequency Communications Black-Out performances during the Earth atmospheric re-entry phase. Particularly, the ESA Intermediate eXperimental Vehicle (IXV) and a slender, high lift-over-drag spaceplane, investigated during previous ESA studies, have been taken into account.

Chemical non-equilibrium analyses have been conducted by means of a commercial CFD code, updated with a customized chemical model comprising of several reacting species and different reaction mechanisms[1],[2]. Different enthalpy conditions, including the most critical for communications, have been considered for both vehicles, assuming different catalyticity wall conditions.

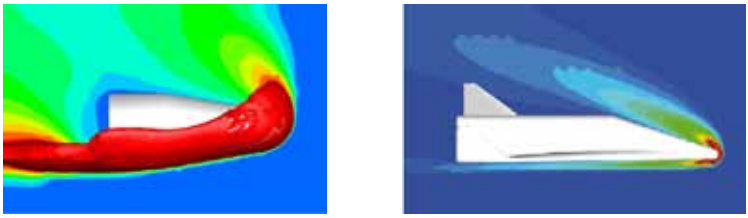

Figure 1. Plasma frequency contours along the symmetry plane for IXV (left) and PHOEBUS (right). A maximum threshold of 1.575 GHz (red color) has been imposed.

The main outcomes of the study show that, for very similar free stream conditions, the slender spaceplane exhibits better communication capabilities when compared with the IXV vehicle. Particularly, the results suggest that IXV would be able to communicate from the leeside for a limited range of angle of sight, while no communications from the windside is possible. On the other hand, for the slender spaceplane, flying at relatively low angles of attack, communications are possible either from the leeside and the windside with very wide angles of sight. This implies a relatively wider Black-Out phase for IXV.

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Numerical simulation of a ballistic impact on the aeronautical structure in composite material

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Composite materials in the form of laminates or sandwich are widely used as ballistic protection thanks to their excellent performance in terms of stiffness, strength and low weight. These structures are prone to various forms of damage in the event of any action outside the plan or as a result of collisions. The present work examines the phenomenon of impact from numerical point of view, using the solver LS-DYNA.

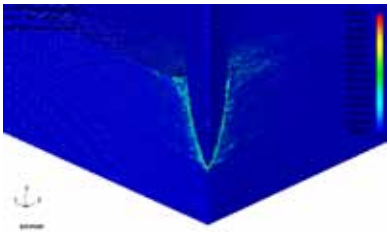

Figure 1. Stress distribution for CFRP target

The work starts from a literature research that allows to realize three numerical - experimental correlations regarding metals[1], composites[2,3] and ceramics materials[3]. This is fundamental to validate the cards used in the software and go to the next simulation phase with the bullet of interest. Since the first material requires excessive thickness and weight to resist to the projectile in question, composite and ceramic materials have to be used; they allow to reduce the weight and have a better impact behaviour. The present work also allows to define a numerical approach for the solution of high-speed impact problems, since "there is no a unitary theory nor a general mathematical model of the impact phenomena, but only a variety of theories, or models, each one valid in a rather narrow range of conditions and assumptions".

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Collision Avoidance Systems for Autonomous Civil UAVs

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Traffic-Separation and Collision-Avoidance are safety-critical requirements to operate every aircraft (also the UAVs) in prescribed environments. Nowadays, there is an increasing interest to promote the use of the UAVs within the civil airspace, even if their integration into non segregated environments presents many regulatory and technical issues. For example, basic requirements state that aircraft shall not be operated in such proximity to other aircraft as to create collision hazards. Also, vigilance shall always be maintained so as to "see and avoid" potential hazards. Manned aircraft comply with these requirements by the onboard pilot that is the ultimate responsible of taking an action. To operate in the same airspace, UAVs need a means to replace the human-pilot capability to "see and avoid" potential conflicts with an "equivalent level of safety". This has led to what the aeronautical community has called the "Sense and Avoid" capability.[1] Such a capability mainly consists of two functions: the "Sense" function and the "Avoid" function. The present research focuses on the "Avoid" function and proposes a strategy to develop a system that can provide an airborne capability to autonomously avoid a conflict. Such a strategy is based on a concept that complies with the ICAO vision of a modern ATM system.[2] The strategy has been implemented through an algorithm by a four-dimensional approach in the time-space domain to detect and resolve a conflict using kinematic constraints. Each intruder or a generic obstacle is modelled through a moving ellipsoid that represents a region that the aircraft must avoid to violate. The proposed approach is suitable to detect and resolve potential conflicts real-time.

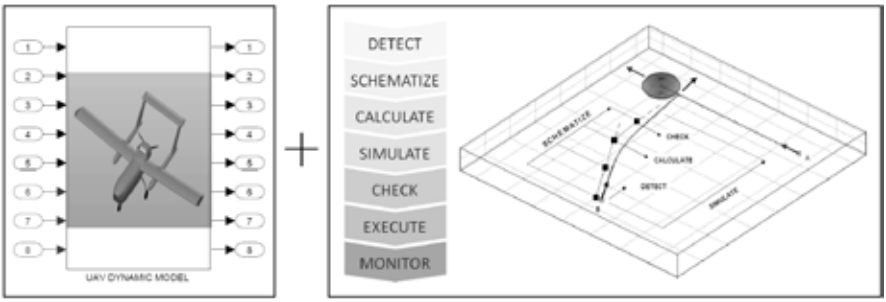

Figure 1. UAVs Models + Avoid Strategy/Algorithms = Collision Avoidance Solution/Actions

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Korea in-flight simulation aircraft development

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The paper presented here contains development of variable stability system (VSS) control laws for the KFA-i to simulate the dynamics of KFA-m aircraft. The KFA-i is a single engine, Class IV aircraft and selected as In Flight Simulator aircraft. The KFA-m is the simulated aircraft and it is based on the F-16 aircraft. The 6-DoF math model of KFA-i aircraft to be used as IFS is developed by separating the linear KFA-i models for longitudinal and lateral motion for VSS control law synthesis and by analyzing and implementing the 6-DoF math model of KFA-m in VSS flight control law. Development of VSS Control law for pitch rate , roll rate, yaw rate simulation for three specified flight conditions using Model Following Technique with rate feedback autopilot for stability provision. The direct lift force controller was also added to the developed VSS control law to simulate the pitch rate and normal g-load simultaneously. The simulation results show high accuracy of KFA-m pitch, roll, yaw rate and pitch rate /g-load simulation. For KFA-m roll rate simulation, asymmetrical deflection of KFX-i horizontal tails or flaperons is needed.

Development of a finite element model For inflatable winglet

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In the present paper a development of a finite element model for inflatable winglet structure will be introduced. Most conventional aircrafts are equipped with fixed winglets to decrease the induced drag; thus, saving more fuel. New projects point towards advanced smart materials and telescopic wing tip devices to obtain an adaptive morphing shape that gives, through performances improvement, a fuel consumption reduction resulting in less pollutants. The focus of this paper is to characterize the behavior of inflatable winglet in terms of inflated and deflated shapes in a multi-bumps configuration. The effect of the material properties on the inflation time and shape will be evaluated. The process used to create a finite element model of the winglet will be presented. Modeling assumptions and dynamic inflation simulation method will be discussed.

HyPlane for Space Tourism and Business Transportation

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In the last decades several examples of supersonic and hypersonic vehicles have been studied and developed. Nowadays the attention is also focused on hypersonic airplanes-like vehicles for passenger transportation at high altitudes and/or for space tourism perspectives.
In the present work a preliminary study on a 4-6 seats hypersonic airplane for a long duration space tourism mission is presented. It is also consistent with a point-to-point hypersonic trip around 5000 km, in the frame of the "urgent business travel" market segment. Main idea is to transfer technological solutions developed for aeronautical and atmospheric re-entry purposes to the design of such a hypersonic airplane. A winged vehicle characterized by high aerodynamic efficiency and able to manoeuvre along the flight path, in each aerodynamic regime encountered, is taken into consideration. Attention is also focused to limit accelerations and load factors, in order to promote a commercial implementation of the vehicle, according to FAA and EASA standards.
Different options are under consideration: horizontal take-off from an airport or air-launch from a mother airplane (such as White Knight Two of Virgin Galactic). A trade-off study between Rocket-Based Combined Cycle and Turbine-Based Combined Cycle engines (RBCC Vs TBCC) is performed to ensure higher performances in terms of flight duration and range, for a given propellant mass. Furthermore, the main propulsive performances of the selected option are discussed and analyzed.
Different flight-paths are also investigated. Among them periodic skip trajectories and steady state hypersonic cruise are analyzed in detail. The former, in particular, takes advance of the high aerodynamic efficiency during the unpowered phase, in combination with a periodic engine actuation, to guarantee a long duration oscillating flight path. In addition, skip trajectories offer Space tourists the opportunity to realize extended missions, characterized by repeated periods of low-gravity at altitudes high enough to ensure a wide view of the Earth from Space.
Then, a trade-off between different flight conditions, in terms of Mach number and altitude, is performed in order to compare the main performances, namely downrange and endurance.
Aerothermodynamic effects are also investigated and proper hot structures and materials identified to sustain the hypersonic flight conditions, characterized by Mach numbers up to 5 in the range of altitude between 10 and 50 km.

The Space Tourism Program of Space Renaissance Italia

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1. President, Space Renaissance Italia
2. President, Space Renaissance International

A school of thought states that the present age is characterized by low cultural vivacity, probably due to the exceeding role assigned to economy. Our age is now compared with the more critical Middle Age, envisaging the need of a recovery period similar to the XVI century Renaissance when, thanks to the enlightened action of families as the Florence' de' Medici, an age of vigorous growth was developed: arts registered an extraordinary vitality, culture regained the essential principles of the classical Greek philosophy, seeding the modern science, with precursors like Leonardo da Vinci, Michelangelo Buonarroti and later Nicolò Copernico, Galileo Galilei.
After the growth due to industrialization and the increase of world population to some seven billions, the effects of the age of Enlightenment are over since its main ideological limit has been reached: the wrong assumption that the world is limited to the planet Earth.
Today, in the XXI Century, we need a new vision of the world, a new renaissance, a Space Renaissance: the world extends far beyond planet Earth! In XX Century the space era moved its first steps thanks to scientists and philosophers as Konstantin Tsiolkovsky, Krafft Ehricke, Gerard O'Neill and other ones. They in fact generated the school of thought that we define Astronautical Humanism. The ideas they transmitted to posterity allow us to benefit of a period characterized by great scientific and technological progress. This period lacks only of resources and a unifying vision in order to succeed transforming the present world, as the Renaissance and the age of Enlightenment did with the Old World.

On 22 March 2013 the Chapter Italia of Space Renaissance International has been founded, with the basic idea to foster the above mentioned association vision, by designing and implementing a national program. Primarily devoted to Space Tourism, the essential items of such program include:

- dissemination of the association culture and vision by means of a general public outreach project incorporating congresses, workshops, concerts, exhibitions, movies
- a youth oriented education project, targeting primary and high schools as well as master, doctorate and post-doc students
- facilitate the general public access to parabolic flights as first steps towards higher jumps to space tourism trips
- promote the development of a national sub-orbital flight project
- stimulate commercial businesses in all of the above mentioned development lines.

This paper will illustrate both the vision and the SR Italia program that, at the date of the AIDAA congress, will be detailed and launched

Alenia Aermacchi: a world-class capability in integration and testing

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With its 100 years of history and successes, Alenia Aermacchi, a Finmeccanica company, is today a major international player in the aerospace industry. Its activities include end-to-end design, development, integration, ground and flight testing for qualification and certification, and through-life support for the most advanced systems, such as high performance combat aircraft, advanced trainer aircraft, military and commercial transport aircraft, unmanned aircraft systems, mission systems aircraft and modern aerostructures for airliners.

Alenia Aermacchi's avionic, structural and general systems design, development, integration, and ground and flight test activities – the core and most delicate activities for a systems integrator – are carried out with the experienced skill of its engineers and state-of-the-art technologies, methodologies and facilities at the Torino, Caselle, Venegono and in Pomigliano d'Arco sites.

Alenia Aermacchi's Caselle is the site where recently two state-of-the-art facilities have been built: the Sky Light Simulator and the Anechoic Shielded Chamber.

The Alenia Aermacchi's system testing facilities embrace from the wind tunnel at Torino plant, to the general system laboratories at Venegono plant, up to the EMC laboratories at Caselle and Vengono plants where equipment, system and different aircraft.

Pomigliano d'Arco test facilities are focused on testing activities of the aerostructures designed, developed and produced in Alenia Aermacchi's plants as well as any international customer and are composed by a M&P, Structural Testing, and Structural/System Integration branches.

The Material and Processes branch specializes in aerostructures material characterization, i.e allowable determination, as well as certification of chemical/physical processes using sophisticated machines and methods. This branch is also equipped with a modern facility for the failure analysis used in the investigation of accident occurred to the aircraft fleets.

Structural Testings, performed in Pomigliano d'Arco and Venegono branches, include state-of-the-art facilities for static and fatigue testing, from development components to certification of complete aircraft, both fixed and rotary wings, like the structural tests on the Boeing 787's horizontal stabiliser and M346 complete aircraft took place. Structural Testings Pomigliano branch includes a NDI testing facility for performing from eddy current to automated ultrasound inspections.

Pomigliano d'Arco Structural/System Integration branch embraces among the other an Acoustic/Reverberant coupled chamber used for vibro-acoustic testing of large fuselage panel, an electrical laboratory equipped with drive test stand up to a 750KW power and a fluid-dynamic facility used for development and certification of aircraft cabin air distribution systems.

Test facility and method for the evaluation of thermal cycling effects on components for space applications

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The investigation of the effects of thermal cycling conditioning on honeycomb parts suitable as main components for TAS-I satellite antennas is here presented. In fact the design process for a reliable space system can't prescind from this kind of test. The samples have been subjected to thermal conditions between -120 C and +120 C for 1000 cycles in order to investigate the effects of the temperature. The environment has been simulated by a dedicated facility specifically designed by SASLab Laboratories of Astronautic, Electric and Energy Engineering Department (DIAEE) of Sapienza University of Rome. For this aim the test facility has been designed and realized using a chamber, wherein heaters have been used for the hot phase and cooler tubes for the cold phase, both positioned inside two parallel plates. It's been decided both to insufflate nitrogen directly inside the chamber in order to better simulate space environment, and to introduce it into tubes in order to cool the plates. The samples have been put between the parallel plates. A software allows, through a PID (proportional-integral-derivative) controller, the automatic monitoring and control of the facility in order to create and maintain the environment inside the chamber. This flexible system allows both tests in vacuum and Nitrogen atmosphere and extreme temperature from -150 °C to +150 °C. A multivariate statistical analysis has been performed in order to better understand the cycles trend and the system behavior, and electric tests, performed by TAS-I, followed the simulation in order to quantify the possible damage occurred to the samples.

Real-Time DSP Experiments on Adaptive Aircraft Windows for Active Noise Reduction

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Sound transmission through aircraft windows significantly affects cabin interior noise environment. An acoustically efficient aircraft sidewall design requires that the window and the surrounding wall area have approximately the same sound transmission loss[1]. In this paper, an active noise control system applied to a triple-pane aircraft window prototype is presented. The acoustic benefits in the transmitted noise are experimentally demonstrated by actively controlling the acoustic radiation of the window demonstrator through piezoelectric stacks, integrated into the window frame in order to enable sensing and actuation properties. The propeller induced interior noise of a turboprop aircraft is simulated in a reference acoustic enclosure suitable for active noise control experiments. The primary acoustic source is simulated as an acoustic field incident to the aircraft window in stationary conditions. A feed-forward control algorithm is developed and implemented in a Digital Signal Processing (DSP) control board to cancel the amount of noise passing through the window. Results of detailed experiments are presented showing the experienced effectiveness in achieving the real-time control of the acoustic transmission through the window subjected to tonal and time-varying noise disturbances.

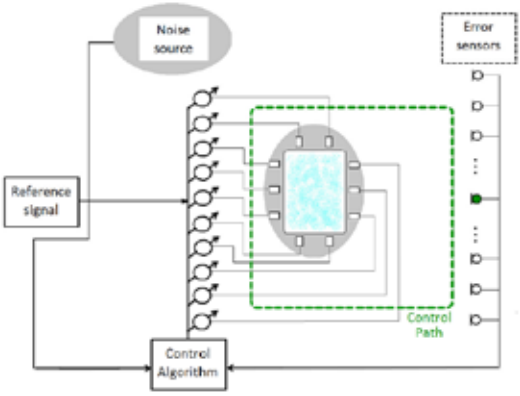

Figure 1. A multi-input-multi-output system for active control of sound radiation

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Flight simulation of a civil high wing unmanned aerial vehicle

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In this paper the UH-UAS MK.2 an existing Civil Unmanned Aerial Vehicle (UAV) developed at the University of Hertfordshire is mathematically modelled and its dynamic behaviour is simulated by implementing the model within the computer software, MATLAB / SIMULINK. Longitudinal and lateral stability derivatives were estimated based on method introduced in the United States Air Force Stability and Control Datcom. A SIMULINK model was developed to predict dynamic behaviour of the UAV. In addition a MATLAB program was written to validate the developed SIMULINK model and further analysis. It was shown that the UAV longitudinal motion is stable while there is a divergent spiral mode in lateral motion of the UAV. Moreover, dynamic responses to various control input, atmospheric disturbances (gust) and initial condition were determined. To conclude, a brief study of augmenting the lateral motion by utilizing the classic control theory and modern control theory were performed. It was shown that the motion can be controlled and a state feedback is designed to control the spiral instability.

A practical method for determination of the moments of inertia of unmanned aerial vehicles

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Study the dynamics and the rotational flight of unmanned aerial vehicles (UAV) such as spinning, requires great consideration of inertial characteristics of the UAV. The moments of inertia are also essential characteristics for flight simulation or developing flight control systems for UAVs and hence an accurate evaluation of moments of inertia is necessary. The aim of this paper is to exhibit the use of pendulum method for the estimation of moments of inertia of an already built UAV, the UH-UAS MK.2, developed at the University of Hertfordshire. The experimental method used here is straightforward and economical to imply on small UAVs such as UH-UAS MK.2. The pendulum method is accurate satisfactorily and has the superiority over mathematical method which is difficult to imply, time consuming and requires extensive information of each individual components of the UAV. The product of inertia is also found in similar manner to moments of inertia, in order to determine the principle axis system. This paper is a preliminary part of an extensive study of flight dynamic and simulation of the UH-UAS MK.2.

An advanced thermal protection system for hypersonic vehicles

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Hypersonic flight has been object of scientific studies for years. Military applications were the first applications. But now the next future for hypersonic flight are commercial applications. This requires an increase of the safety and comfort of the flight mission which make the re-entry phase longer than astronauts re-entry missions.
From this point of view the vehicle thermal protection system (TPS) is one of the most critical point of the entire mission. Many are the key parameters for this system, among them one of the most challenging is the design and materials. In fact the determination of the best material for TPS passes thorough years and years of development. Materials match is another aspect not to be ignored and a theoretical and experimental study is required.
The aim of this paper is to present the development of an innovative thermal protection system suitable for a hypersonic vehicle. The innovation of this system is to be a thermal insulation which can allow to put down the temperature of over 1000°C in few centimetres of thickness and to be a structure which can bear thermo-mechanical loads.
The study and development of this TPS is promoted, in the frame of ASA B2 (Advanced Structural Assembly Phase B2) project, by the Italian Space Agency (ASI) which is envisioning a prominent role to technologies and projects involving atmospheric re-entry capabilities.
In this paper the structure is presented showing, by numerical and mission environment simulations, its capacity to withstand with I-XV requirements. The patented structure is a sandwich structure composed by four tiles. One of the innovations of this TPS is the opportunity to be installed/ uninstalled externally without the necessity to have an access from the inner part of the vehicle. The use of advanced Carbon/ Carbon and Carbon/Silicon Carbide combined with carbon foam materials let the structure to be not only lightweight but also to be reusable and to keep its mechanical properties during the overall mission.

Key words: Thermal protection system, Carbon/Carbon composites, Foam, C/SiC composites

Implicit Nonlinear Simulation of Progressive Failure Analysis of Composite Plates

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The large diffusion of composite material for aerospace structures produces a consequent need for always more reliable methodologies for their correct simulation. Particular interest in this field is devoted to the ability to predict the damage and the response of composite structures from initial loading to final failure considering the realistic behaviour of the stiffness, increasingly damaged. Theories and computations of these phenomena are grouped under the name of Progressive Failure Analysis (PFA).

The aim of this work is the assessment of the implicit nonlinear solutions implemented inside MSC Nastran Sol 400, in evaluating the damage and the behaviour of different panels. Results obtained by this solution are compared with previously published experimental data from the open literature, Ref. [1] and [2], and results obtained by others Finite Elements solvers (Comet [1], Abaqus [2] and Nastran Sol 600 [3]). Hashin failure criterion has been used to predict the failure mechanisms and several different options have been compared in simulating the degradation of the material properties after failure. These options are related to material properties degradation methods (Gradual and Immediate) and to the selected value of the Residual Stiffness Factor (R). The next table shows one of the several comparisons obtained during this work, among the experimental results and two different simulation approaches.

Solver	FPF load [N]	Ultimate Load [N]
Test Data		15671
Comet	6761	14287
SOL 400	7657	14803

Figure 1. Comparison between Sol 400 results, Comet and Test Data

Typical structures analyzed in this work are plates (with and without hole) under tension, compression, bending and combined loads. They have been modeled using *shell* elements and different meshing strategies. The results indicate that a general good correlation with existing test data are obtained. Some scattering of the results have been observed where interlaminar stresses became significant and they may cause failure mechanism such as debonding or delaminations, mainly for compression loads.

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A model for multilayered beams undergoing end loads

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Composite laminated materials have some advantages with respect to metallic media, such as the high strength and stiffness per unit weight, the path loads management capability as well as the possibility to manufacture large size structures, that motivate their extensive use. However they exhibit complex behaviour crossing plies interfaces and thus the proper modelling of composite laminated beam is a crucial point in design step. Analytical and numerical 3-D solutions represent the most accurate approach in modelling such materials but they have high computational costs. As a consequence, to reduce the computational effort, one-dimensional beam model are used instead, even though the accurateness of the solution lowers. In this work, an alternative theory for laminated beams subjected to axial, bending and shear loads is developed with the aim of obtaining a 1-D beam model capable of ensuring the equilibrium and continuity conditions at layers' interfaces. In particular, a layer-wise kinematical model is developed in such a way the point-wise balance equations are fulfilled. Moreover, by imposing the continuity of displacements and equilibrium of tractions relationships at plies' interfaces, the layer-wise kinematical quantities are written in terms of the primary variables of one layer only. The computational effectiveness of the equivalent single layer theories is then obtained preserving the solution accuracy of the layer-wise model, avoiding any a-priori selection of enriching functions. The equivalent beam constitutive relationships as well as the problem governing equations are last written in terms of generalized variables. Results obtained for a cantilever graphite-epoxy [0/90] beam, that has slender ratio *L/h=10* and undergoes a tip shear force *F = 10 N*, are eventually shown in figure 1 in comparison with *2-D FEM* simulation. Good agreement is obtained highlighting the effectiveness of the developed model.

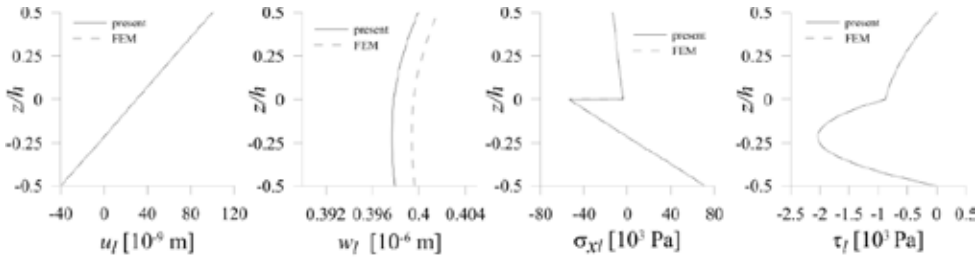

Figure 1. [90/0] beam through the thickness variables distribution at x/L=0.5.

Behaviour of coated ceramic composites for extra-atmospheric structures

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A reusable Thermal protection system has to satisfy several specific requirements. One of the most critical is the control of the oxidation of the materials during the re-entry step. This result may be reached through a proper balance between bulk materials with good mechanical properties and coatings with good thermal barrier properties. Carbon composites are nowadays the most suitable candidates as they have both good thermal resistance and good thermal stability which preserve the mechanical properties at high temperatures. However a further improvement is needed: the development of a coating which allows to optimize both the oxidation protection and the substrate adhesion.
The definition of the nature of elements and their size, the substrate nature in terms of rugosity and chemical composition and the surface pretreatments can strongly influence the coating efficiency during the vehicle mission.
Plasma sputtered oxide films of valve-metals (Ta, Nb, Zr, Ti) deposited on hybrid captive device are proposed in this study as a possible solution to the above-mentioned specifications.
The exposed experimental findings refer to ZrO_2 nanostructured thin films deposited in a RF (13.56MHz) magnetron sputtering reactor, starting from Zr targets (purity 99,99%) in plasma fed with Ar and O_2 in different experimental conditions. After the deposition, some specimens were submitted to annealing performed for 5 min in air at different temperatures in the range 600-900 °C in order to increase grain growth. Chemical and morphological characterization of deposited film was carried out by means of a Field Emission Scanning Electron Microscopy (Supra40 Zeiss Microscope) equipped with an Energy Disperse Spectrometer. In addition on Carbon/Carbon composite samples, as received and coated, dilatometric characterizations have been performed.
Another aspect to be studied for a re-entry system is the efficiency of the coating after the extra-atmospheferic flight.
During the suborbital phase the materials are subjected to an extreme environment where atomic oxygen, outgassing phenomena and thermal cycles can strongly degrade the thermo-mechanical properties.
In the present work different samples realized with carbon composite materials are coated in order to assess the best parameter of deposition. Thermal tests like dilatometer tests and space environment tests like outgassing are performed.

Thermoplastic concepts for A/C Door

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The goal of this work is to describe new structural concepts and manufacturing processes for building an A/C Door made of thermoplastic material.
The Door was redesigned starting from the actual Aluminium one in order to accommodate a thermoplastic-friendly processes . The original interfaces, with the fuselage structure and the opening and handling mechanism, was kept.
Thermoforming, Automated Fiber Placement and Electrical Resistance Welding processes were utilized for the manufacturing and assembling of the Emergency Door. Autoclave forming process was utilized to obtain the final skin curvature.
The new thermoplastic concept was validated by FEM analysis and all processes were studied and optimised in terms of parameters and toolings. Mechanical characterisation was carried out on the produced laminates.
A Door Prototype was manufactured demonstrating the feasibility of this optimised solutions.
The project was developed in the frame of CESPERT research program led by IMAST.

Figure 1. Thermoplastic Door

Using Principal Component Analysis for Damage Detection of Aerospace Structures

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Dynamic responses can be considered as a general indicator of the status of a structure. When this status changes due to a variation of its physical properties, the dynamic responses change too. For this reason, there is a lot of interest in developing damage detection approaches based on dynamic response of structures. Many approaches and method can be found into literature, concerning mechanical, aerospace and civil structures [1, 2]. The main problem in applying this approach is that the variation of dynamic response due to structural damage related to local variation of stiffness, mass and damping is very small. For that reason, more explicit and capable methods are needed to detect the presence of damage even in case of small variation of the dynamic response. This paper presents the results of a research aiming at the development and implementation of a damage detection technique able to both identify and quantify the presence of damage, by using Frequency response Functions (FrF) signals and Principal Component Analysis technique (PCA). After a brief description of the different strategies adopted, the results of a validation phase, related to a typical aerospace stiffened panels, are reported. A number of damaged scenarios are created and for each of them the data base of Frequency response Functions is computed by using MSC/NASTRAN in the range 1-200 Hz. Then, a MATLAB-based procedure to apply PCA to the FrFs matrix for data compression and to implement different detection strategies is developed. In particular, global damage detection and quantification index is defined by using the first 3 Principal components. Damage localization is performed by using differences measured FrF spectral lines of healthy and damaged models that related to the principal component with maximum variations. To simulate the field testing conditions, noise with a various signal noise ratio (SNR) is added to compute FrF data and a noise sensitivity study is conducted to investigate the robustness of the developed damage detection technique to noise.

The results shows that, in all cases considered, there are significant differences between the principal components when damage exist or damage increases, and the principal components variations are able to clarify the structure status that is shown by damage index. The present work also indicates that the PCA-based algorithm is capable for damage localization and structural health monitoring with noise polluted FrFs. Future work includes the experimental validation of the proposed approach.

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Robust electromechanical actuator for primary flight controls

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Electro-mechanical actuators (EMA) are presently used in numerous aerospace applications, but have very seldom been used as primary flight control actuators. There is an increasing tendency, however, to move towards more or even all-electric aircraft, which promises a wider use of EMAs in the future for primary flight controls. The most critical issue with electrical actuation is the sensitivity to certain single points of failures that can lead to mechanical jams, resulting in a reluctance to fully rely on electromechanical actuation for safety critical applications as solutions are heavy and costly (redundancy, fail safe behaviour, etc.) thereby creating difficulties for adoption and certification as well as impacts on costs. In order to address the issue of a possible actuator seizure many research and development activities have in fact been performed to identify ways of making an electromechanical actuator jam-free or jam-tolerant, since this would allow more flexibility in defining the overall architecture of the flight control system. Although interesting and ingenious design solutions have been proposed, they all have so far resulted in complex mechanical designs that on one hand allow the actuator to operate after a jam of an internal component, but on the other hand bring about increased weight, volume and cost, and a reliability reduction due to the much larger number of parts.

A completely different approach was hence pursued by the authors, which was not aimed at making an EMA completely jam tolerant, but at designing it as simple as possible to enhance its reliability while at the same time providing the EMA with prognostic capabilities able to alert of a developing failure. The basic philosophy was to avoid complex and clumsy actuator designs, but to provide the EMA with predictive prognosis capabilities indicating when an incipient fault develops and predicting how, under continuing usage, the fault will eventually become a failure. The system consists of two rollerscrew actuators force summed onto a flight control surface as done with hydraulic servocontrols. The rollerscrews are driven by brushless dc motors with a single-stage gearhead and a clutch; the electric drives of the two motors are each controlled by a dedicated dual redundant remote electronic unit performing closed loop position control as a function of the commands received via serial lines from the aircraft flight control computer. Provisions are taken in the motor drives to accept the regen energy under aiding load conditions and to provide surface damping in the very remote event of a simultaneous failure of both actuators. The actuators electronic units perform control, diagnosis and prognosis of the actuation system and mutually exchange data via a cross channel data link. System prognosis is made possible by processing with dedicated algorithms the information obtained from the collected in-flight data and the from injection of selected stimuli into the actuators during preflight.

As a whole, the two EMAs make up a smart mechatronic system providing high integrity control of a flight control surface with dual mechanical link, dual power source and quadruplex control, providing the necessary airworthiness as well as enhanced safety, reliability and reduction of life-cycle cost.

$PEDE_M$: a new method for the analysis of the stochastic response

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The analysis of the response of a stochastic system, through a discrete coordinate representation, can become computationally challenging, even by using a full modal representation; in fact, many dynamic load cases have stochastic behaviour as the wall pressure fluctuations due to the turbulent boundary layer. In the present work, a new method is presented and discussed and it is named frequency modulated pseudo equivalent deterministic excitation ($PEDE_M$). $PEDE_M$ is based on the pseudo excitation method (PEM), but it tries to overcome the computational neck-bottles of this latter by introducing some approximations which are based on the analysis of the eigensolutions of the dynamic load matrix versus frequency. The solution approach uses three different approximations for the load matrix with reference to three frequency ranges, named *low*, *mid* and *high*; these approximations derive from the eigenanalysis of the load matrix. A criterion to identify the three frequency ranges is proposed, too and it is expressed in terms of a reduced dimensionless frequency. PEDEM is thus applied to a plate response; this test case that contains the most relevant parameters of a structural problem. The results herein discussed show that the correlation area can play a fundamental role in discriminating the quality of the approximation. A good level of accuracy and representation of the stochastic system together with a significant reduction of the computational costs are obtained if compared to a full stochastic response (FSR) or PEM solution.

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DREAMS package for "dusty" Mars

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The ExoMars 2016 EDM mission will reach the Mars surface during the statistical dust storm season. The DREAMS package will have the unique chance to make scientific measurements able to characterize the Martian environment in this harsh scenario. For this reason DREAMS has to withstand several constraints for power, data handling and scientific instruments. A high level of autonomy is required in order to perform correctly all the mission phases planned after the safe touchdown; the system can rely only on internal batteries. Backups for battery switch-ON procedures are planned in order to have an automatic activation of the system at a predefined time after landing.
The CEU (Central Electronic Unit) and the environmental mast and sensors have to achieve high level of thermo-mechanical stresses and particular attention has been used in the design and the testing of each subsystem, especially for the sensors directly exposed to Martian atmosphere.
The measurement sequence must be planned in advance, last update will be sent before EDM probe separation from orbiter; precise synchronisation of sensor acquisition must be performed in order to acquire measurements during significant moments of the day, such as dawn or sunset.
Considering the above mentioned goals and constraints, an overall architecture of DREAMS on board software and performance has been designed and is here presented; furthermore the critical aspects of thermo-mechanical design are highlighted and discussed. Finally, the high level of independence and autonomous recovery is depicted and reported.

Advanced induction welding for thermoplastic composites in the aerospace sector

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Different attempts to develop new techniques to join thermoplastic composites were carried out in the last years, since the achievement of proper joining procedures is the fundamental key point to increase the use of thermoplastic composites in many industrial sectors, and especially in the aerospace sector. Besides the other welding and joining techniques, several studies were carried out on continuous induction welding of thermoplastic composites, since this technique can ensure very high performances, as high shear strength and fatigue properties, high resistance to peel stress, high efficiency and repeatability together with flexibility and good applicability at an industrial level [1-5]. For this reason a new induction welding machine was developed by CETMA in cooperation with SINERGO for continuous welding of advanced thermoplastic composites. This apparatus, in which an innovative system was developed to ensure a proper temperature distribution within the different materials and geometries to be welded, was developed thanks to a huge work comprising numerical and experimental activities in order to optimize the several parameters that have an influence on the final performances of the induction welded joinings. Thanks to the experimental and numerical work carried out, and through the manufacturing of mid-scale prototypes, useful guidelines and procedures for induction welding of composites in the aeronautic sector were gathered.

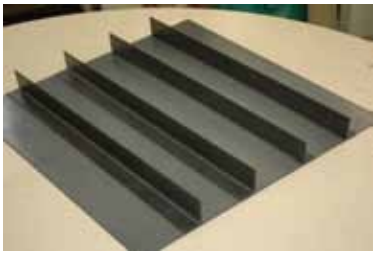

Figure 1: upper panel prototype induction welded PPS-carbon stringers.

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Study and development of a sub-orbital reentry demonstrator

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The Italian Space Agency (ASI) has supported a feasibility study, developed in Campania region by a cluster of industries, research organizations and universities, on a 100Kg class re-entry capsule, able to return payloads from the ISS to Earth and/or to perform short-duration scientific missions in Low Earth Orbit (LEO). The ballistic capsule is characterized by a deployable "umbrella-like" heat shield, that allows relatively small dimensions at launch and a sufficient exposed surface area in re-entry conditions, reducing the ballistic coefficient and leading to acceptable heat fluxes, mechanical loads and final descent velocity. The TPS materials have already been tested in the SPES hypersonic wind tunnel at the University of Naples, and in the SCIROCCO PWT (Plasma Wind Tunnel) at CIRA (Centro Italiano Ricerche Aerospaziali), of Capua, Italy.

ESA is supporting a preliminary study to develop a small flight demonstrator of a similar capsule, to be embarked as a secondary payload in the inter-stage adapter of a sub-orbital Maxus sounding rocket. This capsule will be ejected, during the ascent phase of the Maxus payload, after its separation from the booster, to demonstrate deployment, re-entry and recovery capabilities. The deployable thermal protection system concept may be applied to any ESA mission in the framework of the Science and Robotic Exploration Program, requiring planetary entry and, possibly also to ESA missions in the framework of Human Spaceflight, requiring planetary entry or re-entry. The technology offers also an interesting potential for aerobraking/aerocapture and for de-orbiting.

This paper summarizes the results of the preliminary activities related to the definition of the small scale suborbital reentry demonstrator, including aerothermodynamic, mechanical and structural analyses and preliminary technical definition of avionics, instrumentation and main subsystems.

The system is based on low-cost components and commercial hardware and its payload includes sensors and onboard memories to measure and store relevant properties during the sub-orbital flight, in particular temperature, pressure, accelerations, angular rates, strains, etc.

Exomars: 2016 Missione Overview

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The ExoMars Programme foresees a major partnership between ESA and Roscosmos, with some cooperation by NASA, to explore Mars and prepare for the Mars Sample Return mission.
The ExoMars Programme features two missions, one to be launched in January 2016 and one in April/May 2018. Hence for the 2016 mission ESA will procure a large Spacecraft Composite consisting of a Trace Gas Orbiter (TGO) and an EDL Demonstrator Module (EDM). The Spacecraft Composite will be launched in January 2016 (back-up launch in March) by a Proton Launcher, to arrive at Mars in mid-October of 2016.
The 2016 mission industrial activities are now focused on phase C which will culminate in the System-CDR planned at the end of the current year 2013.
The EDM development is on schedule; in particular the EDM SM has been subjected to leak-tests in TAS-I to prove the tightness of the aeroshell. Sine and static tests will follow to demonstrate capability to withstand the launch and entry mechanical loads.
The functional qualification campaign has started with SW integration on the EDM ATB.
Wind Tunnel Test campaign has been completed and the Aero-Thermodynamic Data Base is now consolidated. A High Altitude Drop Test, to verify the parachute performances in a high altitude environment, is planned in Romania using the ARCA facilities.
At subsystem level the crushable structure (SENER) development tests have been completed and the structure is ready for the final qualification tests planned in the summer.
The TGO Mechanical Thermal & Propulsion (MTP) and Avionics Electronic and Radiofrequency (AER) PDR's have been completed in the course of the year 2012.
The phase C analyses campaign has started with the GNC Robustness Analyses.
The Central Software and Satellite Database (SDB) development has been worked out in staggers (from V1 to V4) and the delivery of the CSW V1 is scheduled in July 2013.
The 2,2 meter High Gain Antenna has entered the detailed analyses phase and its CDR is planned in Sept 2013.
The TGO Harness Manufacturing Review has been held in Jan 2013 and the first of four planned batches is scheduled by June 2013.
At MTP level the final structural, thermal and thermo-elastic analyses will be completed by March 2013.
Testing Activities on Central Tube Structural Model, Propulsion Engineering Verification Model and Thermal Engineering Verification Model are planned to be completed in Q2 and Q3 2013. The MTP will undergo its CDR in July 2013.

Magnetometer Calibration Method for Small Calibration Dataset

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This work presents an estimation method for hard iron calibration settings of a magnetometer where only a reduced dataset is available.

Most 3 axis magnetometer calibration methods require a full rotation about the 3 axis, covering the main directions in the space. These rotations cannot be done in many applications, i.e. when the magnetometer is mounted on a heavy UAV. The main advantage of this method compared with other calibration methods in the literature is the approximation of the offset with measurements only in a few directions of the space.

The method is tested using real data from a magnetometer in the laboratory. Method was checked by obtaining angular rates and comparing those with a gyroscope showing equal performances. The preliminary results show a good performance of this method under the cited conditions.

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Brushless DC Motors Failure Detection using the Continuous Wavelet Transform

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Having in mind the growing interest in Electro-Mechanical actuators and the need for a diagnostic tool to make them even more reliable, this work will be focused on the creation of a method capable to detect different failures of a Brushless DC Motor, based on the analysis of the frequency spectrum of its stator current.

The analysis has been carried out using the Continuous Wavelet Transform (CWT) and its property to preserve signal energy in the transformed domain was used to detect failures which causes some type of asymmetry in the magnetic flux between rotor and stator.

Simulations were carried out using the software Matlab/Simulink and obtained results showed that one of the cited indexes can be used for failures detection and diagnosis purposes with some benefits as a low computational cost, an easy implementation scheme and a high detection power.

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Simulation of Low-Intensity, Low-Temperature Solar Arrays with Software and Hardware Tools

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In this work we discuss issues related to the simulation of low power systems with solar and hardware means. Simulating low power systems is a challenging task as the low-intensity, low-temperature environment, together with possible dust deposition and ice condensation, worsen not only the production of power but also make it difficult to predict it. To overcome these problems, we have developed solutions in terms of software and hardware tools for power estimation and simulation. The developed low power, hardware solar array simulator system is briefly discussed in this paper. Although this solution is reported for the case of Rosetta lander Philae, it applies also to possible low power future missions aimed to perform in-situ operations on comets and asteroids.

Numerical aerodynamic analysis on a trapezoidal wing with high lift devices: a comparison with experimental data

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The aerodynamic analysis on a model of a commercial wide-body twin-jet high-lift configuration has been performed using the commercial software STAR-CCM+ and the supercomputing grid infrastructure SCoPE[1] of the University of Naples "Federico II". The wing, body, flap, and slat geometry is a public domain CAD file available online for the "2nd AIAA CFD High Lift Prediction Workshop"[2]. Experimental investigations on the wing-body model have been performed at the European Transonic Wind-tunnel[3] and results are available online[2].
Inviscid, viscous incompressible and compressible analyses have been performed using three different mesh size (coarse, medium and fine). The inviscid calculations were used to assess how far is the eulerian prediction from experimental data. Viscous calculations have been realized using the Spalart-Allmaras turbulence model[4] at Mach number equal to 0.175 and Reynolds number equal to 15.1 million, while two different mesh topologies have been compared: polyhedral mesh and trimmed (hexahedral) mesh.
Results show that the simple Spalart-Allmaras turbulence model can predict quite accurately the stall and post-stall behaviour, with the coarse mesh providing a difference less than 5% in maximum lift coefficient.

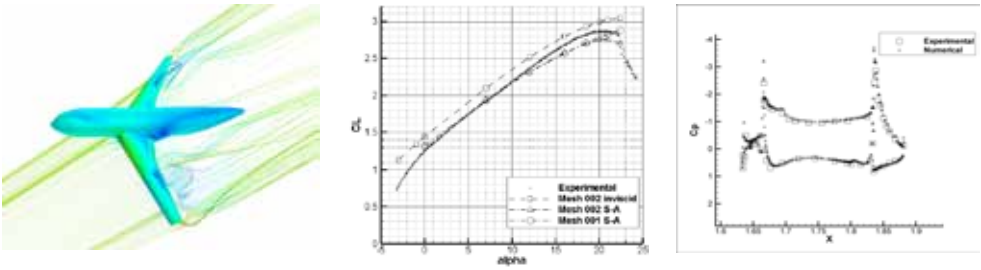

Figure 1. From left to right: streamlines at 25° angle of attack, lift coefficient curve vs. angle of attack, and pressure coefficient distribution on a wing section.

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A new approach in aircraft vertical tailplane design

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The paper presents a new procedure to evaluate the sideforce (and hence the directional stability and control contribution) generated by the vertical tailplane of a typical regional turboprop aircraft in sideslip and with rudder deflection. The evaluation of stability and control derivatives has a deep influence on tailplane design. Clearly, the more accurate the former, the better is the latter. Preliminary design and analysis are often developed with semi-empirical methods, such the one provided by USAF DATCOM, which are based on historical data and statistic analyses on a huge number of configurations[1]. These test cases are often based on obsolete geometries, quite different from nowadays transport airplanes. Besides, different semi-empirical methods provide very different results for some tailplane configurations. In a preliminary design phase, where a complete aircraft model is not available yet, this issue is not trivial, because it is unknown which method provides the correct result[2]. To develop a new procedure to correctly estimate the effect of aircraft's components aerodynamic interference (wing-body sidewash and wake, horizontal tailplane end-plate effect, rudder deflection), a regional turboprop aircraft geometry was chosen, with some constraint such as fuselage slenderness, wing and tails positions and aspect ratio's range. Reynolds-averaged Navier-Stokes CFD analyses were executed on hundreds of configurations. The University's computing grid SCoPE[2] was used to get numerical results in a short amount of time. These results are presented in a few charts to define the aerodynamic interference coefficients and then a new procedure to design a vertical tailplane[3]. The new procedure provides a simple relationship among the aerodynamic interference factors and accurate results for turboprop aircraft configurations, as shown in examples of application.

Figure 1. A typical configuration (left) and the effect of fuselage on the vertical tailplane sideforce coefficient (right)

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Advantages of GNSS-based terminal procedures

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Air traffic control scenario currently presents a clear trend to introduce as much as possible new procedures based on global navigation satellite systems (shortly GNSS) capabilities. This trend, already successful in the U.S., is spreading now in Europe, also due to the achieved operational capability of the EGNOS system, and is expected to further increase with the future achievement of Galileo's operational capability. The expected advantages at the network level are quite remarkable, with the reduction of ground-based infrastructures and the (although far in time) standardization on a single navigation aiding system, useful during each and every step of the flight (take-off, en-route, approach, landing) with substantial benefits for on-board equipment, maintenance, crew's training. Even if this path is clear and widely accepted, several aspects still have a significant interest for researchers, above all with respect to the final flight phases (approach and landing) that are also the most challenging from the technical point of view.

Specifically, newly designed approach procedures to be carried out by means of GNSS signals can be easily simulated to provide a detailed analysis of the trajectory of the aircraft. With respect to the obtained position/time history, it is possible to evaluate their impact on the air traffic compared to traditional ILS- or NDB-based procedures. The paper discusses in detail several examples, relevant to Parma and Perugia airports. By "feeding" the inbound traffic with a traffic scheduler purposely prepared, the performance of the procedures can be evaluated with respect to different classes of aircraft. Spacing in the landing queue due to wake concerns, as well as spacing along the runway and taxiways system due to safety concerns, are duly considered. The model by Blumstein has been adopted to compute the number of aircraft using the runway. As a result, mainly due to the capability to fly tighter profiles thanks to the increased number of possible waypoints, the GNSS procedures show a distinctive advantage in terms of path occupation, and therefore allow for an increased number of take-off and landing operations.

In addition, GNSS procedures provide significant value with respect to the noise impact, first as they add new trajectories to the set of possible routes (therefore distributing the disadvantages) and above all as these newly allowed trajectories are shorter than traditional ones, and decrease the air traffic impact. A qualitative analysis relevant to this issue of ever increasing relevance will be shown in case of Parma airfield. Finally, the reduction in the approach time, other than offering the chance for a higher duty cycle of the aircraft, allows to reduce the fixed costs (above all the fuel): a remark about the way to evaluate such a benefit completes the proposed paper.

A comparison of the drag polar curves of wings using the fluid-structure interaction analyses

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The paper shows some preliminary results of aeroelastic analyses of two half-wing models, having curved and swept planform, carried out at the Aerospace Engineering Unit of the Department of Civil and Industrial Engineering of Pisa University. In the transonic flight conditions the curved planform, as demonstrated in previous papers regarding rigid models of wings, strongly reduces the wave drag effects.[1] The present results include the effects of structure's deformability both for curved wing and traditional swept wing (the wings have the same aspect ratio). The beneficial effects of the curved planform shape on drag polar curves are confirmed. Moreover the curved planform configuration improves the wing's aeroelastic behavior: as an example, adopting similar wing box metallic structures for the two half-wing models, for a fixed value of CL the reaction moments and stress values at the root of the curved wing are reduced by about 5÷8% with respect the data obtained for the traditional swept wing at the same flight conditions.[2]

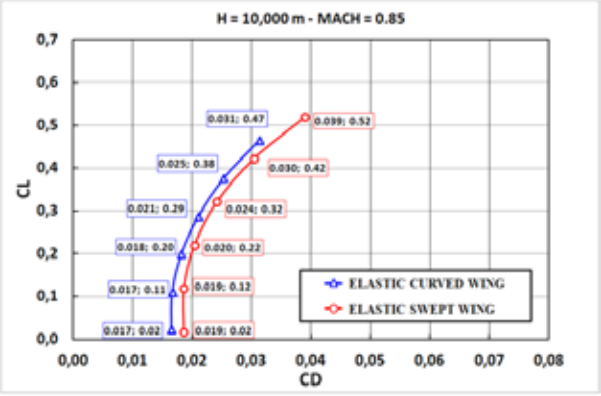

Figure 1. Comparison of the drag polar curves for the elastic wings (the wing-box structures being similar).

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Augmented GNSS for Precision Approaches of Unmanned Aerial Vehicles: Risks and Safety Analysis

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The steady increase in the Air Traffic, combined with the more stringent constraints for fuel consumption and emissions reduction, has produced the need to improve navigation performances of civil aircraft also basing on the GNSS Signal in Space (SIS) performances. The paper firstly deals with the analysis of the state of the art of the avionic navigation systems (certified RNAV and/or RNP) today implemented or under development in the civil aviation, with particular focus on the new methodologies of precision approach with vertical guidance (APV). The idea at the base of the paper is to conceive the possibility to apply RNP requirement where GNSS augmentations are considered for the automatic landing of an aircraft belonging to UAS category. The reason is that commonly autonomous landing functions of UAS are based on complex and expensive technologies (e.g. laser tracking) which neglect performances offered by emerging technologies like augmented GNSS navigation.

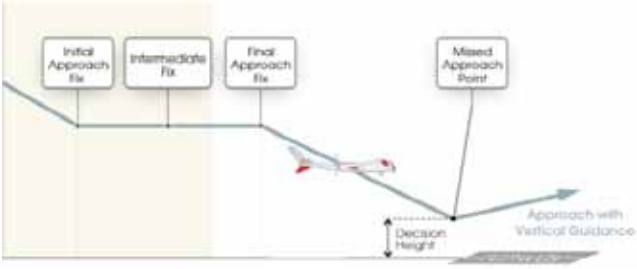

Figure 1. Precision Approach with vertical guidance for UAS

The paper includes a detailed analysis of the international normative listed through ICAO and FAA documents, by focusing on the new "augmentation systems" (SBAS, GBAS, ABAS) and the applicable Technical Standard Operations (TSO). The second step of this work has been to suppose the integration into an UAS avionic architecture of autonomous landing avionics based on GNSS. A Risk and Safety (i.e. FMECA and FTA) analysis applied to the designed avionic system has been performed, thanks to these analyses it is also possible to consider in avionic design important redundancies for ensuring safety during operations. The most promising design alternatives, which result from FMECA and FTA analysis, are finally described and presented in the paper.

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Ant Colony Algorithm for Path Planning of a Quadrotor UAV

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Trajectory optimization problems have been widely considered in aerospace engineering fields due to the importance of defining a flight path that takes into account mission objectives, environment constraints, vehicle capabilities and performance.
The presence of both a high number of constraints and mixed-type variables makes appealing the use of nonconventional optimization techniques, e.g., evolutionary algorithms. Such methods are based on the definition of a population of potential solutions to the problem, that evolve towards the optimum by using a probabilistic approach. They do not need any information about the function to be optimized, but the possibility to numerically evaluate it, thus overcoming the limitations of the purely deterministic approaches.
In this paper an ant colony optimization algorithm is used to find feasible trajectories, through a geometrical approach typical of topological techniques. Ant Colony algorithms mainly provide for a great efficiency and robustness in combinatorial and graph-oriented problems. This ability has been conveniently adapted to find the shortest path between two points in a complex scenario in two dimensions with several constraints. The search space consists of a rectangular region including take-off and landing points.
The domain is discretized with quadrangular elements and a boolean matrix, associated to the mesh, keeps track of active elements (waypoints) to reach the destination. The waypoints sequence is smoothed with a spline which is used to evaluate constraints and objective function.
Intermediate fly-over waypoints can also constrain the ants journey if required.
A numerical example aimed at the maximization of a coverage area and the minimization of the path length is presented in the presence of several environmental constraints, such as no-fly zones, intermediate fly-over waypoints.

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Graphite combustion in high enthalpy supersonic flow

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High temperature combustion of graphite is a subject of interest for different engineering disciplines[1,2] : it has practical implications in coal combustion for energy production as well as in the development of materials for aerospace application such as ablative carbon heat-shields and carbon-carbon composites (C/C-composites). The complexity of the heterogeneous reaction of carbon with oxygen at very high temperature, couples here with the understanding of chemical reactions in the gas-phase and the description of the fluidodynamics of supersonic flows. The paper presents preliminary results obtained by the cooperation of two research groups, committed respectively in coal combustion and in aerospace engineering, to set-up an innovative experiment for the study of graphite combustion at very high temperature (T=1500-2500K) under supersonic conditions. Cylindrical graphite specimen (3mm D, 100mm L) are exposed to a supersonic flow of nitrogen/oxygen mixtures in a small Planetary Entry Simulator, equipped with a plasma torch. The impact of the gas flow on the specimen determines a very sharp temperature rise. A fast IR camera allows to realize bidimensional maps of the specimen temperature throughout the experiment. The IR images are worked out to measure the consumption of the graphite rod. Results are checked against the sample weight loss and used to estimate the rate of carbon combustion as a function of temperature and reaction time.

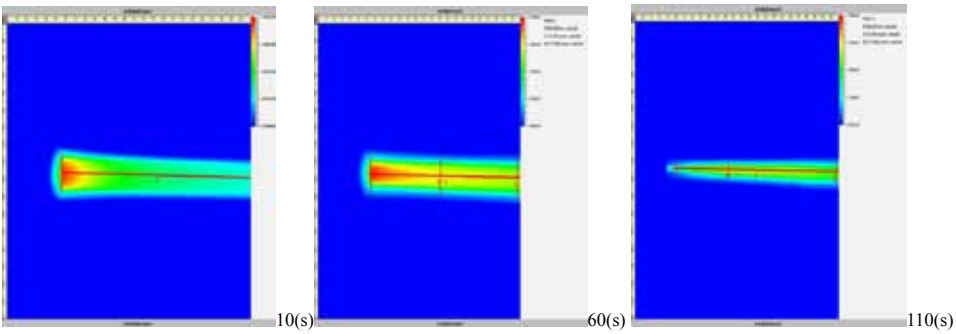

Figure 1 Temperature maps of the specimen at selected time intervals

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Avionic design for civil-military interoperability in Single European Sky

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Single European Sky ATM Research (SESAR) is the on-going European research program aiming at designing and validating a reformation of the Air Traffic Management system. SESAR research program involves also military airspace users [3], for this reason SESAR Work Packages are working together so that in the future military avionics could be able to implement selected ATM functionalities (i.e. Initial 4D and ASPA S&M) defined in the Single European Sky context. In the paper a reference airspace use case for military aircraft is presented as in Figure, and related Communication, Navigation and Surveillance requirements are highlighted from previous studies [2][3].

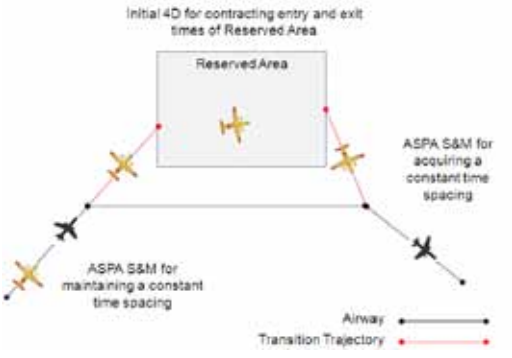

Figure 1. Applicability of Initial 4D and ASPA S&M to military airspace use.

By analyzing the above mentioned requirements it is possible to design technological solutions so that military avionic systems can be able to implement I4D and ASPA S&M functions. Upgrades of typical military avionic equipments (i.e. MIDS/Link 16, Mission Computers and IFF Identificator Friend or Foe) for assuring civil-military interoperability in the future ATM environment has been designed. The aim of the paper is to present results of the study and discuss the avionic upgrades necessaries for allowing civil-military interoperability in a Single European Sky ATM context.

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Fluid-structure coupling effects in synthetic jet devices

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The scientific and technical literature about synthetic jet actuators includes a very wide field of applications such as flow control, heat transfer from limited size surfaces, general enhancement of mixing between fluid currents, generation of micro-thrust for propulsion or attitude control.
The overall design of the actuators need practical modelling tools. The present work is aimed at characterizing the frequency response of a synthetic jet actuator driven by a thin piezoelectric disk and represents an alternative contribution to the Persoons's work[1]; in particular, it approaches the frequency response analysis from the same perspective of Sharma[2], who proposed a frequency response model directly based on fluid dynamics equations, whereas Persoons[1] follows more directly the Gallas et al.[3] perspective based on the equivalent electric circuit approach.
A lumped element mathematical model[4] of the operation of a synthetic jet actuators is both analytically and numerically investigated in order to obtain information about the frequency response of the device; the oscillating membrane is considered as a single-degree-of-freedom mechanical system, while the cavity-orifice components are described by means of proper-forms of the continuity and Bernoulli's unsteady equations. The governing equation system has been numerically integrated in MATLAB environment.
From the analytical viewpoint, it is found that the device behaves as a two-coupled oscillators system and, by solving the relevant eigenvalues problem, simply analytical formulas are given in order to predict the two modified peak frequencies, as functions of the uncoupled first mode structural and Helmholtz resonance frequencies.
The model is also validated through systematic experimental tests carried out on three devices having different mechanical and geometrical characteristics; it is found a very strict agreement between exit flow velocity measurements and numerical simulations for any tested device, for different supply voltages; besides, the analytical formulae yield predictions in close agreement with numerical and experimental findings as well.

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Hybrid Configuration Advanced APU concept for future TProp

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The need for a more efficient and green transport, in order to meet the environment constraints set by ACARE (Aerospace and Defence Industries Association of Europe), has led to new generation of regional turboprop aircraft. This trend is confirmed by relevant research efforts, such as Clean Sky JTI (Joint Technology Initiative), which represents one of the most important European initiatives. It is probable that, to meet the environmental requirements, the system will be design following the All (or More) Electric Aircraft (AEA/MEA) concept. As can be seen on the figure below, the AEA concept consists in converting most of the airplane secondary power, which in traditional design is also constituted of hydraulic and pneumatic power, to electrical one. The paper proposes the study of new propulsion[1] and electric system architectures for a green regional twin-engine turboprop, that can be defined Hybrid Configuration Advanced APU (HCAA). This system architecture (see figure) promises to enhance the system efficiency and, therefore, reduce the flight environmental footprint.

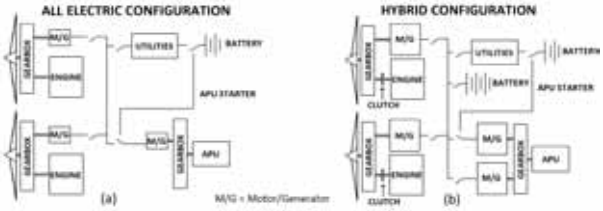

Figure 1. Comparison between AEA configuration (a) and HCAA (b)

The aircraft propulsion is provided by traditional turboprop engine which is coupled with an electrical motor / generator (M/G). The M/G can perform the traditional functions of engine starter and electric generator, but can also generate power together with the turboprop during take-off phase. In this way, the turboprop engine is reduced in size and, during cruise phase, is used at higher operating rotational speed which minimizes the SFC (Specific Fuel Consumption). Moreover, the HCAA architecture allows the green taxi (performed without internal combustion engine) by means of the M/G which is powered by enhanced batteries or other storage devices. During flight, to further reduce the engine fuel consumption, the power required by aircraft utilities is provided by the APU which is turned on during flight. Other advantages of the HCAA system configuration are related to safety during take-off, in particular a better unbalanced condition behaviour (unbalanced field).

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Global dynamics of gravitational liquid sheet flows

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The study of the dynamics of two-dimensional liquid sheet flows (plane jets) subjected to surface tension at the liquid-air interface and falling freely in the presence of the gravitational field (the flow being accordingly spatially evolving along the downstream direction) is a matter of interest since many years, in both theoretical and applied research.
A global instability model has been developed; the flow is assumed inviscid and the problem is arranged in 1D formulation along the streamwise direction by expressing all dependent variables through a coordinate-type expansion in terms of powers of the local lateral distance from the centreline position[1]. The interaction with the external field is modelled by means of an air enclosure located on one side of the curtain[2]. Surface tension is fully taken into account.
Concerning the steady (base flow) solution, the expansion procedure leads to a non linear boundary value problem involving the parameters We and ε, namely the Weber number and the slenderness ratio[3]. This equation reduces to the classical Torricelli's law for vanishing We and/or ε and has been numerically solved in general cases in order to derive more accurate base flow solutions.
The linearized perturbation equations are determined in a standard fashion by superimposing infinitesimal disturbances to the steady solution and by neglecting products of perturbations.
Our study has been restricted to sinuous (unsymmetric) solution of the linearized set of equations. The focus has been put on Weber numbers for which the classical singularity of the evolution operator[4] does not appear. A parametric study in the We-ε space has been carried out by inspecting both modal instability behaviour and non modal amplifications of the disturbances energy. In some circumstances it is found that the optimal amplification of the disturbances energy exhibits a transient growth characterized by time-periodic oscillations. The period of such oscillations is related crucially to the morphology of the spectrum[5]. In order to discuss the physical relevance of such an oscillating behaviour an equation of energy budget is also derived which is used to estimate the contribution of the various physical effects evaluated via direct numerical simulation of the linearized model.

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Reconfiguration Control Laws for Fault-Tolerant Hydraulic Actuators of Fly-By-Wire Helicopters

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This paper deals with the closed-loop control design of a fault-tolerant actuator for fly-by-wire helicopters. The reference actuator is characterised by a complex redundant architecture that allows the system to maintain its functionality even after one or more failures. It is essentially composed of a tandem hydraulic cylinder, an eight-way rotary servovalve driven by a limited-angle brushless motor with four independent coils, four LVDT transducers for the actuator position sensing and four RVDT transducers for the valve rotation sensing. The actuator is interfaced with two independent hydraulic power supplies and with four Flight Control Computer (FCC). Each FCC is equipped with a quadruple PWM electronics for driving the servovalve motors of the four helicopter primary actuators, and with a quadruple FPGA electronics for implementing the closed-loop controls on rod position, valve rotation and motor currents. In normal operating conditions, three control lanes of the actuator are active, while the fourth one is in "stand-by". The system can thus tolerate up to three servovalve coil faults, provided that an appropriate reconfiguration of the actuator control laws is applied. A basic concern about the control laws reconfiguration is that the fault on a control lane is typically compensated by increasing the demand on the remaining active lanes, but this command amplification can bring on system nonlinearities (e.g. voltage or current saturation) with unexpected dynamic behaviour.

In this work, the reconfiguration of the actuator control laws in case of servovalve coil faults is developed starting from the experimental results of a previous research activity, in which the actuator has been tested with reference to both normal (three active coils and both hydraulic systems pressurised) and fail-operative conditions (only one or two active coils). These studies pointed out that the servovalve dynamic response depends on the command amplitude, so a reconfiguration based on a simple amplification of the current demand can generally cause unexpected performances or even instability. The servovalve dynamics has been thus analysed by characterising the variation of the system transfer function with respect to the current amplitude. The reconfiguration of the control laws is then obtained via model-inversion technique, so that the control parameters vary with the current demand amplitude to counteract the variation of the system transfer function characteristics. The effectiveness and the applicability limits of the proposed reconfiguration strategies are verified in simulation, by using an experimentally-validated model of the reference actuator.

Suitability of Using Closed-Loop Current Controls on EMAs for Aircraft Applications

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The conversion of on-board systems to the "all-electric" concept is nowadays a standard trend in aircraft design. Particular attention is worldwide dedicated to the development of Electro-Mechanical Actuators (EMAs) for aircraft applications, and there are many open issues related to reliability, power management, systems interaction, control design and performances. This work provides a contribution to evaluate the importance of implementing (or not) the closed-loop current control in EMAs, depending on the application they are addressed. Actually, the use of current loops can strongly impact on EMA development costs, since they need additional sensors and they must be processed at very high frequency rates. Modelling and simulation activities play a key role in this type of studies, because the control strategies must be defined well before the equipment is constructed and tested, highlighting the possible criticalities.

In this paper, by assuming the same hardware solution (a 3-phase DC brushless motor driven by a PWM electronics), two applications are analysed: position-controlled (flight controls) and speed-controlled (landing gears, flaps or airbrakes) actuators. For both cases, two control strategies are developed, by implementing or not the closed-loop control on the motor currents. The EMA dynamic performances are thus characterised via dynamic simulation models, in terms of control tracking, stiffness, and torque ripple. The basic result is that the use of closed-loop current controls is important for position-controlled applications, while it could be questionable for speed-controlled EMAs, where the requirements in terms of load sensitivity are typically less severe.

Architecture Definition and Safety Assessment of Flight Control Systems for Light Rotary-Wing UAVs

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This paper deals with the architecture definition and the preliminary safety assessment of flight control systems for a light (from 20 to 150 kg) rotary-wing UAV for civil applications. This activity, which is standardised for conventional manned aircrafts, is currently a matter of discussion among aerospace specialists for UAVs. The lack of specific certification procedures and safety requirements for this UAV category actually entails the system engineers to analyse the existing military standards (e.g. STANAG 4671, AER-P.2, AER-P.6) and the documents used for airborne systems certification (e.g. SAE-ARP 4754, SAE-ARP 4761, RTCA DO 178, RTCA 254), up to derive the safety requirements for the system development[1].

In this work, once defined the safety objectives for the reference UAV application (catastrophic effects to less than 10^{-6} fh^{-1}, hazardous from 10^{-6} to 10^{-5} fh^{-1}, major from 10^{-5} to 10^{-4} fh^{-1}), the most relevant functional failures are identified and analysed in terms of Functional Hazard Assessment. Different UAV system architectures have been then defined and compared in terms of Fault-Tree Analysis, by using the failure rate data of modern commercial electric/electronic components. The activity allows to point out that, in a rotary-wing UAV system, the key elements for achieving the safety objectives are the flight control computers and the servoactuators for the primary flight controls. In particular, the number of computers (single or double), the type of signal processing they implement (simplex or duplex), as well as the servoactuator technological solution have a dramatic impact on safety, and they must be regarded as crucial aspects in the development of these UAV systems.

1. EUROCAE Working Group 73 has been established to address the standards required for civilian UAVs to fly in non-segregated airspace.

A tool for the simulation of All-Electric Aircraft systems

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The activity illustrated in this paper has been performed within the Clean Sky European project, whose goal is to achieve significant step changes regarding the environmental impact of aviation. In this direction, the recent trend aims to the electrification of all aircraft systems, even if challenging issues about the management of the on-board power arise in this approach. The All-Electric Aircraft (AEA) concept is based on the total replacement of hydraulic and pneumatic power with the electrical one, and this challenging objective can be only achieved by appropriately monitoring and managing the power requests (e.g. by temporarily reducing the power supplied to some systems during those flight phases in which the total request of electrical power could overcome the maximum available). In the Clean Sky framework a specific work package has been planned for the development of a simulation tool able to aid the engineers in the design and validation of electrical power management strategies. The activity has led to the development of a prototype platform that integrates simulation models of aircraft systems realized according to the All-Electric concept. The on-board system models, developed by our partners of the project, are able to reproduce the functions and the main performances of on-board systems, with particular attention to the power absorption issues. Each aircraft system model is seen by the simulation platform as a series of dynamic models, transfer functions and performance maps, relating mechanical and electrical input energy flows to thermal, mechanical, electrical output energy flows.

The paper describes the software architecture and the methodologies (Co-simulation and integration via S-function) used to integrate the several models in the Matlab/Simulink platform, with particular attention to those cases in which the models have been developed in a different simulation environment (Amesim, Dymola). In addition, the paper illustrates the approach used by the authors in the choice of key items, such as the solver and the integration step, and the methodology used to let the models in "trim" conditions before the simulation start. All these aspects have been treated with a special care to limit the requested computation time, in order to perform in reasonable times the large test campaigns, needed for the validation of power management strategies. Some preliminary results are shown and discussed in the paper, referred to simulation tests characterized by time histories coming from a flight simulator of a regional turboprop aircraft.

A methodology for the identification of inertial properties of small size UAVs

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In this paper, a procedure for estimating the inertial properties of small size aerial vehicle is illustrated. An identification algorithm has been developed that, starting from experimental data, estimates the parameters of a physical model describing the pendular motion of a generic rigid body. The attitude time histories of a structure ("cage"), carrying the object whose inertial properties have to be evaluated, are the experimental data and they are obtained through a measurement unit attached to the cage itself. The cage, designed in order to facilitate the assembly issues, is put in pendular motion thanks to a pivot needle shaped, placed to the cage top and leaning against a beam (figure 1). Before proceeding to the identification of the aerial vehicle inertial properties, several tests have been performed to evaluate the performance of the algorithm. A preliminary effectiveness of the algorithm has been tested via simulation environment, by artificially creating "virtual" time histories. Afterwards, the algorithm has been validated experimentally by loading the cage with a proof mass of known inertial characteristics. In this case, the algorithm errors have been evaluated by comparing the obtained results with the inertial properties predicted by a 3D CAD software where both the cage and proof mass have been modelled. During these experimental tests, specific attention has been focused on the effect of the cage initial attitude on the inertial properties estimate. In particular, a range of initial attitudes has been identified that guaranteed an opportune compromise between wide oscillations of the cage, needed for a correct identification, and negligible aerodynamic effects, not considered in the physical model. After this algorithm test phase, the developed methodology has been applied to a small Rotary-Wing UAV in order to evaluate its inertial properties.

Figure 1. The "cage" structure for fixing small size aerial vehicles

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Evaluation of the avoiding strategies for a prototype Sense and Avoid system of small size UAVs

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This activity is part of a research project aiming to develop Rotary-Wing UAVs (RWUAVs) starting from small commercial rotary wing aircraft models. The UAVs, widely used in military field for a long time, are now becoming interesting for the civil applications such as rescue operations, traffic control, territory surveillance, structural inspections (buildings, bridges) and other numerous activities. The crucial aspect for a large diffusion of the UAV in the civil aviation is their integration in non-segregated air spaces, to be performed without reducing the current safety level guaranteed by the "See and Avoid" capability of the manned aircrafts. This challenging objective can be achieved only by equipping the UAVs with systems, known in literature with the name Sense and Avoid (SAA), having capabilities to identify unexpected obstacles (unpredictable during mission planning) and to elaborate real-time escape trajectories in order to minimize the collision risks.

In this work some preliminary strategies and logics for a prototype SAA system of a small-size RWUAV are developed. In addition, a simulation tool has been developed to test and validate the SAA logics, able to simulate the interaction between the SAA system, the Flight Management System (FMS) and the aircraft dynamics. Currently, the SAA logics manage potential collision risks both in the presence of fixed obstacles and moving obstacles. The developed SAA algorithm acts by means of two successive phases: after the identification of an obstacle, if it is classified as dangerous (high probability of collision occurrence), an avoidance trajectory is elaborated and commanded by the SAA to the RWUAV FMS; at the end of this phase, when the obstacle is overcame, the SAA elaborates a new trajectory in order to regain the original flight path.

The simulation tool performs the flight dynamics simulation for autonomous missions of a reference RWUAV. It is constituted by models describing the dynamic behaviour of a small-size helicopter, by flight control laws and by a flight management system that states the input signals for the autopilot control laws on the basis of the waypoints coming from a pre-defined mission, possibly modified by the SAA logics. The paper illustrates the main results of some simulation tests in order to illustrate the dynamic response of the RWUAV flight model, the correct interaction between the FMS and the control laws, and the action of the SAA logics in presence of obstacle along the RWUAV flight path.

On-Comet Attitude Reconstruction of Rosetta Lander Philae through Solar Arrays Telemetry

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In Rosetta lander Philae, the ability to increase the on-comet power production gives the chance to maintain the system alive, as well as the opportunity to accomplish scientific experiments during the Long Term Science (LTS) phase. This can be accomplished if the lander operates at solar incidence angles that maximize the total power produced by the solar arrays. However, due to strict mass limitations, the lander does not have any system for attitude determination. This lack makes it difficult to identify the mutual Sun—lander orientation during a cometary day. The need to maximize the power asks for a post-landing maneuver to maximize the solar arrays area exposed to the Sun. The only degree-of-freedom is represented by a rotation around the zenith axis.

In this work, a method based on system identification and parameter estimation has been developed to reconstruct the orbit of the Sun relative to Philae in on-comet conditions. The objective it to find the azimuth/elevation angles of the Sun as a function of time. This is done by post-processing the telemetry data acquired few hours after landing. In particular, the voltages of the six solar arrays and their output currents (input to the MPPT) are analyzed in an automatic fashion. This allows us to design the optimal rotation of Philae to maximize the power produced and thus the scientific return.

Contribution to wave drag theory and to its calculation

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In designing aircrafts the pressure-drag reduction at cruise conditions is a very important item, specially for flight at supersonic speeds because the pressure drag gives also wave drag, as well known. To achieve this aim the general results of the linearized potential flow theory.[1,2] permit a preliminary good choice of the fundamental geometrical parameters of the aircraft configuration [3,4]. The pressure drag evaluation of arbitrary configurations as determined both by the trailing vortex sheet in the Trefftz plane and by the axial source distributions (corresponding to areas and forces in Mach planes) is based on the supersonic far field properties. The far field detailed analysis, which is involved in the calculation of the total force and moment, presents some difficulties at supersonic speeds. Some results on this item were presented at the previous AIDAA Congress [5], together with other contributions to the general theory. This paper presents both further results of investigations on the supersonic far field and a procedure to determinate axial source-distributions which reduce the wave drag under some given conditions (the body nose angle, for example). The source-distributions are represented by a new series of regular functions. By a proper formulation of the impermeability boundary condition, the series representing the circulation distribution in the wake of the Prandtl's lifting-line, by the known analogy also used to represent axial source-distributions, gives only bodies with a pointed nose tangent to the Mach cone (a limit condition inconsistent with the small perturbations hypothesis); conversely, the new series gives noses inside the Mach cone, like the Karman-Moore piecewise linear source-distributions. Since the source-distribution is represented by a series of functions with unknown coefficients, the corresponding wave drag is a function of these unknown coefficients represented by a series which is a positive definite quadratic form. For the source-distributions represented by the new series the coefficients of the wave drag quadratic form can be evaluated analytically[6] and the results are given. The Lagrange multipliers method has been used to find source-distributions which minimize the pressure drag under some typical conditions.

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Technical Manual Empowered By Semantic Technologies

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Technical Manuals are documents containing instructions for installation, operation, use, maintenance, parts list, support, and training requirements for the effective deployment of an equipment, machine, process, or system. Every product needs documentation, because throughout its life cycle, it must be serviced, repaired or fitted with spare parts. Furthermore, the functionality and operation must be described. Issues associated with technical documentation are well known to cause errors, rework, maintenance delays, other safety hazards, and administrative actions against individuals and organizations. So good operating and maintenance instruction manuals, repair manuals and spare parts catalogs enhance competitive advantages. Generally, IETMs (Interactive Electronic Technical Manuals) are deliverable products for which the new technologies of interactive electronic data presentations are used to access any part of the technical manual descriptive text, to provide multimedia description of maintenance and troubleshooting procedures, or illustrations.

Recently the strong interest in developing IETMs around Web technologies is due to the immediate value added by the opportunity of sharing information. The rich integration of multiple media enriches the effectiveness of the IETM when the system adapts the contents and display specifications to both the user's profile and the system state. Despite to emerging technologies (e.g. S1000D, ATA100, Semantic Web, etc.) to represent Technical Manual, currently, there is no regulatory specification regarding media, format, turn-around times, or distribution technology for technical documentation. Next-generation technologies provide new opportunities for presenting and accessing technical information (e.g., 3D modeling, embedded video training, and voice recognition) and for content search ability and management. In particular, Semantic Web technologies enable us to represent technical manuals in a machine understandable manner enabling annotation and enhancing delivery of the right information at the right time.

This work presents an ontology-based architecture to address Technical Documentation Challenges in Aviation Maintenance. The proposed conceptual framework consists of two meta-models, Multidimensional Classification and Correlation of Heterogeneous Resources, that enhance user experience during daily maintenance work, enabling the availability of a repair procedure by constraints regarding the failure occurred on a specific aircraft configuration (i.e. fault isolation), such as: the model of aircraft repair, configuration, sold, etc. Specifically, the framework defines a semantic layer that reuses and extends ontologies available in literature (e.g. FOAF, SKOS, MPEG-7, etc.) and exploits lightweight ontologies to guarantee flexible and reconfigurable features (e.g. semantic faceted-browsing, etc.) according to emerging needs in the post-design phases.

Artificial Neural Networks comparison for a SHM procedure applied to Composite Structure

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In this paper different architectures of Artificial Neural Networks (ANNs) for a structural damage detection are studied. The main objective is to create an ANN able to detect damage without any prior knowledge of the model of the structure so as to serve as a real-time data processor for SHM systems. Two different architectures are studied: the standard feed-forward Multi Layer Perceptron (MLP) and the Radial Basis Function (RBF) ANNs. In the standard MLP paradigm each singular processing unit (neuron) is arranged in a series of layer. The excitation is passed through an activation function and then it emerges as the output of the neuron. There are no precise rules for the choose of the number of hidden neurons, only empirical indications. More particularly, increasing the number of neurons increases the power of the network but requires more computation and is more likely to produce overfitting [2]. On the other hand, the RBF-ANN can require more neurons than standard feed-forward back-propagation networks but they can be often designed to reduce the training time with respect to standard feed-forward networks[3]. This kind of ANN consists of only two layers: a hidden radial basis layer and an output linear layer. Three types of RBF-ANN are trained. The first can produce a network with zero error on training vectors by using the same number of neurons as the number of input vectors. The main drawback is that the number of hidden neurons is very high since it must be equal to the number of input vectors. A possible solution is to iteratively create a radial basis network by adding one neuron at each training input, until the sum-squared error falls beneath an error goal or a maximum number of neurons is reached. This represents the second type of RBF-ANN studied. The latter one is a Generalized Regression Neural Network (GRNN) characterized by a special linear output layer with a standard radial basis hidden layer.

With regards to the training data, they are obtained, in term of a Damage Index $\Im_D$ distribution, from a Dual Reciprocity Boundary Element Method transient analysis of the host damaged structure and the bonded piezoelectric sensor. The BEM model allows to compute the electrical signals that are used to define the $\Im_D$ generated by an array of piezoelectric sensors bonded on a delaminated composite skin-stiffner configuration[1]. Thus, the trained neural networks should have the capability of recognizing the location of the damage characteristics.

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Analysis of Ballistic Capture Orbits in the Real n-Body Problem

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A massless particle may perform a ballistic capture about a primary when two or more gravitational attractions are considered. The dynamics governing the ballistic capture depend on the mutual position of the primaries, if these are let to revolve in eccentric orbits. In previous works, the ballistic capture dynamics have been studied in the planar restricted three- and four-body problems. In this paper we extend this analysis to the case of a real system. This is a model in which the primaries move according to the JPL DE405 ephemeris (i.e., three-dimensional orbits with varying orbital parameters) and the gravitational attractions of all the planets, beside those of the Sun and Moon, are considered upon the spacecraft. A number of capture orbits are presented, which are derived through a suitable manipulation of the stable sets. Possible applications to real missions of these ballistic capture solutions are also discussed.

Satellite Advanced Attitude Sensors at UniNa Lab GNC

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This paper presents the most recent activities at the Laboratory of Guidance, Navigation, and Control (Lab GNC) of the Department of Industrial Engineering dealing with design, development, and test of attitude sensors for space applications. The research group at Lab GNC has a consolidated expertise in attitude determination and sensors, both for theoretical studies and hardware development, as well as experiments. The most recent deal with a micro sun sensor (MSS) and a star tracker (ST), along with laboratory facilities to test them indoors.

The digital MSS was developed under the sponsorship of the Italian Space Agency that selected it as a innovative technology experiment of the MIOsat mission. It is a two-axis digital sun sensor based on a CMOS photodetector[1,2,3]. Its peculiarities lie in the original configuration with multiple apertures, which allows for a significant improvement in precision (within 5 arcsec) [3], the neural calibration function, the COTS-based design. This paper describes the MSS and presents the attained performance, as assessed in the dedicated facility[2] that is capable of simulating sun illumination and variable sun-line as resulting from orbit and attitude dynamics of a planned mission segment.

The advanced ST development has reached the stage of fully-functional hardware prototype. It is based on the COTS smart camera by Matrox IRIS P-series, including both a camera head equipped with a Sony-CCD-based focal plane and a programmable processing unit exploiting a 400-MHz Intel Celeron processor. All the software routines required for an advanced, modern sun sensor were developed and implemented in the above unit: autonomous initial attitude determination[4], attitude tracking, autonomous operating mode management. Sensor description is presented along with its validation in the dedicated test facility that was set up[5]. The latter one allows for stimulating the sensor by supplying input star filed scenes as resulting from given pointing or mission segments, i.e. accounting for the relevant orbit and attitude dynamics. Both the sensor and the facility were realized within a cooperation with GCS (Carlo Gavazzi Space at the time, now Compagnia Generale per lo Spazio) under the financial sponsorship of Regione Campania. The results of a thorough test campaign are presented, assessing sensor performance in all the implemented operating mode in terms of sky coverage, reliability, measurement accuracy and precision.

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A comfort based interior design project of an habitation module for the International Space Station

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The interiors of a space habitat for middle-long period stays have to answer to technological and functional requirements, as well as to ensure high habitability levels in order to reduce psychological drawbacks afflicting the crew during long periods of isolation in an extreme environment. The existence of a place for astronauts , in which maximum attention is payed to all the aspects related to comfort answers to the second request. As a result of Transhab project cancellation, today the International Space Station (ISS) is made up of several research laboratories, but it has only one module for housing. This is suitable for short-term missions, as it does not fully meet needs related to privacy: the blending of a public space where every day activities take place and of private spaces for rest, as well as the inadequacy of personal compartment to accommodate all the crew, show the need for new solutions. Design concept of module appositely fit for living during middle-long stays aims to provide ISS with a place capable to satisfy the habitability requirements of comfort and at the same time equipped with innovative technical and structural elements. The paper, after having analyzed Space habitats build up till now an crew psychological needs occurred in a confined environment, describe the project of a new human centered habitation module typology.

Architecture and Implementation of a Middleware Interface for AFDX and ARINC 429

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The main purpose of this work is the study and design of a middleware software layer for civil avionics buses. The goal is to make each specific avionics application independent from the bus, from the manufacturers' hardware and finally, from the avionics hardware board model. It also simplifies and makes the bus communication system more suitable and easier to maintain. In addition, it opens the way to thinking about bus-oriented applications as a means of reducing design and development time. Following the design described in this work, a middleware software tool was implemented for ARINC 429 and ARINC 664 data bus and tested with both ARINC 429 CEI Condor Eng and AIM ARINC 664 board .

Index Terms— Avionics data bus, AINC 429, AFDX, communication layer, middleware service, hardware independency.

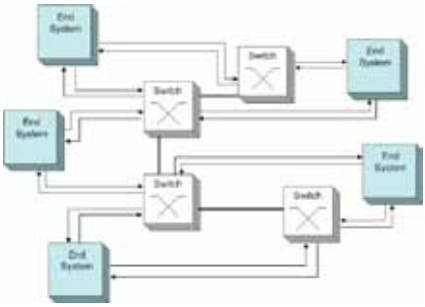

Fig. 1. AFDX Network Topology.

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A Hybrid Formulation for Modelling Multibody Spacecraft

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The two classical approaches adopted in multibody systems analysis are the Euler-Lagrange (EL) and the Newton-Euler (NE) formulations. Both present advantages and drawbacks to be correctly evaluated while selecting one of them for the design of a space system. NE takes into account a complete set of equation of motion for each single body belonging to the system, with their coordinates not dependent on the multibody topology, and applies the constraints' equations in order to represent the kinematic connection among two or more bodies, leading to a Differential Algebraic Equations of motion. On the other hand EL approach derives the equations of motion starting from the Lagrangian function, related to the energy quantities of the system and, through some analytical derivations, it obtains a minimum set of Ordinary Differential Equation (ODE) which describes the behavior of the multibody system dynamics without the numerical errors due to the constraint equations included a posteriori in the NE approach. On the other hand NE formulation enables a simpler assembling of the system equations, which can be easily implemented by numerical codes of analysis, and directly provides as output the reaction forces among the bodies, which cannot be directly determined by using a LE approach.
The ideal solution should be represented by a combination between the two formulations, taking for example the NE formulation for assembling the equation of motion, but describing the system by a minimum set of variables and equations with an ODE system.
In order to simulate the behavior of a space multibody system, the paper shows the possibility of shifting from an NE approach, convenient to understand and write down the mechanics of the system, towards a minimal mathematical complexity, such as the one provided by the minimum variable LE approach, and to swiftly turn back to a NE formulation to calculate the reaction forces and torques among the bodies. The possibility to model the specific case of space systems, in which the platform is floating, is faced by means of the same, convenient approach used for terrestrial, fixed-basis robots taking into account Denavit Hartenberg rules. The overall, revised hybrid formulation, built on both NE and EL approaches, is applied to several case studies where multibody models fit, as the deploying phase of a spacecraft's solar panels and the deploying and grasping maneuver of a space manipulator system.

Low weight design of impact damaged CFRP stiffened panels by new design criteria and PFA

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The object of this work is to outline new design criteria and analysis approaches for a low weight design of composite stiffened panels. The common industrial approach to satisfy the current certification requirements (EASA AMC 20-29) for composite structures, based on the application of high conservative knockdown factors to the material strength properties and/or performing extensive test campaigns, can lead to oversized structures and to an increase in costs and timing. Nowadays a new design methodology, based on the incorporation of SHM (structural health monitoring) systems into composite structures, is under consideration aiming at exploiting the full potential of damaged composite materials in favor of a greater weight reduction. By detecting the damages thanks to SHM systems, the structure could be designed with higher design allowables (more reliable detection of BVID) improving the static strength for a reduced damage size detection. Under this topic, two wing box stiffened panels, one critical at strength and another one critical at buckling, have been sized under static compressive loads according to classical design approaches and criteria (reference panels). In the first part of the work a sensitivity analysis, finalized to assess the influence of BVID allowable on the panels' weight, have been performed. The two reference panels have been re-designed releasing the BVID allowable both on the whole panels and on some of their subcomponents (skin, stringer, etc.), in order to evaluate the weight reduction that could be potentially reached by reliable SHM systems. The results of these analyses provide fundamental requirements for the SHM system definition in terms of "which parameters needs to be monitored and where". Successively, in order to exploit the effective residual strength of impact damaged panels, progressive failure analysis has been performed considering a discrete damage model against the traditional design approach that is based on the first ply failure design criteria on uniformly damaged panel. PFA has been performed on the panel considering a new simplified design model of BVID by simulating this kind of damage with an equivalent hole. This approach will allow to simplify, in the future, the numerical models simulating the low energy impact effects with high computational time savings. It will be possible to avoid the implementation of induced damage models to determine the laminate residual strength after impact, but simply model the laminate with the appropriate hole in the same BVID location. Some results of this approach are shown in this work supported by some impact and CAI tests on different layups and thicknesses.

Flexible composite supports for morphing skins

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The development of flexible skin systems is one of the most important issues in the design of morphing surfaces that can generate aerodynamic forces and can adapt to different flight conditions by means of a continuous and progressive shape changing. Morphing skins should be able of undergoing large recoverable strains in the morphing direction, but they should also retain an adequate flexural stiffness to sustain and transmit aerodynamic loads [1]. The paper moves from a promising solution presented in literature[2], which is based on the adoption of composite corrugated laminates. Alternative and innovative configurations of composite supports are suggested and a technological solution is presented for integrating an elastomeric cover in such skin systems. Parametric FE models are developed to evaluate functional and structural performances indices for all the different types of composite supports taken into consideration. In particular, the axial compliance, the flexural stiffness in different directions and the in-plane shear stiffness of the morphing panels are numerically estimated and compared by varying several design variables.

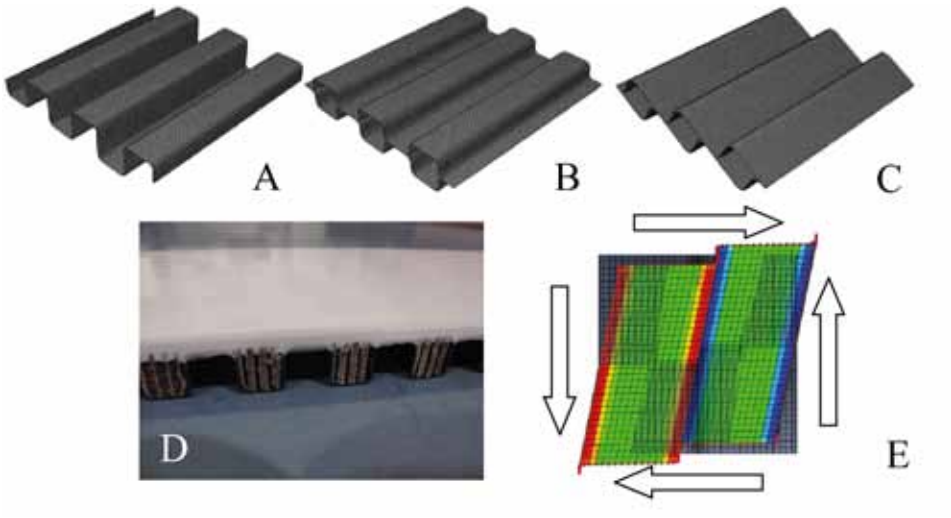

Figure 1. Models of a corrugated composite skin support (A) and of alternative configurations (B,C), manufacturing of a complete skin with elastomeric cover (D) and FE model for shear stiffness evaluation (E)

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Tracking Architectures and Algorithms based on Cooperative and Non-Cooperative Sensors for Multiple UAV Applications

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The low cost of small Unmanned Aircraft Systems (UAS), together with new sensors and miniaturized technologies development, made it possible the employment of multiple UAS to perform some tasks impracticable for manned aircraft or for a single Unmanned Aerial Vehicle (UAV). Indeed, a swarm of UAVs can perform applications, such as detecting, monitoring and measuring the evolution of natural disasters, like forest fires or landslips, more efficiently than a single UAV. Among the years, an extensive research has been carried out especially in the framework of navigation and control techniques regarding a single UAV[1]. Nevertheless, due to the complexity of multi-UAVs management, several open issues still remain regarding the implementation of UAV swarms, which are actively studied by the scientific community[2].

In this paper, the development of tracking architectures and algorithms for multiple UAVs based on the fusion of information coming from non-cooperative (i.e., cameras), and cooperative sensors (i.e., Automatic Dependent Surveillance – Broadcast, ADS-B), is investigated. Different system architectures have been analysed and are described in detail in the paper, together with the required tracking algorithms. In the first configuration, each UAV sends the ADS-B and cameras data to a ground control station which runs the tracking algorithm and performs the tracking of all aircraft. The updated traffic information is then broadcasted to all users within the range of the station without the need of any on-board computation by the UAS. As a consequence, this decentralized approach reduces the computational effort on-board the UAVs and the requirement on the on-board data handling system resulting in a smaller and simpler processing unit, paying the cost of additional complexity for the communications subsystem. In the second configuration each UAV executes the tracking algorithms entirely on-board and autonomously tracks the other vehicles. In this case, the ground station may assist the UAVs by providing cameras data relative to the swarm of vehicles, which are used as support for the tracking solution. The approach implies that each UAV can independently solve for the tracking solution without the need of a direct link with the ground station. This requires a better performing processing unit, but it presents the advantage of making the tracking possible in all applications where a direct link with the ground control station is not possible or available.

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Application of SAR data from COSMO-SkyMed and ALOS for coastal area Bathymetry in the Gulf of Naples

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SAR4BAT project (SAR data fusion for bathymetric data retrieval of sea bottom in coastal areas) is funded by Italian Space Agency with Kell srl as prime contractor and University of Naples as technical consultant. Its goal is the development of SAR-based bathymetric products for coastal area by processing SAR data from COSMO-SkyMed and ALOS satellites. This research has the peculiarity to apply and adapt SAR-based bathymetric data retrieval techniques, typically applied in open waters showing strong tidal currents or significant wave motions over sandy sea beds, in the Mediterranean basin. More in detail, this project applies these techniques in the Gulf of Naples which is characterized by a prevalently rocky sea floor and by different water dynamics. Accurate measurements of bathymetry, intended as the measurement of the morphology of sea floor and then the production of the relevant bathymetric Digital Elevation Models (DEM), are essential to monitor geo-morphological risks in coastal regions, e.g. warp analysis and forecasting of potential flooding effects, and they can also support measurements for marine pollution monitoring. In addition, they can also be useful in underwater coastal archaeological applications for supporting researchers or monitoring the sites. Due to the inability of SAR signals to penetrate sea surface and reach sea bed, SAR-based bathymetry is based on indirect processes with sea floor morphology sensed through the effects it may have on sea surface. SAR echoed signals from sea actually are sea surface echoes and two different techniques have been developed for SAR-based bathymetric data retrieval: wave-based techniques and current-based techniques. In the present paper the results of SAR4BAT project are reported with special attention to the application of wave-based techniques, which rely on the ability of local bathymetry to modify the characteristics of sea surface (swell or gravity) waves. After a state-of-the-art analysis, the paper will report on the selection of a specific algorithm, including the performed error budget analysis to identify critical aspects of algorithm application. The range of suitable depths for SAR-based bathymetry, sensitivities and water depth uncertainties due to waves characteristics, values of current velocity and wind speed for correct SAR-based bathymetric data retrieval, detectable underwater features and SAR data specifications have been determined. Finally, bathymetric data in the Gulf of Naples have been retrieved by processing SAR data from COSMO-SkyMed and ALOS and results validated with pre-existing nautical maps obtained with conventional bathymetric retrieval methods.

A Leading Edge Morphing Architecture for Droop Nose Effect

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The preservation of the laminar flow constitutes a challenging target because of the obtainable advantages in terms of wing aerodynamic performance (i.e. drag reduction). Among the different factors, airfoil geometry and more in detail roughness and surface discontinuities (gaps) play a fundamental role in priming turbulence. The traditional slats, designed and optimized to produce high lift at specific flight regimes (take-off and landing), seriously compromise the laminar regime even if retracted (cruise): the discontinuities at the interface with the wing main body, in fact, dramatically prime the turbulence.

A morphing adaptive approach seems to be a valid solution to this problem. The guiding principle is to substitute the traditional slats with a monolithic morphing structure able to realise in take-off and landing phases the so called "droop nose" effect, this way generating equivalent high lift; at the same time, this architecture in retracted configuration, being devoid of discontinuity elements, strongly contributes to the laminar regime preservation [1]. Against these benefits, however, this approach poses some design challenges: the morphed zone is subjected to high external loads (the depression peak is very close to leading edge) with consequent problems in term of dimensioning of the actuation/supporting structure; moreover the skin, assumed to be rigid enough to withstand the external loads, has to be at the same time flexible to fit the best, without any structural collapse, the target morphed shape.

All these challenging aspects were faced within the "Smart High Lift Devices for Next Generation Wings (SADE)" European Frame[2], arriving at the original morphing architecture object of this work. At first, a preliminary conceptual design was performed, identifying an architecture typology able to produce the droop nose effect and at the same time to keep low the stress level within the skin; the selected architecture is constituted by a truss-like structure connected to the actuation system and to the skin through hinges[3]. Then an optimization (genetic) process was carried out with the aim of assessing the architecture main features (hinges locations) guaranteeing a deformed morphed shape close to the desired one[4]. Also the problem of reducing the actuation forces was dealt with by considering a dedicated kinematic chain, whose amplification factor, decreasing with the architecture extension level (and thus with the external loads) allowed to reduce the dimensions of the actuator. Finally, the manufacture task was performed producing a real size laboratory demonstrator.

The experimental campaign was essentially aimed at demonstrating the concept functionality; in this sense, the achieved actuated deformation and related stress field within the skin were measured through mechanical comparators and strain gages and related to the actuator displacement. The achieved results proved to be in good agreement with the numerical outcomes.

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Series hybrid reconfiguration of a general aviation aircraft: preliminary design

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This contribution is concerned with the feasibility study and preliminary design of a hybrid reconfiguration for the propulsive system of a general aviation light aircraft. The study is motivated by attractive expectations in the reduction of both chemical and acoustic emissions, in view of a possible prototypal realization to be employed as a research testbed and technology demonstrator.
The aircraft chosen for this reconfiguration is Rutan's Long-EZ, a canard, two-seater, pusher-propeller airplane of the experimental category. The native propulsive system, i.e. a conventional aeronautical internal combustion engine (ICE), is to be replaced with a "series" hybrid system composed of an electric motor directly connected to the propeller, and by an existing ICE currently employed in automotive applications.
In the "series" architecture, the ICE, coupled with an electric generator, acts both as the power source for the electric motor and as an in-flight recharger for the battery pack ("range extender"). This entails that two operating conditions are available: a "hybrid mode" where the ICE/generator subsystem provides the electric power necessary to the electric motor and battery pack; and a "pure electric mode", where the ICE is shut-off and the electric motor is fed by the battery pack until complete discharge.
We analysed the constraints set on the single components to provide a higher global efficiency for the complete system when compared to the native ICE. On this ground, we approached the preliminary design of the propulsive system under requirements of overall weight preservation and minimal impact on the existing airframe and handling qualities, seeking the possibility of establishing FAI (Fédération Aéronautique Internationale) records with respect to range, airspeed and time to climb. Translating these goals into performance specifications led to installed energy and power requirements, which in turn triggered the sizing of the ICE, the generator, the electric motor, and the battery pack. The latter proves to be the most critical element, being characterized by technology limitations concerning energy density and charge/discharge behaviour.
A suitable array of components available on the market has been selected according to the design requirements, and a possible practical layout has been conceived. Preliminary verifications confirm the feasibility and compliance with performance specifications, including the mentioned flight performance peaks, when a suitable energy management strategy is employed. In particular, fuel savings up to 20-25% may be achieved in connection with a long haul mission.
Conclusions on this preliminary activity are drawn, together with recommendations for future developments, in relation to further modifications and evolutions of the system architecture.

Experimental and Numerical Modelling for Flag Flutter

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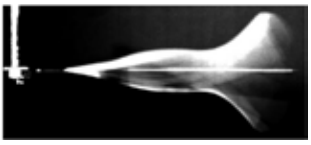
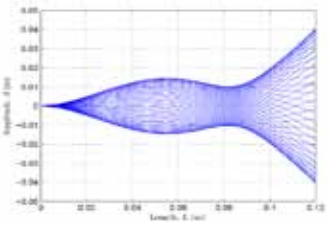
The flutter instability of a cantilevered flag-plate subjected to an axial flow on both surfaces has been experimentally and numerically studied in the present work (see Fig. above). This instability mechanism, which can lead to self-sustained oscillation, is nowadays at the core of prototypes or concept of flow energy harvesters[1]. In this work, three different models are used for examining the instability and the post-critical behaviour of this fluid-structure system and compared with obtained experimental results. Indeed, the flutter boundary, the vibration modes, and the amplitude of limit cycle oscillation (LCO) predicted by the different models are compared with experimental data provided by wind tunnel tests. Beginning from a linear proposed theory[2], the analytical model is then extended through a linear numerical one in which the flutter modes are assumed to be two dimensional but the potential flow, discretized by the doublet lattice method (DLM), is calculated in three-dimensions. The resulting stability problem is analysed and the aeroelastic modes of vibration describing the transition to instability are discussed in detail. The post-critical behaviour is analysed through a nonlinear (both structural and aerodynamic) numerical model where an unsteady vortex lattice method (UVLM) is used. Numerical and experimental results are in good agreement for the flutter onset with the literature results[3,4], including the critical flow velocity at which the aeroelastic system becomes unstable, as well as the aeroelastic mode of oscillation and frequency. However, there are significant differences between the nonlinear numerical model and experiment for LCO amplitude. The comparison between the numerical aeroelastic mode and experimental one, provided by a high resolution video measurement system, is done by using modal assurance criterion parameter. Moreover, a large hysteresis loop is experimentally observed suggesting a subcritical bifurcation, which is not numerically predicted.





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Non-linear modelling for Multi-Disciplinary and Multi-Objective Optimization of a complete aircraft

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The aerospace engineering typically deals with multidisciplinary complex systems, and narrow margins of the design parameters make necessary the introduction of multi-objective approaches in order to pick the best design.
Genetic algorithms, in addition to gradient-based ones, allow to evaluate the Pareto Frontier[1], *i.e.,* the set of best trade-offs, thanks to the current satisfactory level of computer performance.[2]

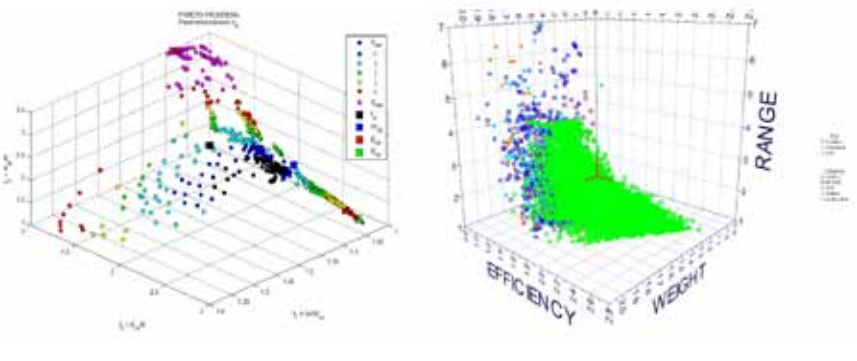

Figure 1. Pareto frontier evaluated by using a gradient-based (left) and a population-based (right) approaches.

In the present paper, an integrated Multidisciplinary Design Optimization (MDO) has been used to solve a Multi-Objective Optimization (MOO) problem for a national regional aircraft comprised of fuselage, tail and wing, where the optimization criteria are minimal structural weight, maximum aerodynamic efficiency and maximum mission range, taking into account also of aeroelastic constraints. Non-linear analyses have been further applied to evaluate the aerodynamic performance (i.e. the aerodynamic efficiency is computed as the ratio of lift and drag coefficients) for a more fidelity evaluation of the induced drag in the optimization process by using a free-wake approach.

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Damage Tolerance in Composite Aeronautical Structures

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The arrival of fully composite primary aeronautical structures in the recent years has been a major challenge to the research community to demonstrate that the use of carbon fibre reinforced plastics can lead to the creation of lighter and greener aircraft while still fulfilling the airworthiness requirements of the certifying bodies.

These challenging requirements are mostly related to the demonstration of damage tolerance capability of composite structures. And while composite-made structures inherently demonstrate exceptional fatigue properties, when put in real life working conditions, a number of external factors can lead to impact damages thus reducing drastically their fatigue resistance due to fibre delamination, disbonding or breaking.

This paper discusses the current state of the art of the regulations relative to the full composite primary aeronautical structures and the tools, tests and models used to predict the fatigue behaviour of these structures. Included are also the publically available documents relative to the approaches to the subject of two major aircraft manufacturers, Airbus and Boeing.

The result of this overview allows pinpointing areas in which additional research efforts are necessary, proposes the topics for further research developments and sets the environment for future contributions to the subject of Fatigue and Damage Tolerance in primary composite aeronautical structures.

Italian Technologies for Active Space Debris Removal: the CADET Project

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This paper aims to illustrate the activities performed by Aviospace in the frame of CADET (CApture and DE-orbiting Technologies) R&D project, whose objective is the preliminary development and functional ground demonstration of enabling technologies required for Active Debris Removal from LEO orbits, with a particular focus on the selection of preferred in-space capture concepts for large, heavy space debris in LEO orbits, such as upper stages of elderly launch vehicles or decommissioned satellites, for which a non-collaborative rendez-vous and capture procedure, to be performed by a robotic spacecraft (namely "chaser"), is required.

Such enabling technologies include:

- techniques for recognition of the piece of debris in orbit (target), based on images obtained in-situ by the chaser spacecraft via optical sensors, both in visible and infra-red fields, by which thermo-optical, kinematics, mechanical and inertial properties of the non-cooperative target can be estimated
- technologies of autonomous guidance, navigation and control for phases of close rendez-vous, final approach and capture
- technologies, strategies and concepts for target capture and solidarization: this project branch includes a trade-off on several different concepts for capture system, aiming to investigate a wide variety of technological groups (including for instance, purely robotics concepts, net and tether-based concepts, inflatable systems, adoption of glues and foams)

For such technologies, current level of development – at least on the national scenario - is TRL 2 and it is planned, as objective of CADET, the reach of TRL 4 through the development of an integrated demonstrator and the associated test setup and environment to be adopted for functional evaluation and validation tests.

CADET project, which has started in January 2013 and is planned to last 24 months, is co-funded by Regione Piemonte according to call for proposal: POR FESR 2007/2013 – linea di attività I.1.1. "Piattaforme innovative" – AEROSPAZIO FASE II.

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This paper is describing exclusively corporate-internal R&D activity, thus no public document has been used as a reference.

Vibrational Energy Harvesting – New solution to increase the efficiency of next space transportation and exploration vehicles

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The use of piezoelectric devices for Energy Harvesting from mechanical vibrations, although is based on an already known technology, it is still an innovative sector since the previous applications have been isolated researches, which did not occurred at the level of industrial production.
The goal is to recover small amounts of energy sufficient to power on-site low-consuming electronic or mechatronic devices (microprocessors, sensors, transmitters, receivers, etc.).
In this frame, Aviospace intends to develop an innovative device providing this capability for space transportation applications, considering also possible spin-offs on earth applications, wherever there are mechanical vibrations, as in any transportation vehicle or industrial machinery (potential customers can be found in the railways, aeronautics, automotive manufacturers, etc.).
Space systems are limited by the availability of electrical power and weighted by miles of wires and cables for power distribution and data transmission. The subject technology would then simplify the usage of such a large number of sensors that you must allocate, often in areas difficult to access or next to prohibitive environmental. In fact the launchers ascent phase is characterized by strong vibrations generated by the engines; hence structures and surfaces are subject to intense vibration. Each of the hundreds of sensors located inside the vehicle could benefit from the vibrations of the structure on which it is installed.
The project paves the way for the simplifications of space systems, especially in terms of wiring, allowing the use of spread energetically-autonomous electronic components as sensors and/or micro actuators. A moderate use of wires implies a reduction of costs of assembly and integration operations (man-hours) and less inertial mass to be lifted off in favour of a greater payload on orbit.
Abatement of wires and harness will be even more effective by using wireless sensor networks where you can use wireless radio links for sensors that communicate directly with the controller board.
The objective of the foreseen activity is the research and development, of a prototype composed of piezoelectric transducer, mechanical resonator and conditioning circuitry. This prototype will be developed and characterized in a representative environment.
Good preliminary results will push towards an improvement design and space qualification activities of the device and thus an entry in the real market of space transportation systems.
The project particularly fits within the ESA Future Launcher Preparatory Programme in the context of new avionics technologies.

Large Debris Removal Mission in LEO based on Hybrid Propulsion

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During the last 40 years, the mass of orbiting artificial objects increased quite steadily at the rate of about 145 metric tons annually, leading to a total of approximately 7000 metric tons. Now, most of the cross-sectional area and mass (97% in low Earth orbit, LEO) is concentrated in about 4500 intact objects, i.e. abandoned spacecraft and rocket bodies, plus a further 1000 operational spacecraft [1]. Simulations and parametric analyses have shown that the most efficient and effective way to prevent the outbreak of a long-term exponential growth of the cataloged debris population would be to remove enough cross-sectional area and mass from densely populated orbits. According to the most recent NASA results, the active yearly removal of approximately 0.1% of the abandoned intact objects would be sufficient to stabilize the cataloged debris in LEO, together with the worldwide adoption of mitigation measures. The typical targets for removal would have typical masses between 500 and 1000 kg, in the case of spacecraft, and of more than 1000 kg, in the case of rocket upper stages [1].

This paper investigates a space mission concept for multiple active removal of large debris objects from LEO, as well as related technological and operational issues. The investigated concept relies on flying a multi-removal space platform carrying a number of Hybrid Propulsion Modules (HPMs) to dock with pre-selected targets, according to a prefixed removal sequence. Each target is then de-orbited in a controlled way by firing the attached HPM package. Alternatively, the partial contribution of the atmospheric drag could be exploited to perform altitude lowering. In this respect, the primary propulsion system of the multi-removal space platform could be used to leave the debris into an orbit where the atmosphere effect is significant, and a HPM could be then used for the atmospheric reentry. This scheme could allow propellant saving due to the exploitation of the natural decay. With reference to the mission concept, particular attention will be given to multiple removal feasibility analysis. In addition, technological and methodological solutions relevant to mission and system aspects, such as debris rendezvous, capture and de-orbiting, will be identified and discussed.

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Evaluation of main parameters in re-entry trajectories

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The selection of the descending path in atmosphere for re-entry vehicles presents serious challenges for the designer. Basic requirements in terms of flight mechanics, dealing with initial and terminal conditions, have to match strict requirements related to the survivability of the re-entering body, in terms of structural integrity as well as in terms of thermal input and accepted temperature raise. The possibility of aero-braking assistance, obviously allowed only if the targeted celestial body is surrounded by an atmosphere, increases the degrees of freedom available to the designer. The paper focuses on this special case, which is also (Earth, Mars) the most important one, looking for an evaluation of the critical parameters (maximum load factor, maximum thermal flux) with respect to the flight dynamic parameter of the trajectory.

The initial step is represented by a procedure proposed by Broglio[1] to approximately identify the initial conditions for suitable descent trajectories as function of a limited number of parameters, namely the load factor and flight path angle at the deceleration peak and the lift to drag ratio. The solutions do not depend on the shape of the body, and the approximations involved are quite reasonable, as shown by a comparison with purely numerical integration[2]. Furthermore, the obtained solutions enjoy a similarity character, allowing the researcher to evaluate different possible trajectories with respect to the engineering-meaningful parameters which are the real drivers of the capsule design.
The present papers builds on this approach by modifying the analytical process to improve the confidence in obtained results and to better handle the flight phases close to the deceleration peak, which are the most critical ones. It can be remarked that one of the key parameters in the original approach was represented by the angular momentum of the descending probe. This parameter can be expanded as a series of the radius at which the deceleration peak is attained. Back-substituting this expansion in the original relations, the obtained integrals allow to more precisely compute the trajectory, while the core of the approach, leading to a quick and easy analysis of the behaviour of the key parameters is maintained, and even better exploited by using symbolic calculus to generalize and speed-up the mathematical steps. Thermal flux and total heat input are promptly evaluated. Some test cases, dealing with both Earth and Mars missions, are considered in order to show the advantages of the proposed approach.

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VEGA FPSA, a Configurable Multi-Mission Flight Software

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VEGA is a multi-payload/multi-mission capable small launcher developed in Europe by ELV under ESA contract, having the Italian Space Agency as major contributor. It performed its maiden flight in February, 2012. After this flight the Flight Program SW was re-developed from scratch as an Italian development, always supported and funded by the Italian Space Agency, with the aim to include in the SW the multi-mission capabilities already provided by the launcher.
With this goal in mind, the VEGA SW department designed a "new concept" FPSA in which the SW can be re-configured in short time to fit the complete mission ranges of VEGA. Its core is the mission timeline, a configurable table-driven state machine that defines the SW operating modes' sequence for each mission and the actions to be performed in each state (for launcher and GNC management).
The GNC (Guidance Navigation and Control) component is included into this SW as a separated library with defined general interfaces towards SW. Like the SW part, also the GNC is a highly configurable module, in which the mission is "designed" according to the specific needs of the customer, enabling or disabling the operative modes defined in the timeline.
GNC missionization allows coping with different trajectories, orbit inclinations, altitudes, PL characteristics (mass, inertia, stiffness, sloshing modes) and specific mission requirements, such as sun lighting, injection accuracy, visibility, re-entry impact zone.
In this paper a presentation of the main steps of the SW configuration and GNC missionization process will be given, demonstrating the extreme flexibility of the new SW developed for VEGA, and flown with success on May, 2013 for the first commercial flight of the launcher.

Keywords: VEGA, FPSA, GNC, Launcher

Flight Control Research Laboratory Unmanned Aerial System Wind Shear On-Line Identification

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This work addresses the on line identification of the wind shear components by using flight data. These ones are obtained during specifically devoted flight tests performed by means of the research aircraft FCRL (Flight Control Research Laboratory) used for the Italian National Research Project PRIN2008 .The studied vehicle which is an unpressurized 2 seats, 427 kg maximum take of weight aircraft is equipped with a research avionic system composed by low cost sensors and computers and their relative power supply subsystem.

A nonlinear mathematical model of the subject aircraft longitudinal dynamics has been tuned up through semi empirical methods, numerical simulations and ground tests. Either longitudinal, normal or angular accelerations due to wind shear have been included into the equations of motion without any restrictive hypothesis on the wind shear dynamic. In this way the augmented state vector to determine is $\mathbf{x} = [V, \alpha, q, \theta\ \dot{w}_g, \dot{V}_{gx}, \dot{V}_{gz}]^T$.

The identification problem addressed in this work has been solved by using the Filter error method approach. The set of unknown parameters to evaluate has been made up of the process noise covariance matrix elements. To settle on the covariance matrix of the measurement noise the actual characteristics of the installed instrumentation has been employed. An algorithm has been implemented to determine on-line the wind shear accelerations. To take into account either model nonlinearities or the presence of nonmeasurable process noise an Extended Kalman Filter has been implemented to propagate the states. Robustness of implemented algorithm has been verified by means of several tests.

The obtained results show the feasibility of the tuned up algorithm. In fact it is possible, by using a few numbers of low cost sensors, to estimate with a noticeable accuracy the augmented state vector. Besides a very short computation time is required to perform the augmented state estimation even by using low computation power. Therefore the implemented algorithm is very suitable for the UAS characteristics. The estimated variables may be used to the implementation of the guidance and control algorithms taking into account the atmospheric turbulence. Wind shear detection on-line could contribute to an efficient safe insertion of UAS in the Civil Air Transport System. In fact it is possible an autonomous reactive motion planning where the vehicle's control system detects previously unknown disturbance, designs a new path in real time, and continue the mission. Besides, by using the tuned up procedure to determine the process noise covariance matrix in case of failure on one or more control devices, it will possible the reconfiguration of the control system in order to ensure fault-tolerant operations.

Aerodynamic Performance Analysis of Three different Vehicle Concepts at Hypersonic Speed

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This paper deals with the aerodynamic performance analysis of three different winged re-entry vehicle at Hypersonic speed. The concepts under investigation, shown in Fig.1, belong to different vehicle configurations, ranging from winged blunt, rather sharp and spatuled body architecture. Both engineering-based and CFD methods have been considered to assess vehicle aerodynamics in the framework of a trade-off analysis. Indeed, thermo-chemical non-equilibrium CFD simulations, with the air modelled as a mixture of five species, are performed at several flow conditions compatible with a typical RLV re-entry trajectory, according to the space-based design approach.[1] The range between Mach 2 and Mach 25 was analysed. A summary review of the concept aerodynamic characteristics, including longitudinal and lateral-directional stability, is performed and reported in the paper. [2]

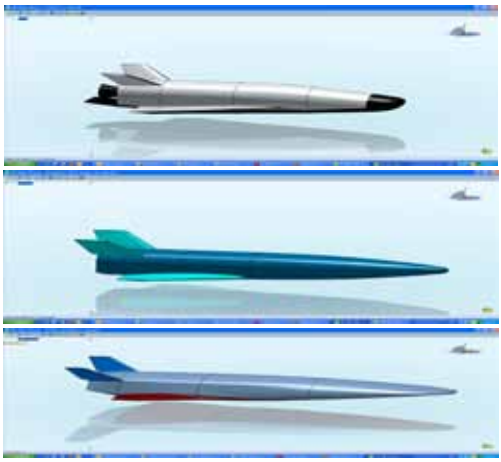

Figure 1. Re-entry vehicle concepts

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What is next in human exploration

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The future of Space Exploration exhibits three aspects: 1. The Mission 2. The Technologies 3. The Market (MTM).
As far as the Missions are concerned it is an easy guess to foresee that exploration to solar planets will be made, what is completely unknown is the time scale (i.e. mid-term or far in the future). The uncertainty is also due to the fact that these missions are somehow linked to the development and to the implementation of new Technologies (like nuclear propulsion and ram/scram jets).
The Markets are of two kinds: 1. Space Agencies, for scientific exploration (e.g. Moon, Mars and asteroids, according to NASA planning) and 2. Space Tourism. Each of these Markets are characterized by different motivations, utilizers, budgets, time scales.
The scientific Market is the one that drives the progress in Space by selecting "impossible" missions (as, for instance, Man on the Moon in the sixties) and achieves them by developing new technologies. The Space Tourism Market, on the contrary, goes wherever one "can" go. Here "can" means to make use of available vehicles, propulsion systems and existing H/W and S/W.
When asking what next in exploration one should bear in mind all the three aspects of the MTM. The most difficult choice is the selection of the short-term scientific exploration due to the objective difficulties for the very appealing Mars mission and due to the lack of appeal of going back to the Moon or exploring asteroids. Space Tourism will be consisting mainly to going back and forth from LEO to ground.
According to the author both the scientific and tourism activities in space exploration will be based on two cornerstones: 1. A new ISS (orbital workshop) and 2. A reentry vehicle (from LEO to ground). The first infrastructure will allow to prepare, refurbish and assemble interplanetary vehicles in LEO and to host Space Tourists. The second must ensure a safe and comfortable transport of humans back to Earth.
In recognition of the above one should select what is next not on the basis of specific new and too demanding missions (too far in the future) but on what will be the necessary items operating in the future scenario. In particular a new reentry vehicle able to fly along the last leg of any space exploration mission. The last part of the reentry vehicle trajectory is the most critical in terms of risks and discomfort and could be improved by proposing a new modality of reentering the Earth atmosphere.
A "low risk reentry vehicle" (that represents the final stage of any exploration vehicle) has been considered (at the level of feasibility study) characterized by a low wing loading (in the order of 100 kg/m^2), a high L/D (sharp leading edges) and by the ablity to fly at higher altitudes (compared to Shuttle) in order to reduce the critical heat fluxes to the vehicle. This vehicle is able to glide to ground and land like a conventional airplane on a relatively short runway. Main features of this vehicle are shown in the paper.
In summary the logical choice on what to do now for Space exploration is start working on the components that will necessarily be employed in any possible future Space exploration mission.

A FEM piezoelectric beam model for damping circuit analysis

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In this work a finite element, developed for straight generally layered smart beam, is used to investigate vibration damping capability of circuit elements. First, the electric state is analytically condensed to kinematical quantities and the mechanical model is then written for shear deformable Timoshenko's beam including the effects of electro-elastic couplings stacking sequence. The contributions of the external electric loads on both the equivalent stiffness properties and the equivalent mechanical boundary conditions are also taken into account. Hermite shape functions, which depend on parameters representative of the staking sequence through the equivalent electro-elastic stiffness coefficients, are then obtained for the beam primary variables. Starting from the weak form of the governing equations and by expressing the kinematical quantities in terms of virtual and actual nodal variables through the obtained shape functions, the definitions of the element mass and stiffness matrices as well as of the equivalent force vector are obtained. It is found that the electro-magnetic boundary conditions are transferred to the FEM representation as work-equivalent axial and bending nodal actions. The State Space representation is then invoked for the assembled smart beam FEM model to favour its implementation using a system conceptual approach. The piezoelectric layers are considered as the electrical current source of the damping circuit which, in turn, controls the amount of difference of electric potential applied on the piezoelectric layers by means of its impedance. Eventually, a cantilever smart piezoelectric-cross ply graphite epoxy laminated beam undergoing a step load at its free end is analyzed. The piezoelectric layers are connected to a resistor R to obtain broadband damping characteristic. Results are reported in figure 1 in terms of beam tip deflection, normalized with respect to the static one, and actuating voltage generated by the smart beam-circuit system.

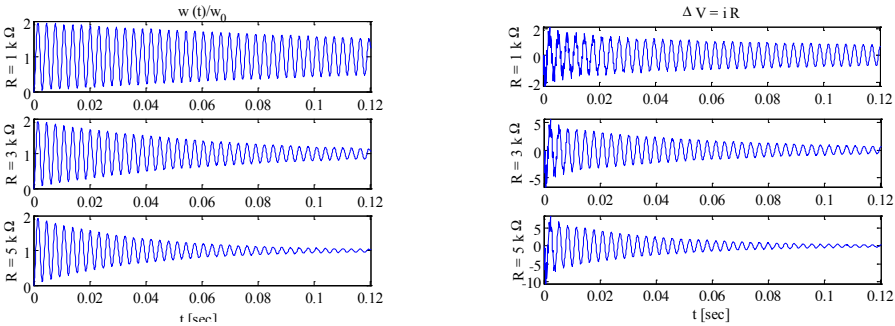

Figure 1. Transient response of [$BaTiO_3$/0/90_2/0/$BaTiO_3$] beam. (left) normalized beam tip deflection; (right) actuating voltage.

FEM design and prototyping of the CFRP sandwich airframe for a hexacopter

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This study concerns the FEM design and the prototyping of the airframe for a hexacopter. This drone belongs to 15 Kg category and it is able to carry a payload of about 4 Kg for about 30 minutes. Its propulsion system consists of six brushless electric direct drive motors, each as 60-size glow engine. There are three couples of counter rotating propellers of 18 inches diameter. It can be used for different applications, but its main purpose is landscape monitoring and surveying by high-resolution cameras and a 3D laser scanner. [1]

The airframe is designed as a six point shaped star and its diameter is about 1.2 m. It is made up by a composite sandwich configuration characterized by two CFRP skins and closed cells foam core. A solid 3D CAD model has been created to be implemented in a FEM code and in a CNC manufacturing procedure to realize the final shape of the mould. [2]

The goal of this study is to achieve the best layup configuration to optimize the weight and stiffness of this component. Several loading conditions acting during the flight have been simulated. In particular, not only the hovering has been assumed, (when the total propeller thrust equals the weight and loads are symmetric), but also the manoeuvred flight, (when the drone is subjected to unsymmetrical loads). This study is performed by commercial FEM code: ANSYS V14.5 [3] and its new tool ACP [4] (Pre-Post Composite).

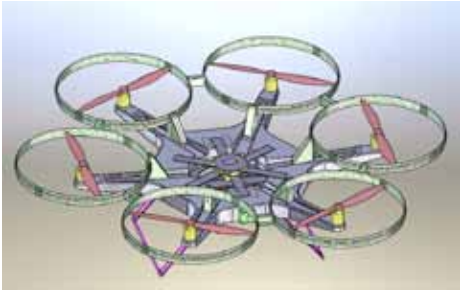

Figure. Hexacopter

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Aerodynamic and Aerothermodynamic of the USV3 Re-Entry Vehicle

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In the last ten years, CIRA is being involved in many research activities related to re-entry systems technologies in the frame of national and international programs. Two of main topics covered are Aerodynamics and Aerothermodynamics with both numerical and experimental approaches thanks to in house developed CFD code, in-flight tests and PWT facility.
Actually, the USV3 project is ongoing to design and to develop an autonomous, unmanned space vehicle able to perform an end-to-end mission from launch, on-orbit operations, re-entry and landing on conventional runway, shown in Fig.1.

Figure 1. The USV3 vehicle

The paper reports on design analysis accomplished to assess the aerothermal environment the vehicle experiences during descent. CFD analyses have been carried out to address flowfield past the concept and surface distributions, e.g., heat flux and pressure, for TPS design scopes. A summary of the USV3 aerothermodynamic characteristics has been provided at several points of design trajectory, according to the Trajectory-Based design approach. The code H3NS, developed at CIRA, was used to perform the CFD analysis with different flow modeling ranging from laminar to turbulent and thermochemical non-equilibrium to equilibrium conditions together with engineering tools. Some preliminary CFD results are provided in Fig. 2.

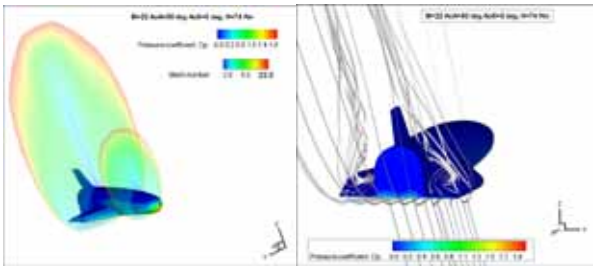

Figure 2. Mach number on vehicle cross sections and Cp on USV3 surface with streamtraces at H_∞=74 km, M_∞=22 and α=50 deg (peak heating conditions).

Development of a One-directional Stiffness Element for the Fish Bone Active Camber Mechanism

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This work details the design, modelling, and experimental validation of a novel one-directional stiffness element for the Fish Bone Active Camber (FishBAC) concept. One of the primary challenges in designing morphing aircraft structures is the paradox of simultaneous stiffness and compliance. The structure must be soft enough to be easily deformed by the actuation system, yet stiff enough to not deform excessively under aerodynamic and structural loading once morphed. In this paper, a one-directional stiffness element is proposed for the FishBAC which addresses this dilemma by increasing the stiffness under external loading without increasing the internal stiffness the actuator must overcome. The FishBAC concept uses a biologically inspired, highly anisotropic internal bending beam spine and a pre-tensioned elastomeric skin surfaces to create a compliant trailing edge capable of large camber changes.[1] The morphing deformations are induced by a pair of antagonistic tendons attached to the trailing edge. Inclusion of a non-backdriveable mechanism between these tendons and the actuator creates a system which exhibits one-directional stiffness due to the ability of the actuator to drive the tendons but the inability of the tendons to drive the actuator. The design of a worm gear based non-backdriveable mechanism that can fit within the geometric constraints of a representative airfoil and carry the required torque levels will be discussed. An analytical model of the one-directional stiffness element is combined with a finite element model of the FishBAC structure, and is used to predict the impact on external stiffness of several potential design configurations. These predictions are then compared to experimental stiffness results from a prototype of the most promising configuration. The automatic locking behavior of the non-backdriveable mechanism is also experimentally verified.

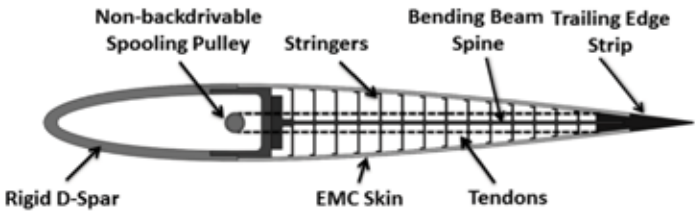

Figure 1. Fish Bone Active Camber Concept.

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Handling of ionospheric delays for Carrier Phase Differential GPS in LEO formation flying

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Carrier-based Differential GPS (CDGPS) is a promising technology for the relative positioning of Low Earth Orbit (LEO) satellites flying in formation. The capability to achieve high accuracy by CDGPS is based on the possibility to exploit the integer nature of DD carrier-phase ambiguities. However, as the separation among the satellites increases, the correlation of ionospheric delays among the receivers decreases[1]. As a result, DD GPS observables are affected by significant errors that complicate the integer resolution task. This paper investigates the effects of different strategies for ionospheric delay compensation on the accuracy in the relative positioning of GPS receivers in LEO over long baselines.

Several approaches exist in the literature for dealing with ionospheric delays. In high accuracy, post-processing applications with dual frequency data[2], the DD iono-delays are estimated within a dynamic filter, e.g. the Extended Kalman Filter (EKF), and are modeled by very simple stochastic models, typically using random walk processes in the filter's state vector. As an alternative, delays are modeled by Lear's model[1],[3], which allows relating the *n* slant ionospheric delays to the Vertical Total Electron Content (VTEC) above the receivers. Even though modeling of the ionospheric delays helps to increase their observability, and thus to aid in the ambiguity resolution task, Lear's model is known to be structurally capable of reproducing actual iono-delays only to a limited extent.

In this paper, a completely ionospheric-free approach is pursued, in which the ionospheric delay are canceled out by combination of dual frequency GPS measurements. Several alternative combinations are investigated based on the ionospheric-free combination of pseudorange and carrier-phase observables, but also and on group and phase (GRAPHICS) and Melbourne-Wubbena combinations.

Based on a relative positioning technique previously developed by the authors[3],[4], the performance of each approach is quantified over real-world spaceborne GPS data made available by the Gravity Recovery And Climate Experiment (GRACE) mission.

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Vessel traffic monitoring in the new Artic routes

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The National Snow and Ice Data Centre (www.nsidc.org) has widely showed the reduction of Artic ice: a large area of open water has started to form around Franz Josef Land and north of Svalbard and Polynyas, i.e. irregular areas of open water, are also appearing in the Kara and East Siberian seas. The Artic sea ice decreases its extent with -2.3 percent per decade linear rate and the current value is the seventh lowest of values recorded by satellites. The melting of Artic sea, mainly due to climate changes, is also leading to potential industrial boom for the Artic regions, both in terms of energy production and good transportation. The interest, both political and economical, of nations is high, since the route through the Bering Strait between Alaska and Russia is 40% shorter than the southern route through the Suez Canal. Consequently, the number of ships using the route is increased from 4 in the 2010 to 46 in 2010 and on December, 2012 the Gazprom, the Russian energy company, did the first delivery of liquefied natural-gas across the Artic.

The 2012 report of Alaska Legislature's Northern Waters Task Forces poses the accent on the risks related to the increase of vessel traffic in the Artic regions (www.mcclatchydc.com), in terms of spills, pollutants, collisions, and such risk is high due to the lack of detailed navigational charts, vessel traffic protocols and search and rescue infrastructure. In this frame, the Marine Exchange of Alaska (www.mxak.org) has built up the Automatic Identification System (AIS) vessel tracking model in Alaska. The AIS is an automatic vessel tracking system based on ship transmitter and on-ground receiver. Currently, there are 90 AIS sites around the Alaska coast and 338 ships have been observed passing through the Bering Strait in the 2010. Unfortunately, the coverage region of AIS receivers is limited and the offshore region are not covered by such service.

The International Telecommunications Union (ITU) has investigated the possibility to receive AIS signal from space since 2006 in order to expand the capability, currently limited nearby the coast, for offshore ships. Since then, other international projects have studied such problem.

With this background, the study of spaceborne AIS system will be performed and the synergy with spaceborne remote sensing will be evaluated, to guarantee adequate coverage of high strategic regions, such as Artic sea, and also to help the birth of search and rescue infrastructures.

Aerothermal analysis of an Aircraft Nacelle in the Framework of a Fully Coupled Approach

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The integration of a powerplant into an airframe, made largely of composite materials, presents challenges in the thermal and ventilation design of the engine nacelle. In fact, high fidelity, fully coupled, "aero-thermal" models must be addressed in the design process.
In this framework, the paper reports on a thermo-fluid-dynamic analysis of the flowfield past an aircraft nacelle (fig.1) equipped with a small turbine engine. The engine type is a pusher one.
The Computational Fluid Dynamics (CFD) simulations couple flow and thermal fields, solving the thermal conduction inside the nacelle wall due to the presence of a hot body represented by the engine and taking into account also for the cooler air flow entering the nacelle intake. Both convective and radiative (coming from hot engine) heat transfer are considered with proper boundary conditions as wall temperature fixed at engine surface and convective heat exchange between the nacelle and the external flow at freestream temperature. Engine nacelle (fig.2) was simplified by removing all items that do not contribute to heat transfer, due to size or temperature, as conduits, wires, screws and bolts. Simplification of the geometry has been done by the Rhinoceros 5 CAD while, for the mesh generation has been used Ansys Icem 14, which realizes also unstructured mesh.
Three-dimensional calculations were performed by solving the Reynolds Averaged Navier-Stokes (RANS) equations with a commercial CFD code, Ansys Fluent 14, which uses the finite volume method. The pressure-based solver was used and to modeling turbulence the standard k-ε model was employed. In addition, the radiative exchange between engine and nacelle was also taken into account, by using the Discrete Ordinate model available in Ansys Fluent 14.

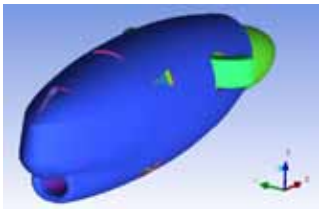

Figure 1. Nacelle

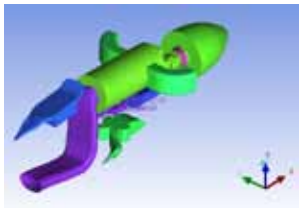

Figure 2. Interior nacelle

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General methodology for demonstration mission design

D. Cardile[1], S. Chiesa[1], N. Viola[1] and M.A. Viscio[1]

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Future human exploration programs point towards new and more challenging objectives. The exploration of Moon and Mars requires new technologies that shall be developed to have them available in the future. ESA defines the maturity level of a technology (or Technology Readiness Level - TRL) on a scale of 1 to 9 [1]. A system is considered flight-qualified if the TRL is 8, i.e. the system has completed a demonstration mission in the space environment. The paper deals with the description of the methodology for the design of the demonstration mission.
Figure 1 shows the developed design methodology. First the technologies, which are necessary for future human exploration and need to be tested, are selected. Then, technologies TRL is assessed according to the European standards. Thus, all the necessary activities necessary to increase the TRL and including analysis, experiments, breadboard/prototype development and tests are identified and planned. The demonstration mission design activity starts after that the performance requirements for the technologies are defined. Thus, the set of possible mission scenario options is defined and the trade-off activity is performed to choose the most cost-effective solution. The trade-off are performed considering mass, cost, design complexity and risk level indexes. Finally, the detailed description of the demonstration mission(s) is provided through a complete set of requirements.

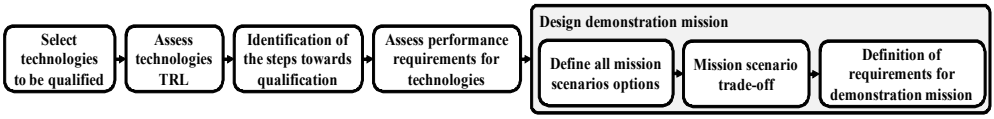

Figure 1. Design methodology

The developed design methodology and the results obtained by the methodology application have been obtained in the framework of STEPS - 2 (Sistemi e Tecnologie per l'EsPlorazione Spaziale – Phase 2). STEPS - 2 is a research project co-founded by EU on the "Misura Piattaforme Innovative" - Phase 2 of POR FESR 2007/2013.

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Wind-Tunnel Rotor Model For Hover And Forward Flight Tests

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Aerodynamics plays a fundamental role in rotary wing aircrafts (e.g. helicopter and tiltrotor) and have an high influence on their performance in all the conditions of the flight envelope. Both in the design and in the analysis of this kind of aircrafts, the designers require considerable knowledge of the aerodynamic environment in which the whole machine, and especially the rotor, operates. In this frame, a research activity is currently underway at Politecnico di Milano to study the aerodynamics of rotors in hover and forward flight conditions.

An experimental test rig, represented by a fully articulated helicopter rotor, has been realized and it allows to study different kinds of rotor blades. The rotor hub had four blades and it is powered by an hydraulic motor (maximum power 16 kW at 3000 rpm). The thrust and the others aerodynamic forces given by the rotor has been measured by a six-component strain gauge balance located under the rotor hub while the torque has been measured by an instrumented holed shaft directly linked to the rotor hub shaft. Under the instrumented shaft, a flexible joint has been used to avoid the transfer of forces to the lower part of the transmission shaft. To measure the pitch, led-lag and flap angles on the rotor hinges, Hall effect sensors have been employed. In this work, four untwisted and unswept blades have been used for the measurements. The blade has constant chord of 0.06 m and its sections are represented by a NACA 0012 airfoil. The internal radius of the blade is 0.20 m while the external radius is 0.80 m.

Experimental results have been compared with numerical calculations that have been performed by a code based on the Blade Element Momentum Theory[1] (BEMT). The code extracts interpolated values of lift coefficient C_l, drag coefficient C_d and pitching moment coefficient C_m, for a wide range of angles of attack, Reynolds and Mach number previously stored in tables[2]. The aerodynamic solver includes wake swirl effects[3] and Prandtl's tip-loss function[4] to compute aerodynamic loads of the rotor in a given flight condition. A good agreement between experimental and numerical data has been found in different flight conditions.

Figure 1. Hover test rig: view of the rotor hub.

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The three-dimensional swirling flow past a sudden expansion

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The unsteady flow after an abrupt expansion, under some conditions switches intermittently between two states: quasi-axisymmetric expansion and gyroscopic-like precessing motion[1]. Here we present an experimental analysis carried out by means of Tomographic PIV[2]. The self-excited flow precession generated by a 5:1 expansion of a round jet in a cylindrical chamber is investigated. The experiments are performed at a fixed value of the Reynolds number of 150,000. Proper Orthogonal Decomposition[3] is applied to extract information on the organization of the precessing motion. This technique highlights the presence of three most relevant modes: the first two are 90° phase spaced and are associated to the jet precession; the third one is associated to the axial motion. The precession frequency is extracted using a Low Order Reconstruction[4] using only a subset of modes (containing the largest part of the energy of the flow field). The jet precession is responsible for swirling flow in the jet shear layer; stability analysis[5] shows as the instability of the axial shear layer is responsible of the generation of helical shaped vortices which characterize the instantaneous flow topology.

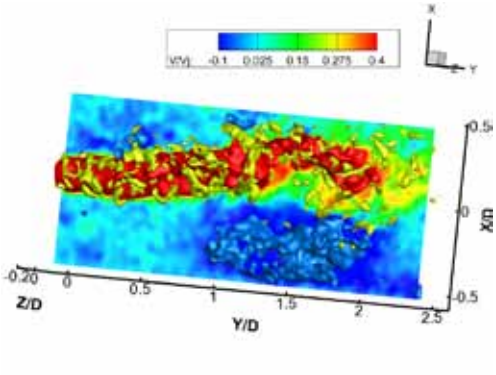

Figure 1. Contour representation of the longitudinal velocity component V/V_j on the middle plane of the measurement volume.

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A Quaternion based Mathematical Model and Control of a Hexacopter

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The main topic addressed in this talk is the quaternion-based trajectory control of a microcopter, consisting of six rotors located on the vertices of a hexagon characterized by the use of three pairs of counter-rotating fixed-pitch propellers. It is well known that UAVs technology is rapidly growing up for both military and civil application [1, 2]. Among UAVs, quadcopter configuration, that refers to a multicopter propelled by four rotors, is the most popular choice for indoor and outdoor flights thank to their manoeuvrability and small dimensions. On the other hand, the design of UAVs with more than four rotors, i.e. hexacopter and octocopter, is nowadays developing due to the further possibility of managing one or more engine failures and increasing the total payload, [3, 4].
Thus, in the present paper a hexacopter is considered and by assuming the drone as a rigid body, it is well known that the differential equations describing its dynamic behaviour can be derived from the Newton-Euler equations. The usual Euler-angle parameterisation of three dimensional rotations is here replaced by the quaternion formulation in order to avoid the so–called gimbal lock. Moreover, the strength of quaternions depends on the linearity of their formulation, on the easiness of their algebraic structure and, overall, on their stability and efficiency. Once the mathematical model is obtained, an original PID control technique is implemented in order to manage the UAV trajectory. This efficient and fast algorithm represents the development of the PD controller presented by Alaimo et al.[5]. Several numerical simulations are performed on different flight configurations, proving the reliability of the mathematical model and of the PID controller proposed.

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Three-dimensional organization of the flow structure in an aero-engine lean premixing prevaporized burner

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An investigation of the three-dimensional flow field of a turbulent swirling jet [1] at Re=50*10^3 generated by an aero-engine injector for lean premixing prevaporized burner [2] is carried out with tomographic particle image velocimetry. This work is focused on the organization of the coherent structures arising within the near field of the swirling jet both in free and confined configurations. The confinement causes an increase of the swirl number: the measured values are equal to 0.90 and 1.27, respectively for free and confined swirling jets. The effects of the confinement induce a larger spreading of the swirling jet promoting the enhancement of turbulence at the nozzle exit, but the expected upstream displacement of the reverse flow stream is not observed. The instantaneous flow field is characterized by the presence of the Precessing Vortex Core (PVC) [3], of the outer helical vortex and of smaller turbulent structures developed both in the inner and in the outer shear layer. A three dimensional modal analysis of the velocity field using the Proper Orthogonal Decomposition (POD) [5] highlights that the flow is dominated by the precessing vortex core. Using the first two POD modes a low order reconstruction of the velocity field is calculated. It is found that, the small-scale structures shown in the instantaneous velocity field are not captured in the low order reconstruction causing a smoothing effect, but the precessing vortex core and the outer helical vortex are properly represented.

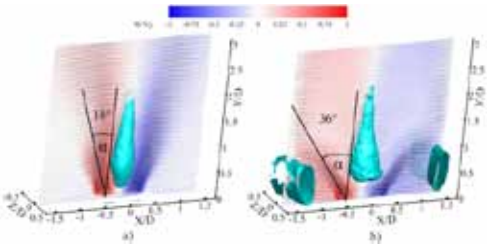

Figure 3 Iso-contours with velocity vectors of the mean velocity maps W/V_j on the plane Z/D=0 and iso-surface of axial mean velocity V/V_j for the free swirling jet (a) and the confined swirling jet (b).

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Mars Dust: CIRA answer to the challenge "Seven minutes of Science" for the International Space Apps Challenge

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On April 20-21, over 9,000 people around the world participated in the known galaxy's largest mass collaboration ever - the International Space Apps Challenge.
Over 40 countries hosted events, and participants came from across the planet to propose ideas for the 50 challenges proposed. Italian event was hosted in Rome by Università la Sapienza.
The challenge chosen by CIRA people is named "Seven minutes of Science" and aims to use for scientific purposes the inert mass ejected by MSL to offset its centre of gravity before atmospheric entry and then rebalance its centre of gravity after atmospheric entry.
The proposed idea is to collect data and dust particles from Mars atmosphere using an aerogel plug inserted in the nose of the re-entering mass and Quartz Crystal Microbalances on the back of it. The objectives of the experiment are:
1) Collect dust particles and store them for an undefined time, for future recovery. (Main)
2) Acquire acceleration, temperature and pressure data during the flight and store them in a solid state memory for future recovery. (Secondary)
3) Transmit acquired data to one of the Martian assets for final transmission to Earth. (Tertiary)
To fulfil the main objective it is mandatory to find and recover the capsules. A possible solution is to implement a radio beacon able to survive the landing and able to transmit a signal that can be received by orbiting satellites.
Second mandatory requirements is to preserve the aerogel insert, preventing contamination at the landing. The proposed solution is to equip each capsule with aerodynamic surfaces that, once deployed, move the centre of pressure in front of the centre of mass. This shall force the capsule to fly upside down, and impacting the surface with the back, preserving the aerogel insert. The deployment shall be triggered by the melting of a restrain and shall be actuated by a spring.

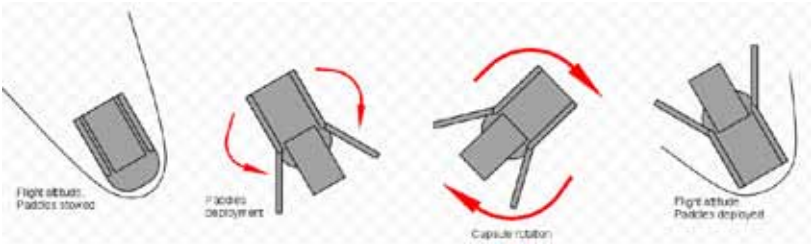

Figure 1. Capsule concept

Evaluation tests on Self-Healing ionomers for space applications

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The ability of some materials to self-repair is a characteristic particularly important for applications in remote or hostile environments, where an external intervention is nearly impossible. An example of such conditions is given by space environment. The development of Self-Healing (SH) materials suitable for space applications could remarkably improve spacecraft performances and liability as well as mission duration. Materials have been developed, which present self-healing capability under defined ballistic conditions. In particular, polymers based on copolymeric ionomers show intrinsic SH capacity, being able to repair themselves immediately after a ballistic damage.

This work is aimed to a preliminary evaluation of possible employment of polyethylene-co-methacrylic acid based ionomers in space environment. The SH capability was studied through hypervelocity impact tests on flat panels in order to simulate the collision with micrometeoroids and debris. Different configurations were considered by varying sample thickness and projectile speed. Aluminium spheres of 1.5 mm in diameter were used as bullets. In the tested conditions, full or partial hole closure was observed. It is interesting to note that, in the same conditions, remarkably large damages are produced by impact on aluminium plates. Healing efficiency was evaluated by leakage tests by applying a pressure difference through tested samples. Observation of samples with a scanning electron microscope and morphology analysis of impact areas were subsequently performed.

For actual applications, the material resistance in space environment should be assessed. When exposed to high vacuum for long time period, polymers may exhibit considerable mass reduction due to loss of volatile substances; this can significantly affect material properties, thus posing a severe limit to its employment in space. Thermal outgassing tests were performed using a high vacuum chamber to investigate the ionomer behaviour in space environment. Quite limited mass losses were detected after the tests. The stability of the material when exposed to UV radiation was also tested.

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Simulation of damage and crack propagation in structural materials with the Peridynamics theory

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Bond-based peridynamics is a non-local continuum theory that formulates problems in terms of integration of interactions between material points[1]. Since the presence of cracks in a solid represents a discontinuity in the material, the classical theory of solid mechanics, based on partial differential equations, presents many difficulties when applied to such problems.
When dealing with discontinuities, the classical finite element method has to be equipped either with interface elements[2] or with x-fem capabilities[3]. However interface elements can be used only if the path of the crack is known a-priori and the x-fem method does not seem to find easy application in 3D cases. Peridynamics is more general in the sense that the crack is free to appear in every part of the structure, following only physical and geometrical constraints, does not require any a priori assumption for the definition of its propagation and does not seem to be more difficult to apply in 3D than in the planar cases. The Peridynamics is also capable to manage multiple cracks interaction phenomena. The authors have developed a static implementation of the peridynamic theory which conserves the advantages of the original dynamic formulation but is not affected by the need of introducing spurious damping forces (like using dynamic relaxation techniques[4]).

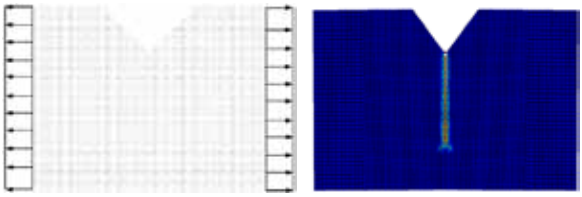

Figure 1. On the left it is shown a V notched plate subjected to a dynamic traction load. On the right it is show the crack propagation path: it is not needed none assumption to define the crack propagation or the crack initial location

The paper will present the basic formulation on which the static and dynamic implementation are based and several numerical examples, with different constitutive laws to illustrate the potentialities of the method.

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A non-linear model for in-plane shear damage and failure of composite laminates

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Advanced composite materials have become crucial in weight-sensitive applications such as aircraft and space vehicles. Material failure is a recognized critical aspect of composite laminates which present many forms of failure associated to the individual behavior of the lamina constituents (matrix and fibers) and to the mutual interaction of the laminae. Typically, composite material characterization is carried out by time-consuming and expensive experimental tests aimed at establishing strengths at both lamina and laminate levels. In this scenario, numerical analyses are believed to be a valid support to the experimental activity in order to reduce the number of tests and to gather, at the same time, knowledge about the interaction of the complex damage mechanisms that occur.

This paper presents a new numerical constitutive model to describe the markedly non-linear shear behavior of composite laminates. This model, together with a model for intra-laminar longitudinal/transverse failure behavior, has been implemented in an user-defined Fortran routine (UMAT) to be used within the non-linear FE code ABAQUS.

A numerical model of the ASTM Standard V-notched specimen shear test (Iosipescu test) has been developed in order to define the key parameters of the non-linear shear constitutive model. This has been achieved by means of a systematic comparison of the numerical results with experimental data obtained during a campaign for the characterization of a composite carbon-epoxy material at the Aerospace Structures and Materials Laboratory of University of Pisa. The material anisotropy and the geometry of the notch have been found to cause the shear strain field to be non-uniform in the notch section. This prevents a direct measure of the shear constitutive law, whose parameters must be alternatively evaluated through an indirect iterative procedure.

The tuned constitutive model has been used to evaluate the importance of in-plane shear phenomena in unidirectional tests on notched quasi-isotropic laminated coupons (Open Hole) manufactured from the same material system. In particular the numerical results are compared both with numerical data from a simplified linear version of the shear model and with experimental data in order to highlight the importance of the material non-linearities for reproducing the experimentally observed failure modes.

A ultralight amphibian PrandtlPlane: the final design

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The Idintos project, co-founded by the regional government of Tuscany (Italy), concerns the design of a ultralight amphibious PrandtlPlane and the manufacturing of a flying prototype. A consortium of universities and private companies participated to the project, coordinated by University of Pisa. The paper describes the general design of the aircraft, including aerodynamics, controls, propulsion, undercarriages, fuel system, interior design etc.
The aircraft presents a PrandtlPlane wing configuration in order to improve the aerodynamic efficiency and to enhance the safety with respect to stall and maneuverability.
The control surfaces (ailerons and elevators) are located on both front and rear wing so that the flight mechanics results different with respect to the conventional aircraft.
The solution adopted for the propulsion system consists of two ducted propellers that are set laterally on the fuselage. The flap system is made of Fowler flaps in the front wing and plain flaps in the rear one.
The interior design of the cabin has been oriented towards a better ergonomic position of the passengers while the dispositions of the commands wants to minimize the possibility of any human errors.

Figure 1. Idintos general layout

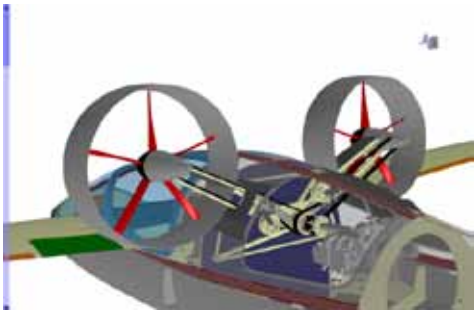

Figure 2. Particular of the propulsion system

The conceptual design of a new large freighter

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The worldwide commerce of the future, especially with growing countries, could be based on very large freighters for a point to point transportation. The paper discusses on a novel transportation system based on very large freighters moving along a set of cargo airports worldwide. The first part describes briefly the mathematical problem of optimizing the positions of a net of airport in order to minimize the transportation costs; a proper optimization model has been developed starting from some optimal location problems[1] in which the cost functional depends by both air and ground transportation. In general, the dependence of air transport may be non-linear with the transportation distance.
In the second part, the paper describes an aircraft configuration properly designed to transport standard ISO containers. The aircraft uses open rotors to reduce the fuel consumption and flies at lower levels. A conceptual design has been carried out considering the properties of existing open rotors. The aircraft is designed with a PrandtlPlane configuration in order to minimize the induced drag and reduce the front wing root thickness to cross the fuselage inside the cargo bay height.
An optimization process is developed in order to determine the best wing plan-form able to minimize the total drag and the Maximum Take Off Weight; in this contest, a preliminary evaluation of wing and fuselage structures and flight mechanics features has been taken into account as optimization constraints.

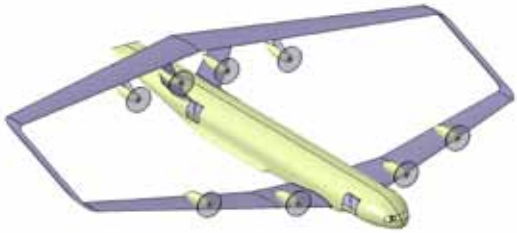

Figure 1. Conceptual layout of a large PrandtlPlane Freighter

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A ultralight amphibious PrandtlPlane: water tank tests on a scaled model

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The first part of the paper describes the design of a ¼ scaled model of a new ultralight amphibian in order to conduct water tank tests; the aircraft is designed according to the PrandtlPlane configuration. In the second part, the results of tests are discussed; different kinds of test have been performed in order to determine the behavior of the hull during the take off: "low speed tests" have been conducted to examine both the initial displacement phase and the transition to the planing one; the "high speed tests" determine the behavior at the highest speeds where hull's dynamics depends mostly on aerodynamics; finally, "stability tests" have been performed to exclude any instability phenomena (e.g. porposing) during the take-off.
The results are the measured forces from the interactions between water and body and, also, the kinematics of the body during the runs at different speeds. During the test runs at the INSEAN-CNR plants in Rome, the aerodynamic forces and moments relevant to the test speeds have been applied by means of actuators, dumping rigs and springs properly designed. Two configurations have been tested, characterized by different positions of the step; the results show that the dynamic stability of the aircraft when running on water are deeply dependent on the step position. More than 300 runs have been carried out with a an enormous amount of data collected; the test program is briefly described and the main results are presented.

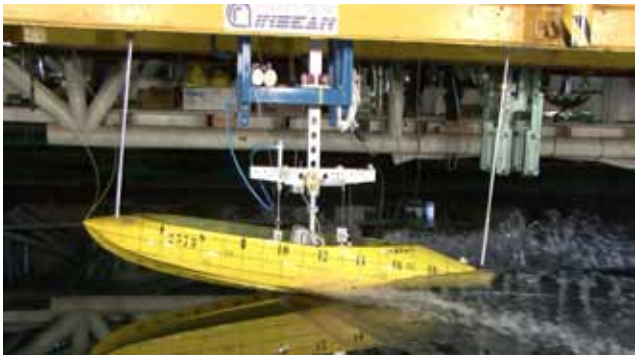

Figure 1. Scaled model during a run

A ultralight amphibious PrandtlPlane: wind tunnel tests

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The design of a PrandtlPlane amphibian is based on an aerodynamic optimization based on CFD and also on the wind tunnel tests on a ¼ scaled model; the tests were carried out at the Technical University in Milan.
In the first part of the paper the manufacturing of the model is described; the model is made of Ureol reinforced with internal steel bars. The lifting system is provided with Fowler flaps on the front wing and plain flaps on the rear one; the ailerons are positioned at the tips of both front and rear wings and contra-rotating elevators are positioned on both front and rear wings. The second part of the paper is devoted to describe the test method and the results obtained. The assessment of the aerodynamic derivatives are accomplished with stream visualizations with different methods. These results allow us to completely define the aerodynamic and flight mechanics characteristics together with the assessment of the limit stall conditions.

Figure 1. Model for the wind tunnel test, detailed design

Numerical validation of a new energetic fracture criterion in Elastic-plastic Fracture Mechanics for Aluminum Alloys.

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In Elastic – Plastic Fracture Mechanics the *paradox of Rice*[1] reflects the inadequacy of a Griffith – like energy balance as crack driving force; during a crack extension the rate of work done by the applied forces is converted into the rate of change in internal energy, so that no surplus energy is available to extend a crack. The paradox is the result of the classical assumption of continuum mechanics, for which stress and strain fields are singular almost at crack tip, while, elsewhere, are continuous. From a point of view of continuum mechanics, for quasi-static crack growth, a fracture criterion might be correlated to some critical condition of the plastic dissipation rate, evaluated as the difference between the rate of the external work and the change in elastic energy; along this line, several studies have been carried out in order to asses a fracture criterion on the basis of the energy dissipation rate.[2-4] However, recent studies of crack propagation problems[5] have shown that the energy dissipation rate depends on the applied load, crack length and specimen geometry, and, therefore, it cannot be considered as a material constant.

In the framework of continuum mechanics a fracture criterion can be restated on the basis of the energy momentum tensor, as shown in numerical studies of 2D crack growth problems[5,6]; in these studies CT specimens have been used, and elastic-plastic work-hardening material of Al2024-T3 has been considered. Under monotonic increasing load, the crack advances when a critical value of the trace of the energy momentum tensor is achieved. These studies show that the critical value of the trace of the energy momentum tensor is constant during the whole crack extension process, and it is independent of the applied load, specimen size, crack length. The results of these simulations show a very good agreement with experimental data. This criterion has been called P-approach.

In order to confirm the new criterion under a wide range of specimen geometry numerical simulations of crack growth in plane stress cracked panels have been carried out[7]; several CCP specimens of different size have been used and Al2024-T3 material have been considered. The results of the studies show that also in plane stress condition a critical value of the trace of the energy momentum tensor can be identified as a fracture parameter. Again a good agreement with experimental data is assessed.

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Adaptive control of nonlinear aeroelastic systems through recurrent neural networks

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Aeroelastic systems have the particularity of changing their stability behaviour with the flight conditions, i.e. the flight speed. In such a view, it is difficult to design a control law which is able to perform efficiently in very different circumstances. Moreover, control laws are tipically designed on linearized, low-fidelity models, and this fact introduces the need of scheduling control laws computed in different flight conditions. Obviously such a design process can be quite a burden, because of the high number of simulations required.
In this context the adoption of neural networks is a quite natural choice, since their adaptivity and fault-tolerance properties, they can be used as adaptive controllers in a wide variety of problems whose dynamics is influenced by fast-varying parameters. Thanks to such characteristics, the mentioned scheduling process is avoided, permitting a huge time saving in the control law design .
In this work recurrent neural networks are employed with the aim of suppressing the auto-excited oscillations of aeroelastic systems beyond the stability limit, identified by the flutter speed. Such oscillations can be divergent, as in the linear case, or bounded, if more accurate aerodynamic models are adopted.
The control law adopted is tailored on linear low-fidelity models through various test, and then is applied, without changing the computed parameters, to a higher-fidelity representation of the same system, represented in this work by a CFD modeling of the aerodynamics. The training of such a neural network is kept active during all the simulations, in order to achieve the required level of adaptiveness. The ability of such a control system is inferred on the BACT benchmark case, evaluating its robustness properties in front of changing parameters and flight conditions.

Generalized predictive thermal control of a thermal-vacuum chamber for space qualification tests

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This work aims at increasing the effectiveness and efficiency of the temperature control in the thermal-vacuum chamber available at the Department of Aerospace Sciences and Technologies of Politecnico di Milano (Milan, Italy). The chamber has a cylindrical shape with both diameter and height measuring 1 m. It is used for qualification tests of spacecraft components and small satellites (mainly cubesats). To this aim, high vacuum conditions (pressure values below 1E-6 mbar) are guaranteed using an air pump and a turbo-molecular pump in cascade. Moreover, the thermal control system is designed to simulate thermal cycles in the range -75 °C to 200 °C. Cold conditions are achieved through a serpentine cooling circuit, whereas the temperature is increased using either electrical resistances or thermal lamps.

Temperature control is currently regulated using a Proportional-Integral-Derivative (PID) controller. Unfortunately, PID regulators tend to be inadequate to control the temperature during qualification tests. More specifically, PID is tuned to effectively control the baseplate temperature of the chamber. However, temperature requirements are usually provided on specific points of the component to be qualified. In addition, each component to be tested has its thermal behaviour. Thus, transient duration and control accuracy strongly depends on the specific test, unless an exhaustive tuning of PID coefficients is carried out.

This work investigates the possibility of solving the above problems by applying the generalized predictive control (GPC) technique. GPC is based on a two-step procedure. First, linear system identification techniques are applied off-line to identify a thermal model of the overall system (including the thermal- vacuum chamber and the object to be qualified). Then, the control action is designed to minimize both the error with respect to the desired temperature profile and the cost of the control action. Thus, GPC is able to adapt to the specific conditions of the qualification test and to optimize energy consumption. In addition, system identification can be performed online to adapt the controller to system nonlinearities and possible variations of thermal behaviour.

The numerical and experimental results presented in this work confirm the adequacy of the GPC method to meet temperature requirements and adapt the control action to specific tests. The effectiveness of the method is assessed by comparing its performances with the traditional PID control strategy.

Numerical and experimental study of Fiber Bragg Grating sensors for Structural Health and Usage Monitoring Systems

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The interest of aerospace industries to Structural Health and Usage Monitoring Systems is continuously increasing. Among the techniques available in literature those based on Fiber Bragg Grating sensors are much promising thanks to their peculiarities in terms of shape and size of the Fiber Optic (FO), low invasivity if embedded in composite laminates, immunity to electromagnetic field, multiplexing capabilities and so on.[1] In the present paper different configurations of Bragg Grating sensors have been investigated. Starting from a numerical model able to simulate the spectral response of a grating subjected to a generic strain profile (direct problem), a new code has been developed, allowing strain reconstruction from the experimental validation of the program, carried out through a number of tests on a chirped grating.[2] The wavelength of the reflection spectrum for a chirped FBG has a one-to-one correspondence to the position along the gage section, thus allowing strain reconstruction on the entire sensor length. Tests conducted on the chirped FBG also evidenced its potentialities for SHM applications, if coupled with appropriate numerical strain reconstructions tools. Finally, a new class of sensors has been studied, Draw Tower Grating arrays.[3] These sensors are Applicable to distributed sensing and load reconstruction over large structures, thanks to their elevated length. Three configurations have been evaluated, having different spatial and spectral characteristics, in order to explore possible applications of such sensors to SHM systems.

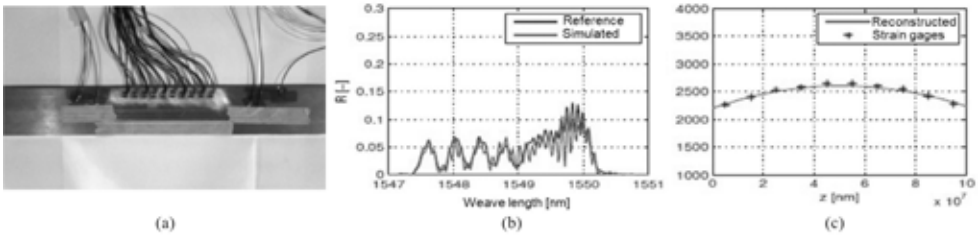

Figure 1. Metallic specimen equipped with 3 different DTG arrays and a standard strain gage chain (a); correlation between acquired and simulated spectra (b); reconstruction of strain profile.

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Multi-purpose Experimental Test-bed for Space and Planetary Exploration

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In this paper we present a test-bed built in collaboration between professors and students of Sapienza for experimental activities concerning the space and planetary exploration (Figure 1).
The work describes some applications of the test-bed and the results on the lunar landing, the lunar roving, the space optical navigation, and the capture of a non-cooperative space vehicle.

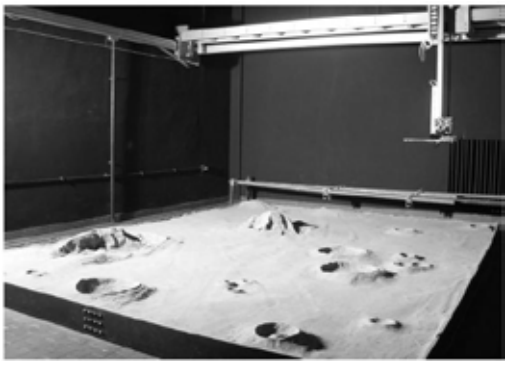

Figure 1. Multi-purpose Experimental Test-bed

The test-bed is composed by a Cartesian robotic frame with a platform on the End-Effector. The working space of the system is about 4x3x2 cubic meters. The platform, of 50x30 square centimeters, can carry payloads up to a weight of 5 kg. On the platform several sensors are mounted: a camera, an IMU, and two infra-red range sensors. These sensors are connected through a wifi net linked to the main control computer. A 7 d.o.f. robotic arm, with maximum total length of 50 cm, can be mounted on the platform in order to perform experimental tests for the capture of a non-cooperative space vehicle. An additional structured-light device is used in the test-bed to identify the geometrical parameters of an unknown object, similar to space debris, in order to test proximity GNC algorithms. A simulated lunar soil is placed on the floor of the working space, where the basalt powder has been chosen for its optical and mechanical characteristics, which are similar to the lunar regolith. The ground has some craters and boulders to represent a simulated lunar surface, in order to test navigation algorithms based on known landmarks. A small lunar rover has been developed with autonomous GNC capabilities to test steering algorithms on the simulated lunar soil.

Design of SMA actuators in antagonistic configuration: development of a technological demonstrator for space applications

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SMA actuators (in wire or strip shapes) are known for their excellent benefits in terms of power to weight/dimensions ratio. The principle of operation is based on the material capability to recovery the undeformed shape when it is heated over its characteristic temperature of Austenite finish; an external force is usually required to the actuator in order to return to its deformed shape and to be ready for the next activation cycle. Alternatively, the actuators can be used in antagonistic configuration[1,2]. Starting from experimental data obtained through a campaign of thermo-mechanical tests on the material, this paper presents the work dedicated to the characterisation of the antagonism. Basing of these experimental results, three couple of wires have been designed and applied to a leg of an hexapod robot for space applications replacing the classic electric motors previously adopted[3]. Environmental conditions of weightlessness are assumed.

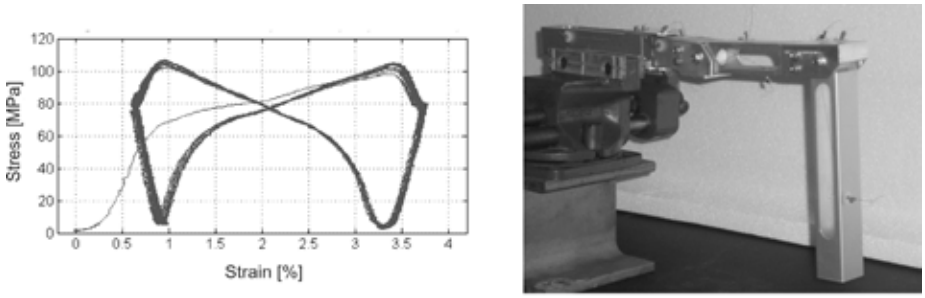

Figure 1. Characteristic "butterfly" diagram of SMA actuators in antagonistic configuration (a); leg of hexapod robot equipped with three couple of SMA antagonistic actuators (b).

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Decoupling techniques of strain and temperature measurements for FBG sensors

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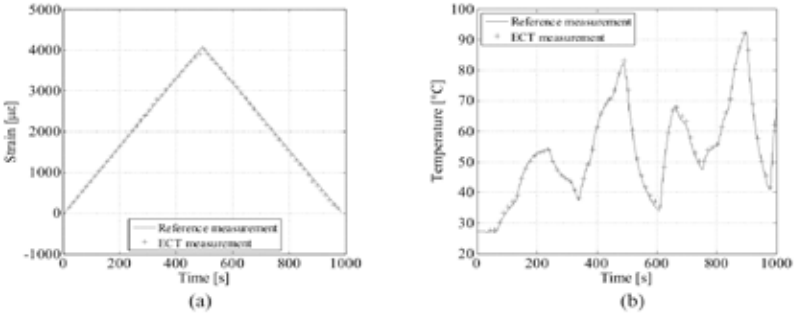
The interest of the aerospace industry for Fiber Bragg Grating (FBG) sensors is continuously growing thanks to their light weight and compact size and to high performance guaranteed by the optical fibers that allow to carry information at high speeds over long distances, through a low power signal characterized by low attenuation. Moreover, the immunity to electromagnetic fields and the high electrical resistance allow them the use near high-potential equipment or in sites at different potentials. Such peculiar aspects of the optical fibers are made even more evident by the recent technological innovations such as the commercial availability of optical fibers with increasingly smaller diameters (50-80μm), which further limit the invasiveness, the development of bending insensitive fibers (high numerical aperture), which minimize the attenuation problems, and the development of non-invasive methods for gratings inscription, which allow to obtain sensorized fibers with mechanical strength of the order of 4%. For all these features can be fully exploited for the development of Structural and Usage Monitoring Systems is however necessary to define the techniques that allow to discriminate the contribution of the mechanical deformation and the temperature variation of the signal acquired by the FBG sensors. Currently in the literature there are several techniques of which none is universally recognized and adopted[1,2]. In this paper, after analyzing the state of the art, the attention will be placed on some of them, investigating both from the technological point of view (as realize the sensorized laminate) that from the experimental one.



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Study of interlaminar fracture propagation in composite laminates using Fiber Bragg Grating sensors

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The attention for Structural Health and Usage Monitoring Systems based on fibre optic sensors embedded in composite structures is continuously increasing. On the other hand the design of composite structures requires the development of numerical tools able to simulate with accuracy the nucleation and propagation of damage inside the laminates.
In order to evaluate the capability of FBG sensors to monitor crack propagations as well as to achieve characterization of interlaminar fracture toughness and to identifier the process zone of the delamination, a campaign of Double Cantilever Beam (DCB) tests and four-point End-Notched Flexure (4ENF) tests have been performed. Thanks to a stable crack-front propagation, the FBG sensors inside the laminate has permitted to measure the deformation gradients during the delamination[1,2].
Moreover, the development of a dedicated production process for composite laminates embedding Bragg Gratings sensors is presented in the paper[3].

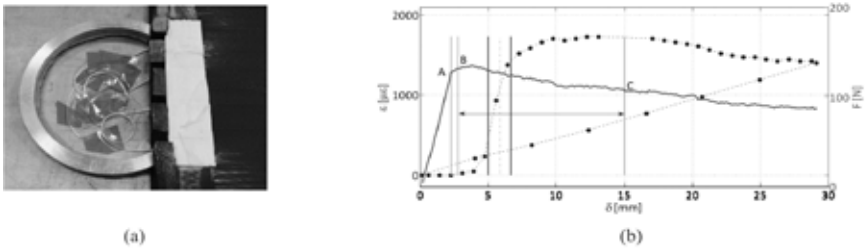

Figure 1. Embedment technique for Fiber Optics (a); Force and internal strain in a DCB test.

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Lab activities to simulate in-orbit proximity manoeuvres

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Ground tests play a key role in verifying many critical aspects of a spacecraft mission, even within the current trend of high fidelity simulation tools. In fact numerical runs of complex manoeuvres still need some realistic indications of the expected system's behaviour to better define model assumptions. To this aim different test-beds have been recently built at the Guidance and Navigation Laboratory at Università di Roma La Sapienza. They share, for reasons of costs and complexity, the limitation of a bi-dimensional representation of the space gravity-less environment. Nevertheless, they allowed to better investigate complex dynamics' phenomena typical to space activities, and a number of interesting indications have been provided by these experimental tests. The paper is intended to present the main characteristics of these test-beds and to discuss their performance and the related research activities.
The first realization is represented by a two-link robotic arm, with a hinge at a fixed shoulder (simulating its mounting on a large and massive platform) and a grasping hand as end-effector. The arm moves frictionless on a plane, either remotely commanded or autonomously identifying its trajectory via image navigation, to perform the requested manoeuvre while avoiding obstacles.
A free floating platform, named PINOCCHIO (Platform Integrating Navigation and Orbital Control Hosting Intelligence On-board), supported by air pads to cancel the gravity effects and pushed by nozzles, all of them feed by onboard compressed air reservoirs, is used instead to simulate single spacecraft dynamics. This bus is equipped with a central processing unit (a PC104 board, eventually substituted by a laptop) and a number of microcontrollers, setting a complete Onboard Data Handling System. With respect to navigation, PINOCCHIO is equipped with an Inertial Measurement Units and several cameras. The platform has been extensively used to investigate rendez-vous manoeuvres, both commanded and autonomous. Concerning the attitude dynamics, different continuous and digital/discrete control techniques (including Bang-Bang, Pulse Width Modulation, and Pulse Width Pulse Frequency Modulation), exploited by eight thrusters, have been implemented to command the yaw angle (1 degree of freedom control). At the same time, PINOCCHIO has been extensively used to understand flexibility effects by adding two lateral panels simulating spacecraft's solar arrays.
Finally, a hardware-in-the-loop set-up has been prepared to analyze the relative motion conditions proper to formation flying missions. Chief an deputy platforms follow their path, evaluating their relative kinematic state thanks to an image-based navigation system, a solution which is currently facing increasing interest for proximity manoeuvres.

Active Camber Morphing Wings Based on Compliant Structures

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The need for more efficient aircraft able to meet the new challenging requirements defined by US and EU organizations, like for example Horizon 2020 recently established by European Community, confronts aircraft industry with the demands for significantly greener aircraft with a substantial reduction of fuel consumption, emissions and perceived noise levels [1-2]. The adoption of these global requirements has two main consequences. Firstly, the greening level becomes one of the criteria for which a new aircraft has to be judged or selected; and secondly, the aircraft configuration itself must be defined to fulfill the greening requirements. Since other design targets, such as economic and technical factors, must be satisfied as well, new design criteria arising from the greening requirements must be taken into account right from the beginning of the design cycle. These new greening requirements cover all the components of the aerospace field, including fixed wing large transport aircraft, regional aircraft, engines and helicopters.

Aiming at this global target, a great effort is underway concerning morphing aircraft and especially morphing wings, based on their potential capability to optimize selected aircraft performance indices during the mission, like for example fuel burning, by adapting their shape. Nevertheless, the design of this kind of devices does not represent an easy task and would require the availability of ad hoc developed procedures able to tackle the conflicting requirements such as the high deformability requested to change the airfoil shape coupled to the load carrying capability and low weight.

The paper summarizes the recent activity of the research group in the field of active camber morphing wings based on compliant structures [3] in terms of both dedicated tools development and specific solutions adopted in the framework of different EU projects, such as SARISTU and NOVEMOR.

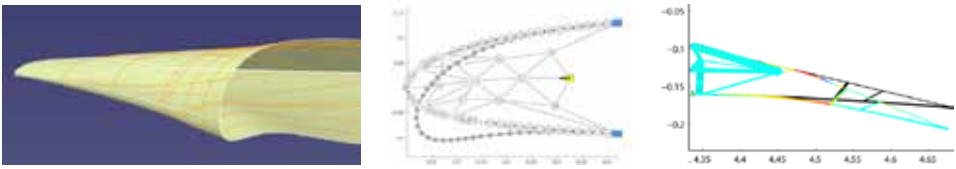

Figure 1: optimal external shape for morphing LE, load paths definition for morphing LE and final compliant structure for morphing Trailing Edge.

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Low cost solar panels for microsatellites

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This paper presents the research activities carried out in collaboration between the University of Pisa, Alta SpA and GAUSS Srl about the design, manufacturing and assembly of a photovoltaic panel for small satellite applications in preparation of a test flight scheduled for early 2013 on the UniSat-5 small spacecraft. The method developed[1] is based on "low-cost" and "low-tech" techniques to assemble and qualify the panel. The approach adopted involves a printed circuit board where bare cells are installed by means of a double-sided insulating adhesive tape and each cell is covered with cerium doped borosilicate glass, using a controlled volatility silicone. Bonding was performed with a dedicated vacuum bag technique, developed in-house. This method allows to achieve a significant cost reduction with respect to traditional techniques, while retaining high performance and avoiding complex technological procedures during the integration. The panels were subjected to electrical characterization and to thermal vacuum test according to ECSS standards. We outline the panel design, the manufacturing processes and the results of electrical and thermal vacuum tests carried out on the protoflight model. The recorded protoflight unit total mass loss was well under the acceptable limits, so the panel has been accepted for space flight. Possible future extensions of the method to produce low cost panels suited for arbitrarily shaped microsatellite surfaces are also outlined and discussed.

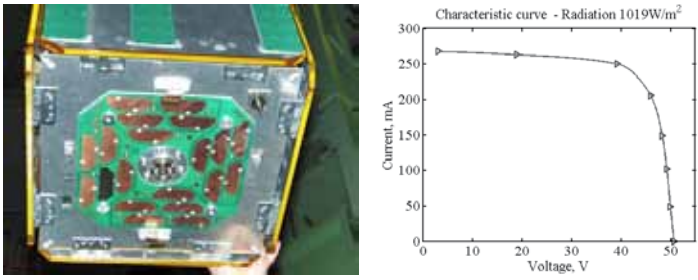

Figure 1. Left, solar panel prototype integrated on UNISAT-5; right, measured I/V curve in AM1.5 sunlight

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A Methodology to Harmonise Safety, Security and Cost-effectiveness in ATC

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Cyber security became an issue for many civil aviation organisations because they rely on electronic systems for critical parts of their operations, which often have safety-critical functions. With increasing air traffic, today's Air Traffic Management (ATM) system is beginning to hit its physical limits, particularly in terms of the number of aircraft that can be managed by human controllers within a given airspace. The industry has designed solutions to automate the routine part of ATM, which when put into place, will greatly increase the number of aircraft that can be managed within a given airspace, leaving the air traffic controller with the executive role rather than having to issue all the routine control instructions. However, the use of new communication methods and technologies will increase the role of cyber security and expose numerous vulnerabilities that do not exist in today's more closed, proprietary, civil aviation systems. These cyber security vulnerabilities have the potential to jeopardize civil aviation safety and efficiency.[1] In this complex scenario, it is crucial the awareness of the interaction between security, safety and cost-effectiveness. Security measures must be considered not only with regard to the level of protection deemed appropriate, but also identifying areas of synergy and potential conflicts between safety and security approaches, and highlighting cost-effectiveness opportunities within certain security and safety strategies. Given budgetary and other constraints, integrating secure/safe and cost-effective design objectives oftentimes would require compromise and tradeoffs.[2] Safety and security have different goals, which may lead to conflicts especially in the implementation of an air traffic control system. For example, the implementation of an authentication mechanism for a safety-related function may increase security since it reduces the risk of illegitimate access, but it may reduce safety since it increases the time needed to access this function. It is necessary to resolve these conflicts, not on purely intuitive decisions, but with a structured approach such that safety and security can be harmonised.[3] The objective of this paper is the definition of a new methodology for carrying out safety and security risk assessment in air traffic control domain, harmonising both safety and security through the use of standard concepts and methodologies from both disciplines[4][5] and showing how they interact in every stage of the life cycle. Both safety and security requirements can be identified at design phase, considering areas of synergy and potential conflicts, and highlighting cost-effectiveness opportunities. For demonstrative purposes, the methodology has been applied to the real case study of approach and landing flight phases scenario, with a special focus on Controller-Pilot Data Link Communications systems.

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Recent developments in ionic liquid field emission electric propulsion

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The study herein reported was aimed at the characterization of the plume of a ionic liquid fed, linear slit FEEP thruster, in terms of composition and velocity of the constituents. Ionic liquid propellants are actively investigated as promising alternatives to alkali metals in field emission thrusters, in order to reduce system cost and ground operation complexity. To this end, a large number of tests was carried out using the EMI-BF4 ionic liquid as a propellant. The thruster was fired in either positive polarity or negative polarities to check the capability to extract anions and cations alone. Then, most of the testing was carried out in alternate polarity mode, in order to avoid electrochemical poisoning of the propellant, due to the unbalanced extraction of charged particles[1]. Such operating mode is believed to be the most promising candidate for flight operation, as it would allow to get rid of an external neutralizer to maintain electrical neutrality of the spacecraft.
Ion beam composition was investigated by means of a time-of-flight mass spectrometry technique. The measurements show that the emitted beam is mostly composed of monomers (BF4)-, dimers (C6H11BF4N2) (BF4)- and polymers $(C6H11BF4N2)_n$ (BF4)- (with n a function of applied extraction voltage). Under the assumption of a certain beam composition, propellant consumption was indirectly evaluated by means of time integration of the emitted current and independently verified by means of direct observation of the depletion of the propellant reservoir. The estimated resulting specific impulse is around 1400 s. The thruster behaviour resulted quite variable, especially when operated at high voltage levels in continuous polarity mode. Better performance was registered in alternate polarity operation with an alternation period of several tens of a seconds at extracted current of just a few μA.

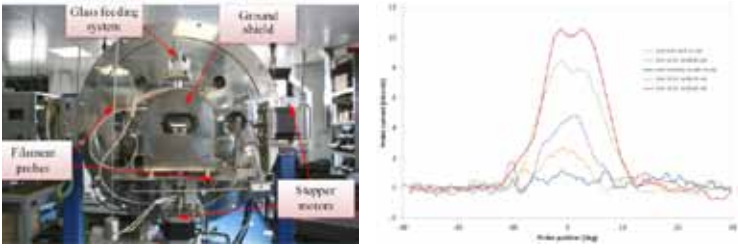

Figure 1. Left: experimental setup; right: exhaust beam profile recorded with an electrostatic probe.

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Scientific use of the sampler, drill and distribution subsystem (SD2)

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Rosetta is the third cornerstone mission of the European Space Agency scientific program "Horizon 2000". Rosetta will be the first spacecraft to orbit around a comet nucleus. It was launched in March 2004 and will reach the comet 67P/Churymov- Gerasimenko in 2014. A lander (Philae) will be released and land on the comet surface for in-situ investigation. Its goals include the determination of the elementary and mineralogical composition of the comet, the identification of traces elements, and isotopic composition of cometary material. One of the key subsystems of the lander Philae is the Sampler, Drill and Distribution (SD2) subsystem. SD2 provides in-situ operations devoted to soil drilling, samples collection, and their distribution to two evolved gas analyzers (COSAC and PTOLEMY) and one imaging instrument (C □ IVA). SD2 was designed to work in very low gravity and wide thermal excursion environment, and to optimize cutting performances with a very low power consumption. Recent studies have proven the existence of a correlation between the drill behavior during perforation and the mechanical characteristics of the cometary soil. This outlines the possibility of using SD2 not only as a tool to support other instruments, but also as a scientific instrument itself. To this purpose, a correlation between SD2 telemetry data and the cometary soil characteristics must be identified. Unfortunately, as the drill rotation and translation are commanded by stepper motors, the variation of power consumption can not be used as an indicator of a variation of the soil characteristics. Consequently, alternative strategies are under investigation, for the use of available telemetry data to determine cometary soil mechanical properties. In this paper the possibility of using the drill as a quasi-static penetrator is presented. Within this approach, laboratory tests on glass-foam specimens of different porosity show that penetration failures can be exploited for cometary soil characterization.

SKYLON: An Example of Commercial Launch System Development

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SKYLON is a reusable single stage to orbit spaceplane that can take off from a runway reach a 300 km altitude low earth orbit with a payload of 15 tonnes and then return to earth for a runway landing. The feature that enables this is the Synergistic Air-Breathing Rocket Engine (SABRE) which has both air breathing and pure rocket modes. These engines allows SKYLON to fly to over Mach 5 and an altitude of 26 km while air-breathing greatly reducing the burden on the subsequent less fuel efficient rocket phase of the ascent trajectory to orbit.

Figure 1. Skylon Taking Off

The project has been conceived as a commercial venture with the objective that the price charged for the launch, covers all operational and acquisition cost with profit. That means access to space becomes a pure economic activity without the need for public subsidy of the development or day to day running costs of the launch activity.

A key way to achieve this objective is the separation of the supplier of the SKYLON system and the operator, following the model in the air transport industry where airliner manufactures build aircraft that are then sold to many different competing airlines. This approach allows commercial development operations without any assumptions about growth in the market for space launches. If this approach to selling SKYLONs is successful, it will lead to considerable over capacity in the launcher market. This in turn creates the conditions for a massive growth in space activity that can be conducted on a purely commercial basis, creating a “virtuous circle” lowering the cost and increasing the reliability and availability of reaching space, until it much closer to current air transport.

USV3 System Development Overview

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The present paper deals with a study of an unmanned re-entry vehicle able to achieve LEO orbit by means of the Italian VEGA launcher, and after an orbital phase, to re-entry and to safely land autonomously on a conventional runway. The USV3 system concept is built on the CIRA heritage of the USV program[1,2] carried out in the last ten years but with the different mission of a technology driven re-entry system demonstrator instead of a scientific flying test-bed.
Different challenging design and technology performance shall be fulfilled by the vehicle configuration, materials and functional architecture. In particular, the vehicle shall exhibit adequate aerodynamic and manoeuvrability characteristics together with a GNC approach allowing flexibility in the re-entry trajectories. Possible re-entry trajectory duration beyond one hour is particularly challenging for TPS design, because it has a direct impact on the thickness of the insulator used to protect the internal cold structure and avionics subsystems. The challenging task of autonomous
landing on conventional runway was added to this vehicle asking for a landing gear design constrained by the limited volume available and the high speed at touch down.
The paper describes, after a general overview of the mission and vehicle requirements and of the mission scenario, the main results of the system analysis on Aerodynamics and Aerothermodynamics, Re-entry Trajectories, Thermal Protection System, landing and sub-systems budgets.

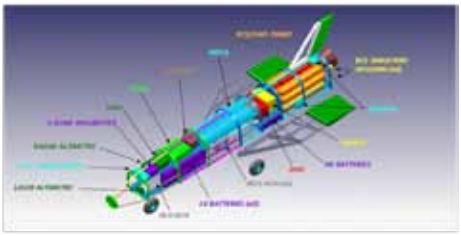

Figure 1. USV3 Internal Layout

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Computational Flow Field Analyses on Aeronautical Oil Cooling Systems

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This work has been conducted in the framework of the European project ESPOSA (**E**fficient **S**ystems and **P**r**O**pulsion for **S**mall **A**ircraft) of 4th call VII FP [1]. The project develops and integrates novel design and manufacture technologies for a range of small gas turbine engines to provide aircraft manufacturers with modern propulsion units, thus improving efficiency, safety and pilot workload reduction. In particular, turbine engine technologies for small aircraft up to 19 seats (under CS-23/ FAR23 regulations) operated on the scheduled and non-scheduled flights are investigated. Two engines (Baseline 1 and 2) respectively 160-180 kW and 400-470 kW have been selected and will be installed on four different platforms: tractor configuration with the engine in the fuselage (TR1); tractor configuration with the engine on the wing (TR2); pusher configuration with the engine on the wing (PU2); helicopter configuration (HE1). In this framework CIRA is involved is the engine integration for the configuration PU2 and TR2 and, in particular, in the oil-cooler air intake design and analysis. To this end computational flow field analysis have been performed to investigate the oil-cooler effectiveness in different operative conditions which the airplane experiments in cruise and ground environments. The commercial code Fluent is used as a solver. Steady turbulent compressible flow simulations are carried out considering the air as ideal-gas with a constant-averaged specific heat. Flow thermal conductivity and viscosity are set by a polynomial formulation. The porous media model is used in order to simulate the heat exchanger. Therefore, pressure losses and temperature increases within the heat exchanger are addressed considering several experimental data available for the oil cooling devices. In particular, thermal power transferred to air is assumed equal to that nominal of real heat exchanger and the pressure losses are reproduced setting the viscous and internal resistance coefficients. To account for turbulence, the $k - \omega$ SST model is considered with Low-Re correction enabled. Some preliminary CFD results are reported in figure 1[2].

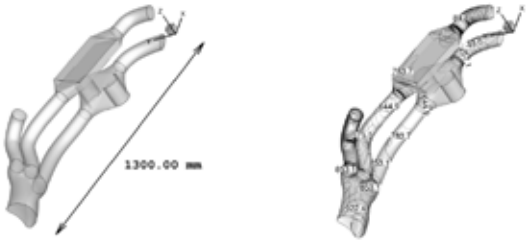

Figure 1 oil cooler geometry and pressure (Pa) distribution[2]

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Elastic cusped rod, plate, prismatic and standard shell models

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The present paper gives an up-dated exploratory survey of investigations concerning elastic cusped rods (i.e., the areas of their cross-sections maybe equal to zero at rods' ends), cusped plates, prismatic and standard shells (i.e., their thickness may vanish at least on some parts of their boundaries.

Figure 1. Some Examples of cusped rods with rectangular cross-sections

Figure 2. Some examples of profiles of cusped prismatic shells

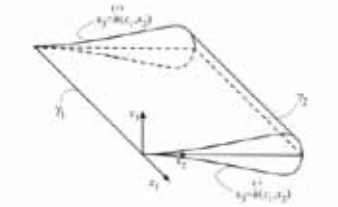

Figure 3. A cusped plate with a sharp γ_1 and blunt γ_2 cusped edges. The thickness $2h := \overset{(+)}{h} - \overset{(-)}{h}$, $2h(\gamma_\alpha) = 0$, $\alpha = 1,2$.

In 1955 I.Vekua[1] raised the problem of investigation of elastic cusped prismatic shells in particular cusped plates. The study of elastic cusped rods, plates, prismatic and standard shells within the framework of classical and so called refined theories mathematically leads to analysis of correct setting boundary value problems for even order ordinary and elliptic equations and systems with the order degeneration in the static case and of initial boundary value problems for even order equations and systems of hyperbolic type with the order degeneration in the dynamical case. Therefore, boundary conditions are not possible to set in the usual form in all the cases of sharpening (tapering) geometry.[2]

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Airline Pilot Training – A Comprehensive and Innovative Approach to Upset Recovery Training

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This paper present a new approach to air transport pilots training based on the use of an advanced simulator capable of very accurate reproduction of high-alpha and post-stall characteristics. In addition, we develop a simple flight training program based on a low-cost piston-engine-powered trainer, suitable to perform high-alpha manoeuvres without limitations. We also develop a light, variable-stability trainer that allows to accurately reproduce pre-defined training scenarios in flight. The combination brings about a reduction of course duration while improving training progress assessment.

Particular attention is paid to:

- The presentation of criteria to analyse wind tunnel tests, for the preparation of the aerodynamic database and mathematical model
- The methodologies to prepare reliable aerodynamic data for the simulation of loss of control conditions of the various categories of airliner aircraft
- A comprehensive approach to the development of a In-Flight Simulation trainer that is fully representative of the aircraft motion in all flight conditions, including post-stall angle-of-attack, loss of control, departure and spin
- Illustration of the significant advantages of using a low-cost two-seat piston-engine powered trainer with side-by-side configuration, designed to perform all loss of control manoeuvres without limitations for the basic URT training
- The use of a variable-stability aircraft to reproduce different aircraft responses, suitable to offer flight experience as regard to Upset Recovery Training and to simulate the behaviour of different aircraft configurations.

Based on our experience, simulation is very important. However, only with in-flight training can the student pilot gain sufficient and reliable experience with regard to Upset Recovery procedures. By preparing for a fast and effective recovery action with the proposed In Flight Simulation trainer, the student pilot will be confident in manoeuvres associated with high alpha, adverse attitude and high-g flight conditions.

Recent development in satellite altimetry over land and applications to Cryosat-2 mission

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Satellite radar altimetry, which was initially designed for accurate measurements of sea surface height, has been demonstrated to be suitable for land surfaces as well.
In this paper, a simplified expression of the flat surface impulse response (PFS) [1], which enters in the computation of the radar Impulse Response (IR) [2], has been found which is valid for a nadir pointing system as well as for small mis-pointing angles [3].
On the basis of this model, simulations have been performed taking into account the system characteristics of the new sensor SIRAL (Cryosat-2), considered operating in LRM (Low Resolution Mode) [4] varying some key parameters such as backscattering coefficient, off-nadir angle, surface RMS height in order to validate the model itself.
The outputs of the simulations show consistent and expected results in the various simulated scenarios. The simulated IRs were compared with real altimetric data from Cryosat-2 SIRAL for different types of targets such as Desert, Ocean, Ice.

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Preliminary design of a compliant mechanism for rib morphing implementation

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Adaptive structures have been individuated as a topic of great interest for researchers working in aeronautical field. This is mainly due to the several benefits which can be obtained by implementing morphing technology in aircraft design: novel structures, in perspective fully-adaptable to different flight conditions, may in fact bring many advantage at system level: from noise emission reduction to aerodynamic efficiency enhancement and fuel-burn optimization.
Such an approach, in spite of related benefits, presents a challenging problem: the same structure has to be stiff enough to withstand external aerodynamic loads without appreciable deformations while being flexible enough to dramatically change its external shape. In the framework of the CRIAQ MDO505 project, the first joined program between Canadian and Italian research centers, academies and leading industries, the authors addressed the design assessment of a novel rib architecture enabling the camber variation of the aileron airfoil through a compliant mechanism. The architecture allows controlled aileron's shape modification in order to improve the wing tip / aileron aerodynamic efficiency at low subsonic speed. On the base of specific target shapes and related external loads, the structural layout of the device was preliminarily defined. The reference geometry was tailored for a full scale wing of a civil regional transportation aircraft, where the conventional aileron component was substituted by the morphing device. Each aileron rib was composed of multiple, suitably shaped, rigid elements whose relative rotations were driven by means of an actuated linear spring. Advanced FE analyses were carried out in order to properly size the compliant mechanism and the actuationchain.
System's capability to reproduce target morphed shapes under the action of aerodynamic loads was successfully proved on the base of FE analyses outcomes.

Preliminary design of a novel morphing rib architecture based on lumped elastic properties

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Aircraft wings are usually optimized for a specific design point. However, since they operate in a wide variety of flight regimes, some of these have conflicting impacts on aircraft design, as an aerodynamically efficient configuration in one instance may perform poorly in others.
Ideally rigid, non-deformable aircraft structures preclude any adaptation to changing conditions. Alternatively, morphing wings can provide adaptive capabilities to maximize aircraft performance in every flight condition. It is therefore not surprising that several research programs are currently running worldwide to explore the feasibility of morphing concepts especially with reference to their benefits/drawbacks ratio. Among these, the CRIAQ MD0505 project was launched; the project represents the first joined research program between Canadian and Italian academies, research centres and leading industries. Referring to the wing tip of a regional transportation aircraft, the program addresses the implementation of combined smart structures specifically conceived to optimize the aerodynamic efficiency; more in detail an adaptive-bump configuration is investigated for the upper skin of the wing box (to control the separation point between laminar and turbulent flow) and a variable camber aileron architecture. In this framework the authors focused on the design of a morphing aileron characterized by active ribs enabling the in-flight modification of external airfoil shape.
On the base of specific requirements regarding target morphing shape to be matched and loads to be withstood, an innovative architecture was developed for the active rib; the rib is chordwise divided in three main blocks connected by crossed springs which assure relative rotation among blocks while contributing to the absorption of external solicitations. In this paper, the preliminary design phase of the rib has been outlined, from the concept definition up to the assessment of structural properties and actuation system through advanced FE analyses.

Application of the Fracture Mechanics methodologies in Aeronautics to improve the safety of railway transport

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On June 29, 2009 a derailment occurred in the central Station of Viareggio; during the derailment, the first tank of the train was cut, the flammable gas flourished out and fired, causing the death of 32 people.
This disaster was first originated from a fatigue failure of an axle and, after this accident, a great attention was devoted to study the fatigue crack propagation in order to determine the initial crack depth present on the axle. This paper describes the results of a research study aimed at determining the mechanism by which a crack propagated in a section of axle until the axle itself failed. Both theoretical-numerical and experimental analyses have been conducted. The theoretical-numerical analyses were performed by means of the classical criteria of Linear-Elastic Fracture Mechanics applied in Aeronautics, while the experimental studies involved crack propagation tests on standard specimens, in order to characterize the materials, as well as "full-scale" tests on railway axles. The series of experimental tests was conducted at the Fatigue Laboratory of the (former) Department of Aerospace Engineering in Pisa. The experiments on specimens and full scale axle allowed us to understand the limits of the classical crack propagation laws usually (and, sometimes, improperly) adopted. The decisive aspect of the research was the possibility to interpreter the markings which are present on the cracked section of the axle (figure 1). The paper underlines all the advantages coming from an engineering culture based on the project requirements and design methods typical of Aerospace Engineering.

Figure 1. Cracked axle section of the Viareggio accident.

Radar Absorbing Materials for Cube Stealth Satellite

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In this work, we propose a research on radar absorbing materials for a cubic satellite made of layered materials. Such a structure is believed to be relevant for low observable satellites operating at microwave frequencies in the broadband from 2 to 18 GHz. The dielectric properties of employed composite materials are analyzed using the coaxial air-line method. Economic aspects, such as low cost materials, are becoming more and more important in aerospace programs. Our solution employs a very scalable, cost-effective solution for providing stealthness to existing or brand new satellites. The particle swarm optimization algorithm is used to design and optimize a layered open (indefinite) absorber. A number of frequencies showing reflection under -20 dB at oblique incidence result from the optimization process. The optimized parameters obtained by optimization are used for the simulation of a test cube stealth satellite. The closed (definite) structure is investigated by the finite element method using COMSOL Multiphysics commercial code. The electromagnetic scattering simulation and the far field analysis is discussed for one of the main absorption frequencies around 8 GHz. At the end the effect of RAM on the electromagnetic field transmitted through an aperture located on the satellite surface panel has been also analysed. In particular RAM produces the attenuation of the electric field values within the satellite and this represents a good effect in terms of electromagnetic interference suppression.

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A new model reduction technique to handle mid-frequency vibrations

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The prediction of acoustic vibrational responses of a complex system in a large frequency band is a key point in many industries. Several techniques try to solve this by computing the responses of the system frequency by frequency, at many frequencies. Here, we propose a new way to do this, which does not need such computations. It is based on the mix between the Variational Theory of Complex Rays (VTCR [1]) which can solve a medium frequency problem very easily an efficiently, and the Proper Generalized Decomposition (PGD [2]) which can find the best reduction model of the VTCR to handle frequency band computations. The presentation will focus on the development of such a strategy, and on its computational efficiency.

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A data compression technique for PGD reduced-order modeling

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Numerical simulation has been playing an increasingly important role in science and engineering. However, when dealing with high-fidelity models, the number of degrees of freedom can lead to systems so large that direct techniques are unsuitable. Model reduction techniques constitute an efficient way to avoid this obstacle by seeking the solution of a problem in a reduced-order basis (ROB), whose dimension is much lower than the original vector space. A posteriori methods usually consist in assuming this ROB by the decomposition of the solution of a surrogate model relevant to the initial model (see e.g. [1]). A priori methods follow a different path by building progressively an approximate separated representation of the solution, without assuming any basis (see e.g. [2, 3]).
This work focalizes on the Proper Generalized Decomposition (PGD) which belongs to the second family and is used herein to solve problems defined over the time-space domain and which are eventually nonlinear. For solving such problems, the PGD, originally introduced as the radial loading approximation, consists in seeking a separated time-space representation of the unknowns and the iterative LATIN method is used to generate the approximation by successive enrichments [2]. At a particular iteration, the ROB which has been already formed is first used to compute a reduced-order model (ROM) and find a new approximation of the solution. If the quality of this approximation is not sufficient, the ROB is enriched by determining a new functional product using a greedy algorithm. The PGD has been applied for solving many types of problems in the context of the LATIN method and allowed to decrease the CPU cost drastically [3]).
However, model reduction techniques are more particularly efficient when the ROM needs to be constructed only once, which is not the case with the greedy algorithm, especially for nonlinear problems. In that case, the various operators must be updated along the iterations and the calculation of the ROM represents a large part of the global CPU cost. A new algebraic framework is, herein, proposed to simplify the elementary operations on PGD fields, making the ROM generation less expensive. It is based on the concept of *reference* times, points and parameters and allows to define a *compressed* version of the data. The space of *compressed* data shows interesting properties dealing the elementary algebraic operations. That should lead to important improvements in terms of calculation performance.

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Flutter Analysis of a Large Aircraft Model for Wind Tunnel Tests

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The greening of Aeronautics and Air Transport calls for a quantum leap in performance through a consistent, coherent and holistic approach focusing on the integration of advanced technologies and validation of results in a multidisciplinary approach leading to full-scale ground and flight demonstrators. Leveraging on such demand, the Green Regional Aircraft (GRA), one of the six Clean Sky platforms, aims to deliver low-weight aircraft using smart structures, as well as low external noise configurations.

In the framework of the GRA low noise domain, the WENEMOR project was launched to carry-out aero-acoustic measurements on a wind tunnel test model representative of different aircraft configurations equipped with rear-fuselage open rotor systems, operating in both pusher and tractor modes. Due to the large scale of the test model (1:7.5 of the actual dimension), to its elasticity and to the fully powered propulsive system, it was considered mandatory to address aeroelastic instability analyses in order to assure tests safety.

Rational approaches were implemented in order to simulate the effects induced by variations of design stiffness and damping values, especially for the engines/pylons connection; reliable aeroelastic models and advanced computational strategies were properly implemented to enable fast flutter analyses covering several configuration cases in terms of power plant installation and tail empennages layout.

Numerical models generated for the evaluation of normal modes were successfully validated through ground vibration tests. Flutter clearance was finally demonstrated up to four times the maximum flow speed expected during wind tunnel test campaign.

Horizontal axis hydroturbine Shroud airfoil analysis and optimization

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The present work concerns the optimization of the shroud of a horizontal axis hydroturbine. The main aim is to improve the hydroturbine efficiency by designing a new shroud airfoil through an optimization process that maximize, as cost function, the power coefficient. To achieve the objective, an optimization algorithm has been developed, whose target is, starting from a given airfoil, the automatic generation of new airfoil and the evaluation of the objective function. The objective function analysis has been executed using CFD, with software STARCCM+, with an axisymmetric model, to minimize the computational cost. The optimization process was carried out by software MATLAB, by using supercomputing infrastructure SCoPE of the University of Naples Federico II. The base airfoil selected for the optimization process is the *Selig 1223* [1]. The chosen numerical optimization method is NSGA-II [2], it has been included in the optimization routine developed through software Matlab, in the DII. The starting airfoil is designed for high-lift regimes, so it gives excellent performance in these kind of applications, so was not expected a very high increase of the power coefficient. However the optimization process gave rise to a power coefficient increase of 5.2%, with respect to the original airfoil, but this increasing can be certainly improved by refining the algorithm, and in particular by distributing the process on parallel processors. The CFD analysis, in axisymmetric flow field and actuator disk hypothesis, gave reliable results, in agreement with previous works, developed with different software, and with experimental results.

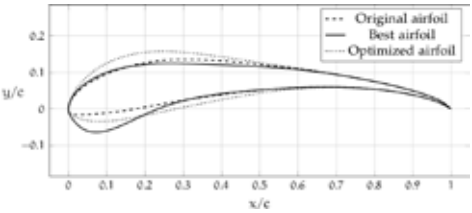

Figure 1. BC = ±0.05: optimized airfoil.

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Effect of loading factors on the analysis of aeronautical structures by component-wise models

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The use of various finite elements (FE) for the analysis of reinforced-shell aerospace structures is discussed in this paper. One-, two-, and three-dimensional FE models from a commercial code are compared to higher-order beam theories, which are implemented by using the Carrera Unified Formulation (CUF).[1] CUF is a hierarchical formulation allowing for the straightforward implementation of any order-beam theories without the need of ad-hoc formulations. The attention is here focused on a novel approach denoted as Component-Wise (CW). [2,3]

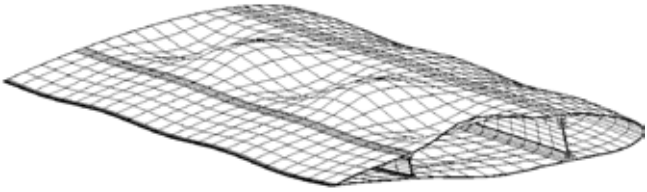

Figure 1. Shell-like mode of a cantilever wing structure by the one-dimensional CW model

According to CUF, Lagrange-like polynomials are used in CW models to discretize the displacement field on the cross-section of each component of the structure. Depending on the geometrical and material characteristics of the component, the capabilities of the model can be enhanced and the computational costs can be kept low through smart discretization strategies. The global mathematical model of complex structures (e.g. wings or fuselages) is obtained by assembling each component model at the cross-section level. Next, a classical 1D FE formulation is used to develop numerical applications. A number of typical aerospace structures are analyzed. Static and dynamic analyses highlight the enhanced capabilities of the proposed formulation. In fact, the CW approach is clearly the natural tool to analyze aerospace structures, since it leads to results that can be only obtained through three-dimensional elasticity (solid) elements whose computational costs are at least one-order of magnitude higher than CW models.

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Vapour cycle for avionics rack temperature control

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To increase usefulness and effective life of the existing tactical aircraft, significant avionics upgrades are required. The next generation of electronics will be densely packaged and will require increased cooling capacities with high flow rate and low coolant temperatures. Therefore advanced cooling design with low impact on aircraft Environmental Control System (ECS) performance and cabin comfort become a key factor for tactical aircraft avionics update.
From this perspective Vapour Cycle Cooling System (VCCS) offers a cost-effective solution which avoids the redesign of avionics modules or aircraft cooling systems, and does not affect the cabin comfort. VCCS behaviour has been simulated for its evaporator air side through a dedicated Computational Fluid Dynamics (CFD) approach, providing the flow balancing of the circuits and evaluating the relevant pressure losses and temperature pattern. In particular, using an iterative approach, the mass flow openings between ducts and rack have been sized in order to satisfy the cooling requirements of the equipment installed inside. The CFD model has been demonstrated to be a powerful and flexible tool that allowed to quickly identify the adequate solution and simultaneously to minimize the impact on the aircraft, reducing also the involvement of experimental activities.

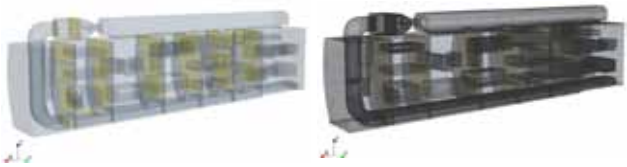

Figure 1. Cooling system air side CAD model (lhs) and mesh (rhs)

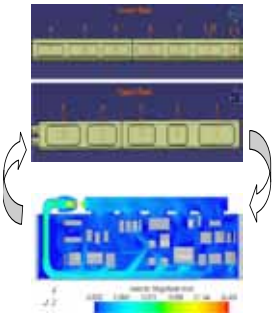

Figure 1. CFD iterative process to reach the target balancing

Multi-disciplinary Robust Optimization: Composite FEM-based Design

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The success of a developed design solution depends on a carefully balanced design that best exploits and considers the interactions among the numerous traditional engineering disciplines such as aerodynamics and structures, as well as the life cycle disciplines of cost, manufacturability, serviceability and supportability[1]. An effective procedure for conducting multi-disciplinary robust optimization analyses on composite structures is presented. Combination of efficient CAE tools, numerous concept solutions exploitation, effective surrogate models and multi-disciplinary and multi-objective optimization algorithms are adopted in order to exploit a preliminary composite wing design. In particular, material mechanical properties and stacking sequences assessment in combination with CFD and structural analyses permit to investigate independent optimized shapes and specific laminate candidates. Multi-disciplinary robust optimization approach faces both "Concept & Definition Phase" and "Design Phase": the former aspect is taken into account in order to assure certainty performance prediction and to give technical indications at the early stage of the project . The latter phase, using highly advanced methodologies, as draping/flat wrap predictions and multi-scale material models, achieves detailed design solutions. Critical design requirements can be also considered and introduced into automatic loop adopting design under uncertainty methods and highly iterative approaches.

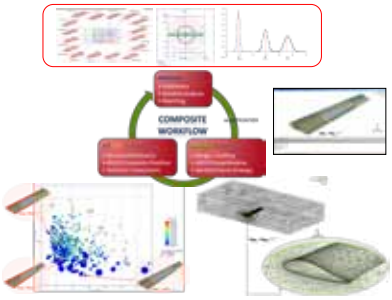

Figure 1. Multi-disciplinary Robust Optimization Approach

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Wind tunnel tests of a new commuter aircraft

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Tecnam Aircraft Industries and the Department of Industrial Engineering (DII) of the University of Naples "Federico II" are deeply involved in the design of a new commuter aircraft that should be introduced in this market with very good opportunities of success. The wind tunnel tests campaign of the so called "P2012 Traveller" aircraft has been performed in the wind tunnel facility of the DII.
Tests of a 1:8.75 scaled model have been performed on different configurations through a 3-component longitudinal and lateral directional internal strain gage balance, in order to estimate both longitudinal and lateral directional stability and control derivatives of the aircraft under investigation.
Reynolds number during tests was about 0.55 million. Tests have been performed with transition strip placed on the all lifting surfaces(wing and tail-planes) at about 5% of the local chord.
Many tests have been performed for different aircraft configurations with the aim to estimate the effects of the different components on the aerodynamics characteristics of the aircraft, such as flap, elevator and rudder deflections, fuselage, nacelles, landing gear and winglets. Have been tested also 3 different position of the horizontal plane, in order to evaluate its right positioning respect to the wing and ensure a good value of longitudinal static margin. With the purpose to carry out a right sizing of the vertical tail plane and rudder, 3 different vertical surfaces have been tested during the lateral directional experimental tests.

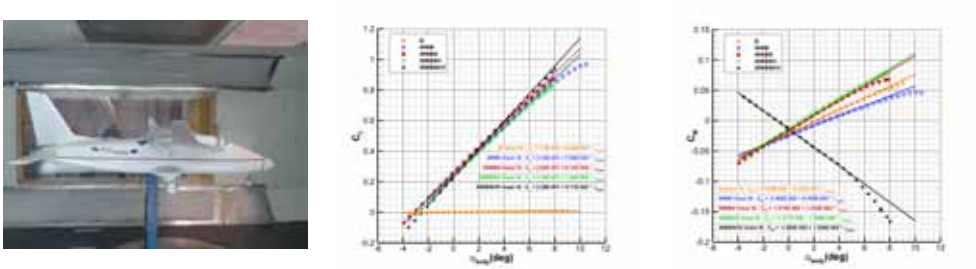

Figure 1. From left to right: complete aircraft configuration, lift coefficient curves vs. angle of attack, pitching moment coefficient curves vs. angle of attack.

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Determination of mercury librations using bepicolombo HRIC

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BepiColombo is an upcoming joint ESA/JAXA mission to Mercury. In particular the High Spatial Resolution Camera (HRIC), part of the SIMBIO-SYS (Spectrometer and Imagers for MPO Bepicolombo Integrated Observatory – SYStem) instrument suite, will characterize in detail the surface of the planet.
In this work the BepiColombo rotation experiment is analysed: goal of the experiment is to investigate Mercury's interior measuring its rotational state.
In this experiment images of surface regions taken at different epochs are used to retrieve information on Mercury's rotation and libration parameters.
This analysis requires the use of an accurate model of the rotation of Mercury, to correlate the position of observed landmarks with planet libration. Then model parameters can be derived from observations using a maximum likelihood estimator.
Uncertainties on spacecraft position, spacecraft attitude, imaged landmark position and camera intrinsic parameters result in the overall uncertainty on the estimated parameters.
Simulations of the experiment and uncertainty analysis show that, with a small number of landmarks/images, the total planet libration can be measured with a good accuracy.
This analysis provides also support for the better design of the experiment in order to attain its scientific goals.

Keywords: image analysis, uncertainty, libration, Mercury

ETRUSCO-2: an ASI-INFN project of technological development and "SCF-Test" of GNSS laser retroreflector array

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The **S**atellite/Lunar/GNSS laser ranging and altimetry **C**haracterization **F**acility (SCF) and SCF-Test are respectively a new test facility and test procedure to characterize and model the detailed thermal behaviour and optical performance of Cube Corner laser Retroreflectors (CCRs) for the Global Navigation Satellite System (GNSS) in laboratory-simulated space conditions, developed by INFN-LNF and in use by NASA, ESA, ASI and ISRO. Our key experimental innovation is the concurrent measurement and modelling of the optical Far Field Diffraction Pattern (FFDP) and the temperature distribution of retroreflector payloads under thermal conditions produced with a close-match solar simulator. The apparatus includes infrared cameras for non-invasive thermometry, thermal control and real-time payload movement to simulate satellite orientation on orbit with respect to solar illumination and laser interrogation beams. These capabilities provide: unique pre-launch performance validation of the space segment of Lunar/Satellite Laser Ranging (LLR/SLR); retroreflector design optimization to maximize ranging efficiency and signal-to-noise conditions in daylight. Extra Terrestrial Ranging to Unified Satellite COnstellations-2 (ETRUSCO-2) project goals will be achieved using the innovative test procedure described in [1].

Figure 1. ***S***atellite/lunar/GNSS laser ranging ***C***haracterization ***F***acility optimized for ***G***alileo and the ***G***PS-3 (SCF-G)

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From STEPS to STEPS 2: Development of Space Exploration Technologies in the Piedmont Aerospace District

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Building upon the important results obtained by STEPS (**S**istemi e **T**ecnologie per l'**E**s**P**lorazione **S**paziale), a second phase of this research project has been recently undertaken as a joint development of technologies and systems for Space Exploration supported by Regione Piemonte, the European Regional Development Fund (E.R.D.F.) 2007-2013, Thales Alenia Space Italia, SMEs, Universities and public Research Centres belonging to the network "Comitato Distretto Aerospaziale del Piemonte" the Piedmont Aerospace District in Italy.

STEPS2 has been conceived in line with the Global Space Exploration Plan and associated stream of initiatives with the aim to catalyze and bring to maturity the technology development initiated in STEPS for potential technological demonstrations in near-term space missions like:

- robotic exploration of Moon and Mars
- ISS utilization as technological test-bed for several exploration technologies
- re-entry transportation and their related technological demonstrators

STEPS2 main objective, in fact, is to close the gap between the TRL levels reached by the selected technologies with the STEPS programme activities (i.e. 3 or 4) and the level required to apply/ demonstrate these technologies in space (i.e. 5).

Taking into account the potentiality for near-term applicability, the following STEPS technologies have been selected for further development in STEPS 2: Precision Landing, Surface Navigation, Smart Skin, Landing Legs, Regenerative Fuel Cells, RVD & Mechanisms, Inflatable and Environmental Protection, Ablative/aerothermodynamics, Health Management Systems / Ultralight Structures.

This paper, after an introduction on the STEPS achievements, will present the main results of the first year activity on STEPS 2 and will highlights its perspectives.

Figure 1. STEPS Pressurized Rover and Lander Demonstrators

Flow simulation of a prop-fan configuration based upon structured mesh with sliding boundaries

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A procedure for simulating unsteady flows with surfaces in relative motion was developed, based upon a structured multiblock U-RANS flow solver[1]. Meshes produced in zones of the flow field with different rotation speed are connected by sliding boundaries. The procedure developed guarantees that the flux conservation properties of the original scheme are maintained across the sliding boundaries during the rotation at every time step.

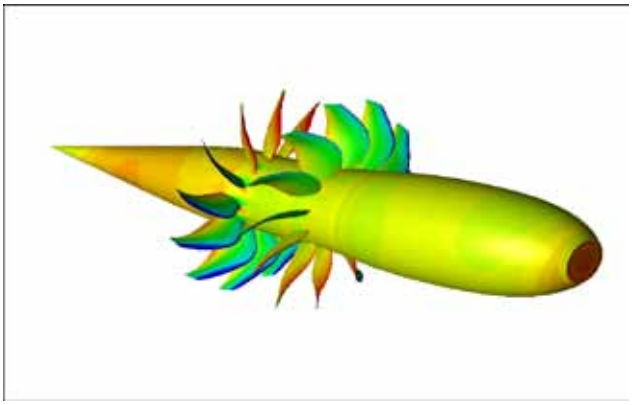

Figure 1. Pressure distribution on prof-fan configuration V_∞=35 m/s incidence 6 deg. phase=257 deg.

The solver turns out to be very efficient, allowing computation in scalar mode with single core processors as well as in parallel. It was tested by simulating the unsteady flow on a prop fan configuration with two counter-rotating rotors. The comparison of results and performances with respect to an existing commercial flow solver (unstructured) are reported.

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EXTICE: EXTreme ICing Environement

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Recent aircraft incidents and accidents have highlighted the existence of icing cloud characteristics beyond the actual certification envelope currently defined by the JAR/FAR Appendix C, which accounts for an icing envelope characterized by water droplet diameters up to 50 μm (so-called cloud droplet). The main concern is the presence of super-cooled large droplets (SLD) such as freezing drizzle, in the range of 40-400 μm, or freezing rain, with droplet diameter beyond 400 μm. International airworthiness authorities, namely the Federal Aviation Administration (FAA), Transport Canada (TC), and the European Aviation Safety Agency (EASA) are intending to jointly develop and issue updated regulations for certification in SLD environments based on investigations of consultative expert panels coming from research establishments, industry and national aviation regulatory bodies: "Appendix X". If implemented, the proposed new rules will require aircraft manufacturers to demonstrate that their product can safely operate in SLD environments. To do so, they will be requested to demonstrate that specific capabilities comply with the new regulation. Compliance has typically involved actual flights into natural icing conditions, as well as the use of engineering simulations of the natural environment provided by experimental means, icing tunnels and tankers, and analytical methods, namely ice prediction computer codes.

Therefore, it is necessary to enhance existing simulation tools to accurately predict individual drop dynamics and ice accretion involving SLD. This will require further research into the hydrodynamics of large drop impact and solidification onto oblique surfaces and the subsequent modelling of these processes in computer codes. Specific phenomena to be addressed are droplet break-up in shear flows, modified drag of large and/or deformed drops, the impact and splashing of drops upon oblique impact and the solidification of sheared liquid layers. These aspects require first experimental and theoretical treatment followed by analytical modelling and verification. Furthermore, the same conditions must be duplicated in icing tunnel facilities. The generation and introduction of the SLD into the flow stream must be tuned and proven to accurately yield real-flight conditions in a reproducible and well-controlled manner.

For a better understanding of the SLD icing hazard problem a project named EXTICE have been carried out by CIRA with the cooperation of several European company in the frame of VII FP EU funded projects. The objectives of EXTICE were twofold. One objective is to reduce aircraft development cost by improving tools and methods for aircraft design and certification in an icing environment. The main results, including basic water droplet research activities, icing wind tunnel tests, numerical simulation and flight tests will be presented in the framework of this paper.

Rad-Hard, In Flight, Reprogrammable Field Programmable Gate Array (FPGA) Architecture For Satellite Computers

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The purpose of the paper is to evaluate the application of a "rad-hard" in flight reconfigurable FPGA (Field Programmable Gate Array) architecture for space systems and to investigate his "serendipity" in On Board Computer and Data Handling for high performance satellite applications.
The new availability of FPGA strongly resistant to the main radiation effects of single event effects and total ionizing dose effects push the cutting edge of the technology to implement the core of an On Board Computer and Data Handling system towards the SRAM-based FPGA architecture.
Advantages of Field Programmable Gate Arrays (such as flexibility of design, shorter time-to-develop, lower cost, etc.) make them a suitable component for use in small satellites. Another important advantage, which can be explored, is the possibility of system reconfiguration during the mission life of the satellite.
Soft intellectual property (IP) cores written in Very High Speed Integrated Circuits Hardware Description Language (VHDL) are available to build a complete system (microcontrollers, Universal Asynchronous Receiver/Transmitter (UART), Controller Area Network (CAN) bus, Memory Management Unit (MMU), Floating Point Unit (FPU) and more).
A choice of implementing soft processors, or to code directly the control algorithms as dataflow machines are available to the designer[1].
So far, high-density FPGAs have been used in payload systems of microsatellites: however the introduction of rad-hard versions of such devices (Xilinx, Actel) paves the way for their use on the OBC.
Commercial Off The Shelf (COTS) philosophy is thus preserved, but with some degree of caution.
An evaluation of the performance of some soft processors (Nios II, LEON) that can be embedded in the FPGA design has been made with a realistic scenario which comprises the propagation of a state vector and its transition matrix by means of Runge-Kutta (RK4) 4th order numerical integrator, extended by Richardson extrapolation (RK4R) for a LEO orbit solution[2]. In addition, computation time required for a Kalman filter time update has been also evaluated.

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Status and Perspectives of Hypersonic Systems and Technologies with Emphasis on the Role of Sub-orbital Flight

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In the first part of the paper it is referred how the availability of efficient reusable launchers (RL) is a key factor both to afford important orbital infrastructures and to establish the basis of future Systematic Space Exploration campaigns. It is pointed out how great part of the technological effort required for the development of such launchers would be synergistic for the development of "high speed (Mach 4-5)" aircrafts to connect in a few hours any point on the Earth surface (today, antipodal distances can be covered in not less than one day).
It is discussed how, historically, the concepts of Expendable Launchers (EL) and RL have common origins (2nd WW and further on), purposes and components such as engines, and how, later, the RL / high speed aircraft (hypersonic) have been a research theme for 60 years even though with lacking of practical results. Conversely, the EL, as known, has represented and still represents (with the remarkable exception of the "Space Shuttle") the only solution to reach and overcome Earth orbits.
Focusing on the today prospects, in our opinion it is confirmed the opportunity to reconsider RL as effective alternative, together with the possibility to develop high speed aircrafts. For this purpose, currently proposed and existing projects such as Orbiting / Re-entry Vehicles (carried into orbit by EL) are considered and discussed. Furthermore the promising field of sub-orbital aircraft for Space Tourism is analysed as the naturally forerunner of the hypersonic flight transportation.
An accurate analysis about more promising practical applications and proposals in this field, as well as about the maturity of related technologies, easily leads to consider the development of a new aircraft for Space Tourism as an opportunity to afford hypersonic flight. Small space tourism aircraft not only represent a new class of aircraft, it could also be a good basis, by acquiring hypersonic cruise capability, to develop an aircraft that could be the naturally future of current business aviation.
In the paper a logical roadmap is discussed bridging today aeronautics with tomorrow hypersonic stratospheric flight, taking into account also economic aspects.

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Small Satellites: roles and perspectives

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Nowadays is more and more growing the interest among European MoD to space assets of rapid deployment and low cost implementation to support military and civil operations. Small satellites and innovative launching capabilities let to look at the micro and nano technologies field with a renewed interest in order to match this new and challenging space requirements[1]. Small satellites technologies are not "new", San Marco A, launched from Wallops Flight Facility, Virginia, US on December 15, 1964, was a 115 kg satellite, spherical in shape with an Atmosphere, Electron Content-Beacon, doomed to gather precious information about atmospheric density in the upper layers.

Figure 1. San Marco A (the first Italian satellite, and one of the earliest non-Soviet/US spacecraft)

There is a new emergent perspective to high tech small sat related with three innovative ingredients: the focus on mission requirements, the use of advanced miniaturized technology and the research of innovative launching concepts for space access. A new goal for space issues oriented to define a new concept of small and low cost spacecraft or constellation to perform missions and tasks domain of complex and expensive satellites. This new approach is primarily based on a payload-oriented and economic mind-set to focus on development of enabling technologies and to research of market opportunities in order to allow investments and additional capitals in the business. Low cost will be always an important issue but the term ''small" related to a satellite platform shall not refer any longer to a system with reduced performance, but rather to a system that profits of advanced technologies and reduced mass and volume for enhancing performance and satisfy requirements at a cost/effective ratio. In this respect developing such systems will be a way to respond to the need for new space missions for military, institutional, scientific or commercial purposes and will help to improve the way in which institutions procure their space systems.

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A Space Tug for Earth satellites servicing

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The paper deals with the conceptual design of a space tug to be used in support of Earth satellites transfer manoeuvres.
Usually Earth satellites are released in a non-definitive low orbit, depending on the adopted launcher, and they need to be equipped with an adequate propulsion system able to perform the transfer to their final operational location. In order to reduce the mass at launch of the satellite system, an element pre-deployed on orbit, i.e. the space tug, can be exploited to perform the transfer manoeuvres; this allows simplifying the propulsion requirements for the satellites, with a consequent decrease of mass and volume, in favour of larger payloads.
Several utilization scenarios can be identified depending on the final users of the tug, which may correspond to different requirements for the definition of the system. In particular, in this paper, two major applications are discussed, which mainly differ for the type of targets that can be collaborative or non collaborative. In both cases, the idea is to exploit as much as possible the Italian assets and in particular the VEGA launcher. A common core can be identified, which shall be provided with advanced systems for navigation and docking, robotic devices and instruments, and systems for the orbital refuelling (the space tug here presented is conceived to perform many satellites transfers from low to high orbits, and vice versa, if needed). Furthermore, the space tug is envisioned to perform the retrieval of payload on board a satellite, moving it from high to low orbits, and support its re-entry on Earth, by transferring it to a dedicated re-entry vehicle.
The paper reports a detailed description of the considered utilization scenarios, defining the missions and the major elements (launcher, space tug, satellite standard platform, Earth re-entry vehicle). Along the paper the adopted methodology and the main results are discussed, highlighting the performed trade-offs and justifying the major choices.
The second part of the paper focuses on the space tug conceptual design, from the assessment of the requirements up to the main system budgets (mass, volume, power). Particular attention is given to the major interfaces among the various elements, highlighting the main differences between the reference scenarios: the configurations obtained for the two scenarios are presented.

Multidisciplinary optimization for gas turbines design

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Recent international regulations[1][2] impose to reduce fuel consumption, pollutant and noise emissions for greener aircraft and engines. Focusing on propulsion system, the prefixed goal can be approached either by developing innovative architectures or by pushing the current Ultra High Bypass Turbofan (UHBT) concept towards its theoretical limit. In both cases, the intensive application and tuning of high-performance and multi-objective optimization strategies is imperative. Especially in the framework of UHBT the design of Low Pressure Turbine (LPT) is a critical and challenging task, since this component has a great impact on Specific Fuel Consumption (SFC) and only a multi-disciplinary approach can allow achieving the best configuration.
State-of-the-art LPTs are already characterized by high quality standards, thus they offer very narrow margins of improvement. Typical design process starts with the Concept Design (CD) phase, in which flow path, number of stages, velocity triangles and profiles solidities are defined using mean-line (1D) and other low-order tools, and evolves through the Preliminary Design (PD) phase, which allows the geometric definition of 3D airfoils by extensive use of CFD.
In this context, the authors have developed different strategies and algorithms that have been implemented in each of the aforementioned design phases. The purpose of this work is to describe the optimization techniques, their settings and how to implement them effectively in a multidisciplinary environment. Starting from a reference pseudo-randomic second order method, the authors have introduced a multi-objective response surface approach based on Artificial Neural Network (ANN), a multi-objective Genetic Diversity Evolutionary Algorithm (GeDEA[3]) and an Artificial Bee Colony-like optimizer (ABC), parallelizing and customizing them for the gas turbine study. Moreover, speedup and improvement arrangements are embedded in different hybrid strategies with the aim at finding the best solutions for different kind of problems that arise in this field.

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Model Sensitivity Analysis for the Numerical Simulation of an Engine Air Cooling System

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Since long time, there has been a progressive demand for high efficiency and high specific power output engines. Therefore, the availability of heat exchanger characterized by high cooling effectiveness represents a demanding design issue.

In this framework, the paper deals with the numerical analysis of a cylindrical heat exchanger for an air cooled engine. The heat exchanger geometry is shown in Fig.1. Several three-dimensional flowfield computations in steady state conditions are carried out by considering that the heat transfer rate depends upon the relative wind velocity, geometry of heat exchanger surface, external surface area and ambient temperature. In particular, two different turbulence models, Spalart-Allmaras and Standard k-ε, are accounted for in the thermo-fluid-dynamic analysis. The effect of the radiative heat exchange, by using the *Discrete Ordinate model*, is considered as well. The numerical results are compared with experimental and numerical data provided by Yoshida et al. [1] and Agarwal et al.[2]. e.g., Figs.2 and 3 compare different values of surface average heat transfer coefficient obtained with CFD data and experimental data, respectively. Comparisons among different model settings are provided in such a way to achieve a model sensitivity analysis as well. Computational mesh domains have been generated with *Ansys Icem 14*; while CFD calculations have been carried out solving the Reynolds Average Navier-Stokes (RANS) equations with the commercial code Ansys Fluent 14. The pressure-based solver was used to realize a time-steady simulation.

Figure 1. Simulated geometry

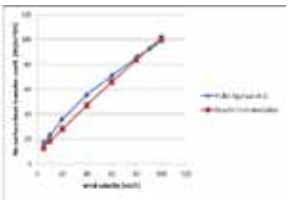

Figure 2. Comparison with CFD data and present results

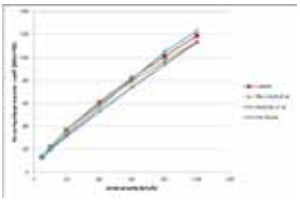

Figure 3. Comparison with experimental data and present results

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Conceptual Design and Optimization of Double Envelope Airships

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The recent interest in airship has lead to the need of innovative solutions, in order to improve the efficiency of the lighter than air vehicles in terms of costs and payload. One of the main issues that made the airships suited and competitive to such applications was the possibility to use hydrogen as lifting gas. Due to its high flammability and after the Hindenburg disaster, the hydrogen was substituted by helium.

At the present time there are a lots of examples of vehicles carrying huge quantities of dangerous and flammable goods in safety, by means of appropriate devices and precautions.

This work will deal with the development and the optimization of a new arrangement of non-rigid and semi-rigid airships. The innovative design concept is based on the introduction of a double envelope configuration: the core filled with hydrogen protected externally by helium, for safety.

Clearly from this arrangement arises the weight and cost problem, due to the use of two layers to hold the gases. An optimization analysis will be developed in order to find the best design solution for several airship dimensions. The method will be applied at first on simplified airship shapes, like ellipsoid, for different lengths and aspect ratios. The envelope material characteristics are taken from reference work regarding the new trend in airship technology.

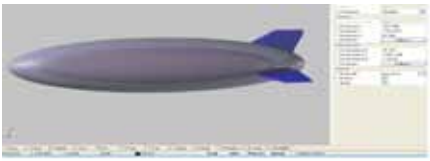

Figure 1. Double envelope airship example

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The stability of an Airship in Different Empennages Configurations

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In the last years the airships have brought a renewed interest by the scientific community for their nature of a static lift, that makes them suitable for several missions requiring low speed and noise. The airship is a unique aircraft with slow dynamics and its stability and manoeuvrability have always been important aspects of its design; they mainly depend on the empennages configuration and on the weight and buoyant lift effects.

In this work a method is proposed, in order to investigate the effects on the longitudinal and lateral stability of an airship in different empennages configurations.

The longitudinal and the lateral linear model of the airship will be obtained only by combining geometric and aerodynamic data and the expressions of the initial trimming settings will be provided. The comparison between the "cross" empennages configuration and the "inverted Y" one is carried out for an unmanned non rigid airship. Results are illustrated by considering different weight conditions, including the so called heaviness condition, that means the airship weight exceeds the buoyant lift.

An example response of the lateral-directional linearized model is shown below.

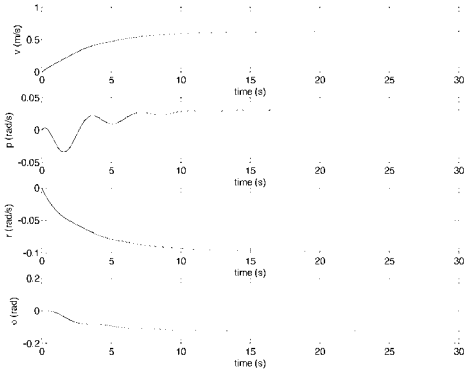

Figure 1. Inverted Y configuration-lateral response to a 5° rudder step

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A comparative analysis of optimization strategies for High-Lift system optimization

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The design of High-Lift (HL) systems represents a very complex task in aircraft industries, due to its multidisciplinary, multi-objective and multi-point nature. In the design of HL devices several performance indexes are to be improved or at least controlled, at different flight conditions (*e.g.*, Takeoff and Landing). Meanwhile, airworthiness requirements pose important boundaries to the design space and often complicate the optimization problem formulation. Additionally, both manufacturing and structural constraints must be early included in the design to ensure that the designed shape can be manufactured and guarantees the structural stiffness needed to sustain the high aero-loads occurring at such conditions. Finally, both mechanical integration and kinematical reliability aspects of the deployment system must be taken into account, such that unrealistic designs are avoided. All these features make the design of a HL system particularly difficult to be comprehensively tackled with a human based approach, due to both the large number of design variables involved and the large number of the constraints to be included, often translating into conflicting features and producing a narrow and sparse design space. Thanks to the maturity reached by the numerical optimization techniques, Computational Fluid Dynamics tools and the increased availability of computational resources, the large potentials and capabilities of automatic optimization can be nowadays exploited to enhance the design quality and reduce the design cycle time (costs). The DeSiReH project [1] (Design, Simulation and Flight Reynolds Number testing for advanced High Lift Solutions), aims at improving the aerodynamics of HL systems by considering, in a coordinated approach, the development of both efficient numerical design strategies and measurement techniques. Within this paper, an overview is given of the HL numerical optimization activities carried out in the Task 1.2 of the DeSiReH project, entitled "Evaluation of Different Optimization Strategies". Within this task, a group of 7 partners considered a realistic optimization of a Wing-Body HL configuration in the full HL flight envelope, both in 2D and 3D frameworks[2], and adopting different approaches in terms of employed flow model, meshing techniques, geometry parameterization and optimization approaches/strategies. The results obtained will be compared, efficiencies/deficiencies of the adopted approaches will be highlighted, and suggestions for future improvements will be provided.

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Experimentation of Fiber Optic FBG Sensors in a CFRP Aerospace Component

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This paper describes experimental activities performed on specimens representative of an aerospace component to verify the possibility of using optical fiber sensors during structural and environmental testing. The tests have been carried out in the Alenia Aermacchi factory in Venegono Superiore (Varese), in collaboration with DIAEE and DICMA Departments of Sapienza University of Rome. The experimental activity was aimed to demonstrate the possibility of monitoring aerospace components using Fiber Bragg Gratings FBG sensors, embedded inside composite materials . The specimen used for the tests were realized during internal testing activities performed by Alenia Aermacchi, and were intended to be used for destructive tests after a simulated 'aging' of the material. The components were cut from plates made of 72 plies of prepreg carbon fiber layers. Two specimen carrying 8 FBG sensors each were manufactured. The optical fibers were embedded during the manufacturing of the CFRP plates, to test the survivability of the fibers in an industrial environment. The FBG sensors were also used to monitor the stress of the material after the curing in an autoclave. The test plan involved also three other specimens to be monitored with FBG sensors glued on the external surfaces.
The tests were performed in several steps:

- Realization of the two specimens with embedded fiber sensors (July 2012);
- Non-Destructive Tests (ultrasonic scan, X-rays) to check the positions of the fibers inside the specimens from the CFRP plates;
- 'Aging' of the specimens in hot-and-wet conditions (submerged in water at T=70°C for 31 days);
- Interrogation of the FBG sensors after aging, to analyze the effects of wetting the material;
- FBG sensors were installed on the external surface of three specimens after aging;
- The specimens were used to perform destructive testing under a special pulling rig. The destructive tests were performed under hot conditions (the specimen was heat to a T=100°C using hot air).

The FBG sensors were positioned close to the Resistive Strain Gages used by Alenia Aermacchi to monitor the tests, so that the readings from the two kinds of sensors could be compared. The results are discussed in the paper.

Fatigue simulation of aeronautic parts using time-homogenized models

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When dealing with the numerical simulation of material fatigue, it seems more relevant to use a time transient evolution model describing how internal variables, such as plastic strain, or isotropic damage, evolve with respect to time, rather than classical fatigue life estimations. Indeed, these latter generally do not allow to accurately take into account the chronology of the applied cycles, or the inertia effects when high frequency loading cycles are applied. However, the computational cost associated with such a simulation can be prohibitive if each individual cycle has to be computed: this is all the more prohibitive as combined cycle fatigue is studied, where two periodic loads, whose associated frequencies are very different one from the other, are applied to the structure.

Therefore a periodic time homogenization method has been proposed in [1]: the plastic strain evolution within a structure is computed in a quasistatic framework. Since then, several extensions have been studied, such as the dynamic framework [2] or how to describe an isotropic damage evolution [3, 4]. The time homogenization method is based on the assumption that two different time scales (a fast one, associated with the fast cycles, and a slow one) can be defined and decoupled. It then allows to solve the different equations of the reference problem at the slow time scale only, by taking into account the averaged effect of the fast cycles in the homogenized solution.

The method has been validated on academic examples in the quasi-static [4] as well as the dynamic case [2]. The aim here is to apply this strategy on actual specimen geometries used in the European project PREMECCY [5]. Once the material evolution law has been identified, it should be possible to compare the fatigue life predictions with those obtained in experiments and then to have a tool to predict fatigue in structures undergoing their actual mechanical environment. The interactions occurring between fatigue and vibrations should then be enlightened.

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FADEC Logic and Icing Prevention in Aircraft Fuel Lines

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This paper summarize the work done to explore the possibility of extending the Full Authority Digital Engine Control (FADEC) logic to manage and prevent fuel icing hazard conditions in association with advanced fuel systems controllers toward a distributed fuel icing protection system architecture. Fuel icing may lead to fuel starvation and the use of fuel icing inhibitors is only a part of the remedy.
Gas turbine engine fuel systems are very susceptible to the formation of ice in the fuel filters. In general FADEC prevents the ice contamination thru the control of Heat Exchangers installed along the fuel lines by using the engine oil temperature and engine fuel measurement with the specific actions depending upon the temperature values and the aircraft flight conditions. The times when the greatest heating is required, i.e. when icing of the fuel filter is most likely, are often those times when the engine is not operating at maximum power, for example, during a lengthy descent from high altitude, or at idling in cold climates. Fuel system design criteria should prevent any ice accumulation within the fuel lines however in severe operating conditions where a ice is probable it is auspicated the FADEC logic could also reduce the pilot workload and maintain an adequate flame out margin beyond the operating envelope limitations set by the type certification. In general FADEC flameout and auto-relight detection logic is directly linked with fuel icing problems since the ice hazard is included in a broad list of other malfunctions leading to an engine flameout.
The most common FADEC logic provides continuous ignition and attempts in flight restarts with an automatic relight before the engine loses power. The work focus is thus given on how to manage the chances of engine failures in case of fuel ice contamination by analyzing various aircraft systems of heating fuel. Aircraft and engine fuel systems form one integrated heat management system and fuel recirculation to the aircraft tank is also managed by FADEC to limit the fuel and oil temperatures or to pressurise the fuel tanks. In case of a fuel icing problem, for instance if the engines are eventually "frozen" at idle, a quick response in a certain time frame is critical since a loss of Thrust (LOT) during flight at low altitude requires immediate action. The work done extends the state of the art analysis on ice management in the fuel system and investigates the specific role and design features of engine's fuel anti-ice components in order to determine their efficacy while looking at the possibility to extend their emergency behaviour under severe ice conditions. The challenge to the advancement of Intelligent Engines is then the development of new algorithm meaningless at this stage, like the evaluation of ice accretion rate in the fuel lines, in order to activate a FADEC extraordinary response and eliminate the risk of blockage. Innovative approaches to set FADEC engine speed when penetrating to heavy weather conditions is the next target . These new complimentary methods include fuzzy logic (FL), neural networks (NN), genetic algorithms (GA), and probabilistic reasoning (PR).

Aeroelastic design of Versatile Thermal Insulation (VTI) panels

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Launch vehicles design and analysis is a crucial problem in the space engineering. The large range of external conditions and the complexity of the space vehicle make the solution of the problem really challenging. The problem considered in the present work deals with Versatile Thermal Insulation (VTI) panel, embedded in the Cryogenic Upper Stage Technologies (CUST2) frame, that is a part of the FLPP (Future Launchers Preparatory Programme) sponsored by ESA. VTI is attached to the outside of the Upper Composite LH2 tank cylinder in order to reduce heat fluxes during the long coasting phases. During its mission VTI-panel[1] is exposed to a large number of load that have to be taken into account in the design procedure.

Figure 1. Configuration of the VTI panels around the criogenic tank

The aeroelastic behaviour of Versatile Thermal Insulation (VTI) is investigated in the present work. In the first part is presented a review of the available results from literature related to similar problems, the effect of various Mach regimes, including boundary layers thickness effects, in-plane mechanical and thermal loads, non-linear effects and amplitude of limit cycle oscillations (LCO) are considered.
Some preliminary analyses[2], only in the supersonic regime, have been performed with a dedicated finite element model. The models[3] used for coupling orthotropic layered structural model with Piston Theory aerodynamic models allows the calculations of flutter conditions in case of curved panels supported in a discrete number of points.
Advanced Computational Aeroelasticity (CA) analyses were perdormed by using various dedicate commercial software (CFX, ZAERO, EDGE) in order to investigate the aeroelastic behaviour in the transonic regime. A Wind Tunnel (WT) test campaign was carried out in order to assess the computational tool in the analysis of the problem. The results show that the aeroealsticity play an important role in the design of the VTI panel.

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Electronic Speckle Pattern Interferometry (ESPI) for impact damages evaluation on CFP

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In this work, the application of Electronic Speckle Pattern Interferometry (ESPI) in composites, which are used in the aeronautic field, is presented. Through real-time surface illumination by visible laser (i.e. 532 nm), the ESPI technique allows the non-contact, non-destructive detection of micro-deformations, micro-cracks, residual stress and delaminations. The measurement range and accuracy is related to the light wavelength and the deformation value is measured by half-wavelength multiples. The method records the surface field differential displacement, due to thermal or mechanical strains. A CCD camera records the whole field deformation into images to be processed. By this technique, it is possible to reveal hidden defects and to evaluate the effective delamination area due, for example, to an impact damage.

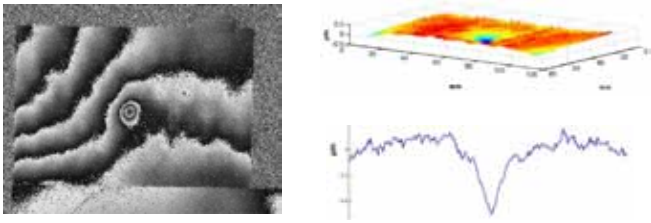

Figure 1 CFP: contrast phase image (left) – 3D elaboration (right)

In this study, ESPI technique has been used to evaluate the effective delamination area of damaged Epoxy-Carbon Fibers Composites that have been manufactured by Pulsed Infusion, an Italian patented innovative vacuum assisted infusion process. In particular, the composite panels have been realized by using a one-component commercial aeronautical resin (RTM6 from Hexcel) and eight dry unidirectional carbon plies having a quasi isotropic stacking sequence $[0°, 90°, +45°,-45°]_s$ and then, have been subjected to low velocity impact tests at different impact energy levels. A good agreement between the ESPI results and literature impact model data has been found, which confirms the reliability of the proposed technique.

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Optimal Design and Acoustic Assessment of Low-Vibration Helicopter Rotor Blades

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Main rotors play a fundamental role in helicopter dynamics, providing both lifting force and thrust but, as a by-product, they are sources of vibrations and noise. The reduction of these annoying effects is of primary interest for rotors designers. The objective of this paper is the presentation and application of an optimal procedure for the design of helicopter main rotors generating low vibratory hub loads, that considers blade shape and structural properties as design parameters. It is a very challenging goal,[1] in that it deals with an inherently multidisciplinary, multi-dimensional, constrained minimization problem, characterized by non-linear, multi-modal objective functions. Because of this, the optimal solution has been determined through the application of a binary genetic algorithm, under aeroelastic stability constraint. Within the optimization process, vibratory loads and stability behaviour are predicted by an aeroelastic tool for helicopter rotors recently developed by some of the authors,[2] that is based on a nonlinear, beam-like model, suited for the analysis of arbitrary curved-elastic-axis blades. For the sake of computational efficiency, a surrogate wake inflow model is introduced for the analysis of blade aerodynamic loads. Numerical results demonstrate the capability of the proposed approach to identify low vibratory hub loads rotor blades. The influence of the wake inflow surrogate model on the optimization process has been examined, as well as the robustness of the solution at off-design operating conditions. Finally, an aeroacoustic assessment of the rotor configurations identified is carried out, in order to examine the impact of low-vibration blade design on the emitted noise field.

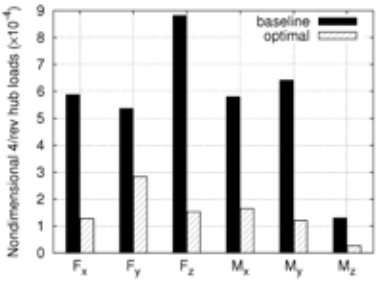

Figure 1. Figure caption example

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An Isothermal Characterization of Fluid-dynamic Configurations for Ultra-lean Mixture Combustion Stabilization

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Lean Premixed Combustion (LPC) is the aim of several gas turbine (GT) configurations to achieve near zero emissions of NO_x. However, combustion stabilization of lean and ultra-lean mixture remains a key issue for both conventional and alternative LPGT based on internal recirculation concept, since it has been recognized that the use of mixture close to the lean flammability limits can lead to combustion driven oscillations problems.
Here, a novel configuration based on opposed multiple jets is proposed. Such a configuration can represent an alternative to conventional one, ensuring very high level of combustion products mixing with lean/ultra-lean fresh mixture, overcoming combustion instabilities problems.
An isothermal characterization of the flow patterns inside the combustion chamber has been carried out by means of Particle Image Velocimetry (PIV) and numerical simulations with RANS approach.
More specifically, a parametric analysis of the mixing process has been performed varying the main process parameters, namely inlet jet Reynolds number and jets number.
Results highlighted that for all the configurations considered, the mixing process is strongly enhanced as compared with a free jet, chosen as reference case.

Assessment of a state-space aeroelastic rotor model for rotorcraft dynamics analysis

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This paper deals with the assessment of a methodology developed by some of the authors[1] for the identification of the state-space representation of helicopter rotors aeroelastic behavior, which relates hub motion and blade pitch controls to the loads transmitted to the fuselage. It is suited for the simulation of the dynamics of comprehensive complete helicopter configurations. Observing the inherently time-periodic nature of theoretical formulations describing rotor aeroelasticity, the state-space form identification method consists of the following three-step process, under condition of rotor blade aeroelastic stability: (i) (multi-harmonic) responses to a set of small-perturbation harmonic inputs are evaluated within a prescribed frequency range; (ii) the values of the corresponding transfer function matrix (linear time-invariant approximation of the aeroelastic operator) are determined from the harmonic content of the outputs; (iii) the transfer function matrix is approximated in rational-matrix form. The poles introduced by the rational forms are related to the dynamics of the blade degrees of freedom (not explicitly appearing in the proposed aeroelastic representation).

In the paper, the focus is on the assessment of accuracy and computational efficiency of this state-space rotor aeroelastic modelling. To this aim, it will be compared both with alternative approaches suited for simple aeroelastic models with explicit dynamic variables (like, for instance, those based on quasi-steady aerodynamics), and with time marching responses of the complete aeroelastic system. Further, the computational cost of the proposed methodology will be examined, with the scope of determining the optimal application of the above-mentioned three-step procedure for an efficient state-space model identification. Finally, the state-space aeroelastic rotor model will be applied to complete helicopter configurations for fixed-commands and pilot-in-the-loop stability analyses.

The numerical investigation will be carried out using a rotor aeroelastic tool developed by some of the authors,[2] which is based on beam-like blade structural modelling, coupled with aerodynamic loads predicted either by a quasi-steady, sectional formulation or by a boundary element method for potential flows capable of taking into account aerodynamic interactions such as main-tail rotor interference and wake-body impingements.[3]

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A Reduced Order Model for a rapid evaluation of SCIROCCO PWT nozzles flowfield

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The numerical simulations of the Scirocco Nozzles, able to reproduce critical flight conditions in order to qualify spacecraft components, is very time-consuming due to the very complex physical phenomena involved in. The description of this flows require huge number of Degrees of Freedom (DOFs) if solved with a Full Order Model, like a RANS code.
From the point of view of the Industrial objectives of the Facility, a fast and accurate rebuilding analysis of a Test Campaign is hopeful and desired, in order to reduce the preparation time needed to design each test (reducing the 'time to market' of the Facility).
This considerations represents good motivations to define and build a Reduced Order Model (ROM) of the PWT Nozzles, using the Proper Orthogonal Decomposition (POD) technique. The ROM is based on previous Full Order Model CFD simulations. In particular, a Database of 30 Aerothermal FlowFields of Scirocco nozzles was collected.
Each realization in DB is a sample of the Operative Envelope of the facility, parameterized in terms of two reservoir parameter, H_0 and P_0.
The numerical simulations was conducted with in-house CIRA code, H3NS, able to simulate three-dimensional subsonic, supersonic to hypersonic flows of a reactive mixture of perfect gases in thermal and chemical non-equilibrium.
The Proper Orthogonal Decomposition is applied to the DB simulations, resulting in a new representation of this one, described by 'optimal' POD modes ('optimal' in average sense), and scalar POD coefficient, also note as 'evolutionary coefficient'.
Defining a functional form of the relation between the scalar coefficients and the PWT reservoir parameters (H_0,P_0) with Kriging technique, it is possible to evaluate, in the limits of the Scirocco nozzle Envelope, every nozzle conditions with the POD-ROM model here defined, without additional NS computations.
Furthermore, a Cross-Validation analysis of the ROM is performed, based on Leave-One-Out technique. This error analysis gives a way to a progressive refinement of the ROM, with further sampling of the envelope of the Facility, selecting regions with large errors. In this way, the POD subspace is enriched.
In conclusion, the final tool is a flexible instruments able to compute the full aerothermal flowfield of the PWT nozzle with acceptable approximation, by-passing huge CFD computations.

Application of analytical models for thin delamination buckling in composite materials panels

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The phenomenon of delaminations significantly reduces the resistance of structural components under compressive load; at last, growth of the delamination zone may lead to premature failure of entire structure. The use of non-linear FEM analyses for delamination buckling and growth simulation with the VCCT techniques, even if accompanied by global/local coupling, is still unsuitable for preliminary design and optimization of composite structures. For this reason, in the design of aerospace structures, the practice for taking in account the strength reduction induced by these defects is to introduce an artificial threshold by keeping strains below some limiting value at ultimate levels of load.
Faster methodologies (analytical and/or empirical) for delamination buckling and growth initiation critical load estimate are desirable in order to support the effective "damage-tolerant" design of composite structures.
The most used method for the delaminations analyses is the Raileigh-Ritz energetic method, used with a guessed buckled shape of the delamination. With these assumptions, many authors (e.g. [1], [2]) have analysed the typical delamination shapes, as circle and ellipse in simple cases. For real cases (irregular or "peanut" delaminations), some authors use FEM analysis ([3]), and other explore the possibility to use the simple geometries of circle and ellipse ([4]).
In this paper a new developed analytical model for the calculation of the global buckling load of a plate with a delamination, local buckling load of delaminations with different shapes, and delamination growth loads are presented and applied to several test cases for validation purpose. Analytical results are compared with FEM results both for isotropic and composite material. The test cases are chosen in such a way to be representative of the most important cases of delamination which can be straightforward analysed with analytical methods.

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LARES Satellite: the best test particle for testing General Relativity

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The LAser RElativity Satellite (LARES) is an Italian Space Agency laser ranged satellite. Soon after the successful launch with the VEGA maiden flight on the 13th of February 2012, we started to analyze the ranging data from about 40 stations of the International Laser Ranging Service (ILRS). The satellite is not provided with electronic equipments, power system or attitude control, it is a passive satellite covered with optical Cube Corner Reflectors (CCR) that send back to the same direction of emission an incident laser pulse. This allows the accurate positioning of the satellite, that is important because the geodesic motion of a test-particle is at the foundation of the Einstein's theory.
Aim of the LARES mission is in fact to test frame-dragging and the Lense-Thirring effect of General Relativity. That is a spinning body distorts spacetime, dragging the inertial frame around it and the orbital plane of a satellite. In the case of the LARES mission, the shift of the line of the nodes will be accurately measured versus what predicted by the Newton's Law. Analysing the data of LARES, LAGEOS and STARLETTE satellites starting from the launch date of LARES, a comparison among the orbits shows that the LARES motion fits better the theoretical geodesic motion of an ideal test-particle than any other orbiting object in the solar system. We found in fact that the deviation of the along track acceleration from its geodesic motion is less than 0.5×10^{-12} m/s2.
In the paper, the scientific objectives of the mission and the preliminary results of the analysis will be reported. The paper will also address the outstanding behaviour of LARES as a test particle for fundamental physics and geodesy and how that has been achieved.

Blade Vortex Interaction 2D modelling for rotor noise control synthesis

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Helicopters operate in extremely complex aerodynamic environments, with rotors working very close to their own wakes. As a consequence, rotors are one of the main sources of noise and vibrations, with fluid-structure interaction phenomena playing an important role.[1] In particular, during manoeuvers and low-speed descent flight conditions, one of the most relevant fluid-structure interaction mechanism producing noise and vibrations, is the Blade Vortex Interaction (BVI), that produces impulsive aerodynamic loads on the rotor blades.

The aim of the present work is to present and apply a methodology for the identification of a multi-cyclic higher harmonic control, based on the actuation of the blade pitch such to generate loads alleviating those from BVI (anti-BVI loads), and hence reduce emitted noise and structural vibrations. The blade pitch actuation is defined by a feedback control law obtained through a multi-cyclic controller which, in turn, is derived from an equivalent two-dimensional, multi-vortex, parallel BVI problem that simulates blade cross sections aerodynamics in BVI conditions.[2] This approach yields a particularly efficient computational procedure for the synthesis of the control law.

The proposed multi-cyclic controller will be applied to a realistic helicopter main rotor in descent flights. Numerical investigation will assess the effectiveness of the control action in alleviating BVI blade loads and emitted noise, and the computational efficiency of the control synthesis methodology.

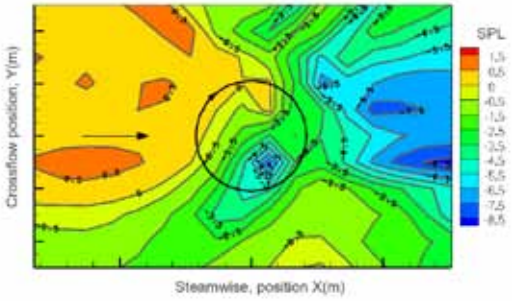

Figura 1. OASPL reductions [dB] due to control action.

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LARES mission: engineering aspects

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LARES is a satellite of the Italian Space Agency and has been successfully launched with the new VEGA launcher using the inaugural flight VV01. LARES is the main payload and has been released, first, after 55 minutes from lift-off, using a specially designed separation system. Eight more university satellites were on board and were released in an elliptical orbit with a very low perigee to fulfil the orbital debris mitigation measures. The main payload has been injected in a circular orbit at 1450 km altitude. This height was the maximum achievable on the qualification flight, though the launcher capability had no such a limit. This maximum altitude was required to minimize atmospheric drag and the satellite has been designed to minimize all the non-gravitational perturbations acting on the surface of the satellite. This was of paramount importance because the mission objective is to test Einstein general relativity, and any unmodeled effect could spoil the accuracy of the relativistic measurement. With the optimal design achieved this non-gravitational unmodeled effects are maintained below 1% of the Lense-Thirring Effect (LTE). LTE is the orbital node shift induced by the Earth rotation and predicted by general relativity. This shift is very small and amounts to about 4 m/year for LARES. To maintain the total error around or below 1% also the gravitational uncertainties need to be handled. For this purpose data from a constellation of three laser ranged satellites (LAGEOS 1, LAGEOS2 and LARES) along with the newest description of the Earth gravitational field by GRACE are used to perform the measurement. The satellite is passive and covered with 92 Cube Corner Reflectors (CCRs) that have the properties of reflecting back to the emitting ground station the laser pulses independently on satellite attitude. Another aspect of the mission is the ground segment which is constituted by the International Laser Ranging Service (ILRS). About 50 laser stations are located in different part of the globe: counting the time of flight of laser pulses sent to the satellite and back to the stations it is possible to range the satellite with accuracy that, for the best stations, can reach few mm. By solid triangulation, using orbital estimation programs and using more stations it is possible to achieve the satellite position and ultimately the orbit. In the paper all the engineering aspects of the mission will be addressed.

Collision risk studies using the open source flight dynamics model software library JSBSim

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This paper presents an application of a desktop flight simulation software in the field of collision risk assessment. The conceptual problem addressed here is the analysis of flight trajectories with a deterministic tool to support statistical studies of aircraft impact with on-ground obstacles.
The practical case considered is that of a hypothetical wind farm to be located in the proximity of a given aerodrome. Each turbine tower of the farm is potentially unsafe for flight operations, and one has to make sure that their designed placement complies with the airworthiness regulations. These are based on the definition of different conventional volumes surrounding the aerodrome whose boundaries, e.g. IHS (Inner Horizontal Surface), TOCS (Take Off Climb Surface), Conical Surface (CS), ATZ (Aerodrome Traffic Zone), OHZ (Outer Horizontal Surface), have to be carefully taken into account when introducing new obstacles.
When some of the wind turbines violate slightly the clearance rules, the airworthiness authority requires specific "aeronautical studies" aimed at demonstrating that each new obstacle does not modify the established safety level and the regularity of flight operations.
Aeronautical studies nowadays may take advantage of the availability of advanced engineering flight simulation software. These deterministic tools help to select a range of critical flight situations as a base for subsequent statistical studies for collision risk assessment.
The flight simulation software presented in this paper is JSBSim, an open source flight dynamics model (FDM) software library. JSBSim is a high-fidelity, 6-DoF (Degree-of-Freedom), general purpose software written in the C++ programming language. The library routines propagate the simulated state of an aircraft given inputs provided via a script or issued from a larger simulation application. The inputs can be processed through arbitrary flight control laws, with the outputs generated being used to control the aircraft. Aircraft control and other systems, engines, etc. are all defined in various files in a codified XML format. The library consists of approximately 70,000 text lines in 185 files. Begun in 1997, JSBSim has an international team of active developers and user contributors. It is released presently as open source software (OSS) under the LGPL license, and can be incorporated into larger flight simulation architectures (such as FlightGear, or OpenEaagles).
Thanks to a large worldwide community of users of this free simulation and modelling tool, many advances have taken place, and a variety of uses have been demonstrated.
JSBSim can be run as a standalone batch application when linked with a stub routine. This is the way we have used the flight simulation software to carry out our collision studies. The figures below report some examples of trajectory analyses. These enabled a preliminary collision risk estimation for airplanes of a given category flying in the proximity of the wind farm.

Keywords: component; Flight simulation; aircraft modelling, collision risk.

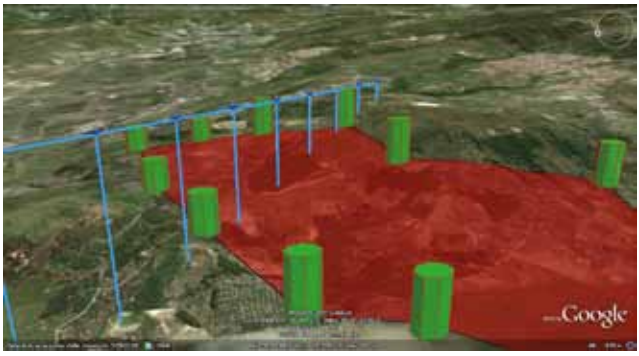

Figure 1. Simulated flight path colliding with the topmost point of the wind farm.

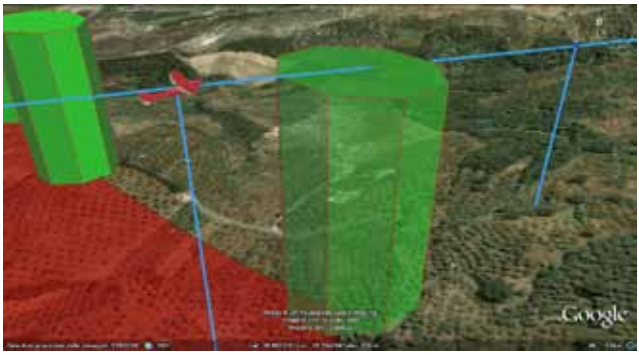

Figure 2. Close-up of a colliding flight path.

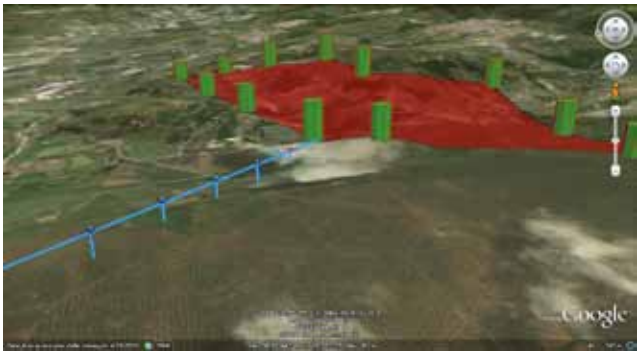

Figure 3. Collision with the base of the lower most point of the wind farm.

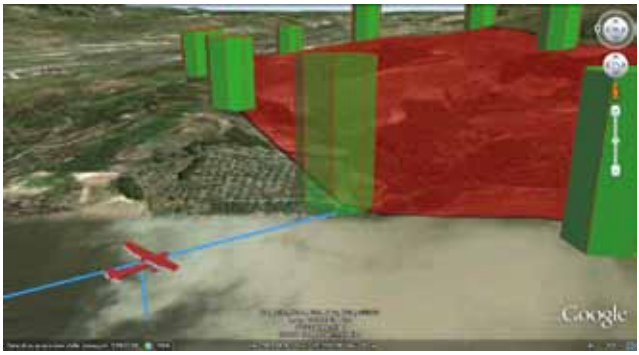

Figure 4. Close-up of a colliding flight path.

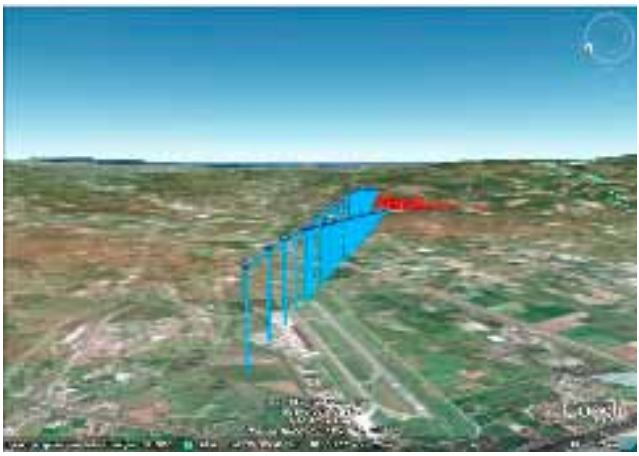

Figure 5. Three-dimensional view of two critical flight situations: engine failures with subsequent colliding trajectories.

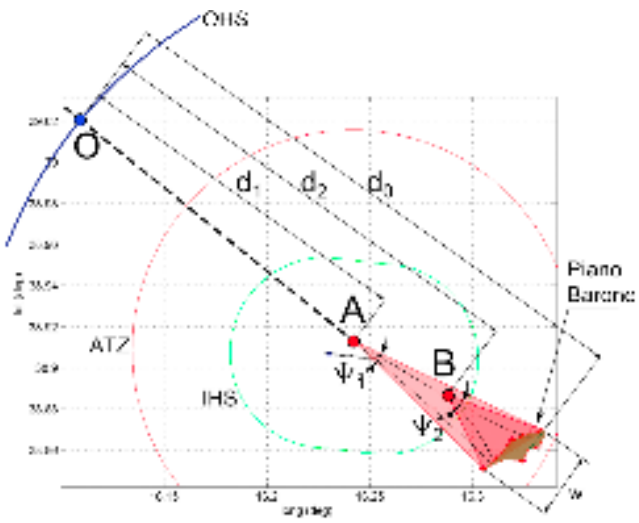

Figure 6. Geometrical definition for preliminary estimations of collision risk (cased on previous flight simulation analyses).

MISTRAL: Air-Launchable Micro-SaTellite with Re-entry Capability

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MISTRAL fits into the broader range of space re-entry systems for recovery and return on Earth of samples and others materials from space that may become of great importance in the future. In fact, with the recent end of the NASA Space Transportation System program (Space Shuttle), this activity depends nowadays only on the Russian Soyuz TMA capsule, thus putting limits and economic constraints to the development of space activities. In this scenario the development of a low cost, easy to use, small capsule could demonstrate to be a convenient alternative to perform different types of scientific and technological missions.

The primary objective of the MISTRAL project is to develop a multi-purpose air-launchable 30 kg class micro-platform with re-entry capability. This approach decouples the use of the platform from the availability and intrinsic limitations of any ground launch base, providing to the system high flexibility with respect to a specific mission and guaranteeing short time to use. As an R&D project, MISTRAL will develop a full prototype ready to execute a demonstration mission in which the payload will be essentially focused on monitoring and eventually managing the functional and health status of the capsule during its first flight.

The design choices stem from economic and practical reasons given the need and opportunity to develop in the medium term a reliable system with cost levels capable of enabling wide applicability. The project aims to develop research and experimental development to reach the prototype demonstration phase for a small space re-entry capsule, able to return limited mass and volume payloads back to Earth from Low Earth Orbit.

The main characteristic of the capsule is a deployable front structure that will be used as both an aerobraking device to slow down the capsule and produce the orbit decay, and a heat shield during the most demanding re-entry phase. During the orbital phase, the deployable structure will be used to control the duration of the orbital decay phase in order to assure the right approach to the defined aerocapture point, where the re-entry phase starts. The deployable “umbrella-like” structure can also be integrated with other functional elements, such as solar panels, antennas, payloads, etc.

Despite the domestic industry has in the past participated in activities aimed at developing re-entry spacecrafts, also in the frame of European programs, so far a capsule with similar characteristics has been neither in Italy nor in Europe produced.

The project will be developed in the frame of the Campania Region Aerospace District (DAC), by a cluster including large industries, SMEs, research organizations and universities with the aim of acquiring the necessary know-how to plan the industrialization phase of the product, qualified and suitable for different commercial applications.

This paper will illustrate characteristics and key technologies associated to the capsule, giving also proper view of the programmatic aspects.

Analysis of LAPCAT A2 Vehicle Scimitar Engine Nozzle

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This paper describes numerical and experimental activities performed in LAPCAT-II EC-funded project[1,2] to assess the performance of the A2 vehicle Scimitar engine nozzle[3,4]. Different nozzle geometries have been analysed to determine the best method to minimise base pressure effects and verify the theoretical design. CFD activities are dedicated to analyse the nozzle plume/external flow interaction at different flight conditions, and the nozzle flow at Mach 5 cruise condition with different physical modelling, with also a look to combustion products and nozzle throat sizing heat fluxes.

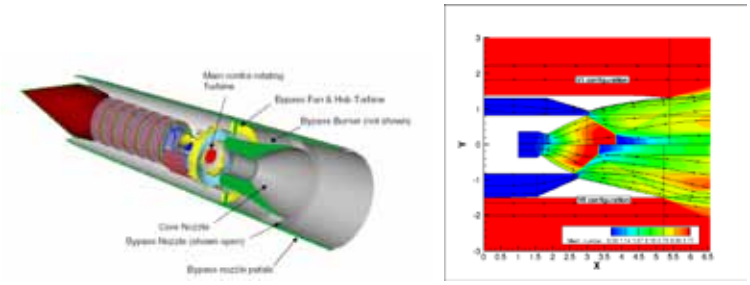

Figure 1. Scimitar engine (left) and CFD results in terms of Mach number contours (right)

Scimitar coaxial nozzle experiments have been performed at GDL hypersonic wind tunnel for Mach 4 trajectory point, to properly assess nozzle plume/external flow interaction and base pressure effects. After CFD rebuilding and comparison with the measurements, the full paper will end with some considerations and conclusions about nozzle design and performance, so allowing a re-assessment of vehicle's overall performance and the definition of a detailed development roadmap.

Acknowledgements

This work was performed within the "Long-Term Advanced Propulsion Concepts and Technologies II" project investigating high-speed transport. LAPCAT II, coordinated by ESA-ESTEC, is supported by the EU within the 7th Framework Programme Theme 7 Transport, Contract no. ACP7-GA-2008-211485. Further info on LAPCAT II can be found on http://www.esa.int/techresources/lapcat_II.

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Aircraft Seat Engineering & Certification

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Since 1974 Aviointeriors supplies airline companies with customized interior products. Focused its manufacturing, mainly, on passenger seat but has within its capability list, also, manufacturing of furniture, sidewalls, galleys, lavatories. The seat design is developed to be installed onto cabins for Boeing, Airbus, ATR and other passenger aircraft in accordance with TSO/ETSO design approval letter. In details the requirements to obtain, from EASA and FAA, the approval are referred respectfully to CS rules and FAR rules. Certification process for passenger seat, referred to Part 25, is developed on the integrity of the structure and occupant safety, conjunction to be made perfect with the functional, aesthetic and comfort performance. With the above mentioned regulations, certification process required testing to demonstrate the structural integrity and occupant safety. Due to the complexity of seat design on the customer request in terms of comfort to be offer to occupant inside cabin , kinematic simulation and ergonomic studies are performed with a frequency so high like the same made for the developing of a cockpit for a car.

Figure 1. Aviointeriors Venus Seat and Furniture for a First Class

A lot of testing are required for the seat equipped with In-Flight Entertainment (IFE) available to aircraft passengers during a flight. A lot of environmental, abuse and dynamic fatigue testing are required for the qualification of seat to install onto a cabin as per an aircraft layout. In conclusion the intent of this argumentation is the presentation of engineering and certification activity surrounding a singular product , like an aircraft passenger seat, to be installed on old aircraft and on aircraft , into next future, such as new and bigger B787 and A380.

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Experimental investigation on the heat transfer of impinging synthetic jet in different regimes

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Synthetic jets or zero-net mass flux jets are recently widely studied for the convective heat transfer enhancement especially in electronic cooling applications[1, 2]. Such studies focused on seeking to determine the heat transfer mechanisms in impinging synthetic jets varying several characteristic synthetic jet parameters, for example stroke length and nozzle-to-plate distance. In this work, a classical circular impinging synthetic air jet is studied to evaluate the convective heat transfer coefficient achieved through the jet impingement on a heated flat surface. The experiments are carried out using IR Thermography, through the heated thin foil method, at a fixed Reynolds number equal to 2,200 but over a range of experimental parameters including stroke length and nozzle-to-plate distances such to perform all the synthetic jet heat transfer regimes according to McGuinn et al.[2]. The employed device is a twin circular synthetic air jets which is obtained through a loudspeaker that splits a cavity in two sub-cavities. The loudspeaker, whose diameter is 270 mm, splits the cavity in two sub-cavities with a volume V equal to 2 dm^3. The two pipes, attached to both sub-cavities, have a length L of 210 mm, an inner diameter D of 21 mm and, in order to obtain the classical configuration, one of the two synthetic jets is deflected by using a bended tube at the exit of the orifice.

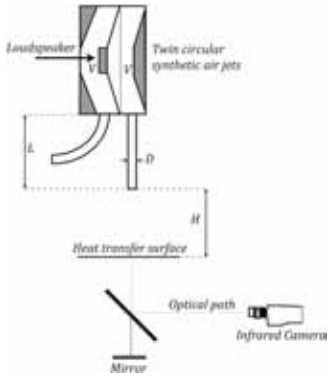

Figure 1. Schematic of the experimental setup

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The inverse Finite Element Method for shape sensing of aerospace structures

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Shape sensing generally involves the reconstruction of a deformed structural shape using surface-measured strains. This technology can enable effective real-time monitoring of structural integrity, provide feedback to actuation and control systems of morphing structures, and monitor the deformed shape of embedded conformal antenna systems.
Critical issues in the definition of a viable shape sensing algorithm are: computational speed, robustness with respect to inherent errors in the strain measurements and ability to model complex structural topologies under a wide range of loadings, material systems and inertial/damping characteristics. Tessler and Spangler [1] developed a robust and efficient algorithm for the full-field reconstruction of displacements, which is amenable to general built-up shell structures. They employed a least-squares variational formulation for the shape sensing of plate and shell structures that accounts for the complete set of deformation modes of first-order shear deformation theory (stretching, bending, and transverse shear). A C^0- continuous discretization of the displacement field was applied to the functional, yielding the formulation of an inverse Finite Element Method (iFEM) [2]. Recently, with the goal of analyzing an important class of space structures, Gherlone et al. [3] applied the iFEM variational framework [1] to develop several three-dimensional, shear-deformable beam and frame inverse finite elements.
In this paper, the general iFEM methodology for beam, frame, and plate formulations is presented. Shape-sensing applications to structural components generally used in the aerospace industry will be presented and discussed. Both numerically generated and experimentally measured strains will be used as input data for the iFEM-based displacement field reconstruction.

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Multi-Body Model Validation of a Landing Gear System for a General Aviation Aircraft

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The present work is aimed to numerically validate the experimental drop test results [1], related to the landing gear of a general aviation aircraft, in order to define an appropriate simulation methodology able to save time, costs and risks due to structural design and experimental test campaign required in the certification phase.
The aircraft selected for this research activity is the AP-68TP-300 Spartacus, an Italian nine-seat, twin-engined, high wing monoplane, realized by Vulcanair S.p.a..
The multi-body approach has been developed through the MSC Adams software, starting from a simplified 1D model up to a more detailed 3D one.
The comparison between numerical and experimental results in terms of load factors has been carried out in accordance with CS-23 [2-3] (Certification Specifications for Normal, Utility, Aerobatic and Commuter Aeroplanes), and it has shown a good correlation, especially for the 3D model, since it better fits the real behavior of the entire system.

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Study of volcanic ash particles through PERM lean burn combustor

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Volcanic eruptions can eject huge quantities of solid material (ash) into the atmosphere that poses significant threats to aviation. Ash ingested by jet engines may lead to the immediate deterioration in engine performance and possible failure. The strong contrasts in temperature inside the engine provide an environment that will cause the solid ash particles to melt and then re-solidify. Consequently they can coat fuel nozzles, with impact on reduction of fuel mixing efficiency and restriction of air passages through the engine. This causes surging, immediate loss of engine thrust and ultimately results in engine flameout. After the outburst of the Eyjafjallajökull volcano (2010) in Iceland, the European Commission supported research related to the impact of volcanic ash on core engine components. In the framework of NEWAC[1] European research program, AVIO developed a tailored CFD code that includes advanced models for solid particle tracking, heat up, particle-wall interaction and deposition in order to obtain a better insight into the phenomena occurring in a combustion chamber when volcanic ash is ingested. The above software is a post-processor that uses as input a converged CFD reactive flow-field solution obtained by using AVIO BODY3D in-house code. The lean burn combustion system, based on the PERM (Partially Evaporated and Rapid Mixing) injection system concept, designed and developed in the frame of NEWAC SP6[2], has been the object of such CFD investigation. All calculations have been carried out at the same operating conditions, corresponding to the cruise point NEWAC FCC S/R cycle. A model sensitivity analysis focused on the variation of the ash density and the ash particles diameter distribution has been carried out. The fraction of sticking particles has been evaluated as well as the fraction of particles that pass through the combustor exit and inner/outer bleed ports. Finally the assessment of particles temperature level reached at the combustor exit plane has been done.

Figure 1. Zones where ash particles have stuck.

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Modelling of Gas Turbine Combustor Ignition and Altitude Relight

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The requirement of altitude relight of a combustor in the operative envelope of an aircraft engine is particularly critical for low emission combustors based on the concept of lean combustion.
This topic is at moment object of innovative research and for full annular combustors test plant are used where altitude conditions are simulated in order to analyze the behaviour of a combustor in terms of pressure, temperature, mass flow rate and fuel air ratio.
For the complexity of phenomena of ignition and flame propagation in presence of spray liquid fuels in turbulent flows an approach of cut-and-try type is used even today.

The aim of the paper is to describe the development of a model for the numerical simulation of the flame propagation based on a RANS-CFD application. This model allows characterizing a combustor in term of ignition as a function of the position and performance of an ignition system.

The model is implemented in suited version of Avio in-house CFD code BODY3D developed for the analysis of reactive turbulent flows in combustors.

Starting from a stabilized non-reactive and two-phase flow field calculated in the pre-ignition conditions inside the combustor a number of flame particles are injected in the domain and tracked in a lagrangian way with a simplified Langevin model that uses a stochastic differential equation.
The flame particles are simply convected by the turbulent flow and undergo random walk to model dispersion.
Every time that a particle enters a cell of the computational domain where the fuel/air condition and turbulent flame speed are favourable, the cell is ignited and a new flame particle is generated, starting from that position with boundary conditions dependent from turbulence by means of a generation of random numbers.
The flame particles switch off when they enter in a cell where the conditions are adverse or when they hit a solid wall.
The simulation must run a number of times (about 25) in order to get the Probability Ignition Number, that is a measure of the success or fail of the ignition in the present conditions.
The model has been validated with the experimental data on a tubular burner carried out at Cambridge University.

Experimental and Numerical Assessment of Ultrasonic Wave Propagation in Sensorized Carbon Fiber-Reinforced Epoxy Laminates

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The propagation characteristics of Lamb waves in composites are investigated numerically and experimentally in this paper. The numerical tests are performed with the explicit FE solvers LS-DYNA[1] and ABAQUS[2] and modeled using 3D element as continuum or thick shells and solid elements employed separately to construct the composite panel models. To verify and compare the element performance in predicting the ultrasonic wave propagation, dynamic analysis is conducted for a composite laminate. The results obtained from the analysis of the FE model are the time histories of the node displacements; these time histories are processed to obtain the group velocities of the Lamb waves. Finally, the velocity prediction is compared with the experimental velocities and theoretical velocities calculated with the resolution of the Rayleigh-Lamb frequency equation that allows to plot the dispersion curves of any wave mode. For laminated composite plates a good agreement is found between numerical, analytical and experimental data over a wide variety of lay-up sequences, especially for the simple model using one continuum shell element through the thickness.

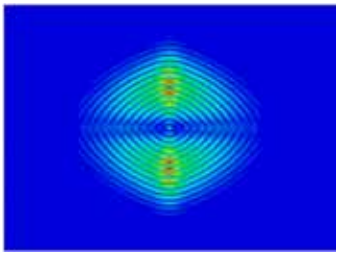

Figure 1. Equivalent tensile stress at a specific time in $[0/90]_4$ composite laminate using one thick/continuum shell element through the thickness.

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Structural Analysis of Damaged Structures through 1D Refined Models

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The proper detection of damages in structural components is of primary importance in many engineering applications. The detection of damages is, in fact, required to evaluate the reliability of structures. A tool to evaluate structural damages is the modal analysis since damages can affect the natural frequencies and modal shapes of a structure.
In this paper, damages are introduced in various structures and their effects are evaluated in terms of variations in natural frequencies and modal shapes. This work could be considered as a preliminary effort aimed to the creation of a set of guidelines and recommendations on damage effects to be used for damage detections.
Computationally cheap 1D structural models were used in this work. These models are based on the Carrera Unified Formulation (CUF) and provide shell- and solid-like accuracies with far less computational costs than shell and solid finite elements [1-3]. 1D CUF models are built according to arbitrary expansions of the unknown variables above the cross-section domain of a structural model. The order and the type of the expansion are free parameters of the analysis. In this work, Taylor and Lagrange polynomials were used.
Results show that 1. Damage effects can deeply vary depending on the damage intensity and location, 2. 1D CUF models can detect typical behaviours of damaged structures such as the bending-torsion coupling, 3. 1D CUF low computational costs are of particular interest since many analyses are required to create a reliable set of guidelines for the damage detection via modal analysis.

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From numerical modeling to acoustic virtual prototyping

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Acoustic performances represent an important business aspect both referred to aeronautical product than transportation means in general. This because of the daily growing attention to annoyance and comfort parameters related to vibro-acoustic phenomena.
Very often, numerical modeling represent a powerful tool for the prediction of expected noise level once structural characteristics and noise source specification have been defined. These model can be assumed as relative simple when pure acoustic interaction are involved in geometrical elementary configuration and may become very complex when strong interaction of structural and acoustic elements are involved as wells as the frequency range of interest increase.
In any case, the availability of different, complementary approaches as those based on FEM, BEM, SEA, Ray Tracing , among the others, let assume that appreciable results can be achieved. By the use of these tools it is possible, for example, to compare the results of different technical solutions or to verify the correspondence to technical specification, avoiding the cost of the real prototyping.
In this scenario, it can be stated that one of the bigger limitation of these technique is the unavailability to investigate the subjective (more that objective) response to noise exposure that in many case in considered an important parameters when comfort or annoyance aspect need to be evaluated.
That is the reason why deep interest in going to be dedicated to the "acoustic virtual prototyping" intended as the auralization process of a numerical simulation, that would guarantee the opportunity to "hear" the noise more than analyse its "technical descriptors".
It is important to underline that the not-stationary peculiarities of the phenomena, require that relative implementing tools have to be very fast in the signal computation as extremely precise in the signal reconstruction to guarantee the correspondence of "virtual " noise to real expected one.
The present work will present some results related to the implementation of a specifically designed digital FIR filters that, starting from results of "standard" numerical models (FEM/BEM or others), are able to reconstruct the time related system response and to digitalize the expected noise.
First test have been performed on a geometrical simple box set-up, in relation to which both numerical model and experimental test campaign have been realized. The Matlab/Simulink implemented filters have showed good results in signal reconstruction opening to further application at more complex systems and real-time implementation.

A mesh morphing based technique to efficiently perform FSI analyses for aeroelastic design applications

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In this paper an innovative and fast method to tackle aeroelastic problems dealing with aircrafts is presented. This procedure is based on the use of the finite volume commercial solver ANSYS Fluent coupled with the RBF Morph. This tool is capable to manage the structural displacement of the deformable structures of an aircraft by properly imposing a combination of their modes through mesh morphing. Before running the FSI analysis, modal bases of the structures are computed by means of a FEM solver and then imported into the morpher. During the CFD computing stage these modes are combined and applied on the fly by morphing the mesh of the computational model so as to gain the deformed configuration. Mesh morphing is accomplished according to the Radial Basis Function mathematical technique whilst the surface aerodynamic loading is determined by performing the integration of modal forces directly on the CFD mesh. The major benefit of proposed approach is that the modal parameterization has to be built only once, whilst the new CFD model becomes intrinsically elastic during the calculation phase, thus drastically reducing the computation time. This process has been applied to diverse industrial cases of interest with the purpose to characterise the accuracy and reliability of the proposed approach, especially when dealing with very large models. In all cases, the modal approximation error has been carefully monitored and in general a very good agreement has been observed.

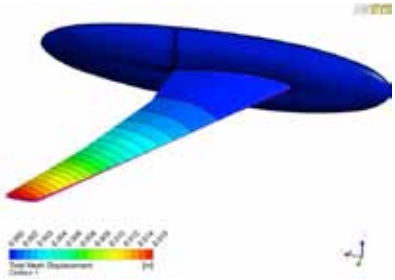

Figure 1. Industrial application model

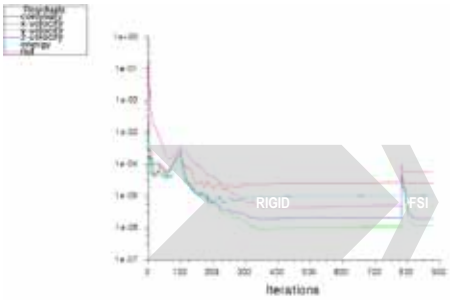

Figure 2. Computing convergence history

Skin stringer debonding evolution in stiffened composite panels: a novel numerical procedure

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In this paper, a numerical study, on the behaviour of stiffened composite panels including skin-stringer debonding is proposed. Traction and "T-pull" tests have been simulated taking into account the skin stringer separation by adopting a Cohesive Zone Model (CZM).
It is well known that CZM based FEM models have the advantage of being mesh and time-step independent (differently from Virtual Crack Closure Technique VCCT based models); however the choice of CZM parameters which regulate the interface behaviour of CZM elements results almost arbitrary and somehow empirical differently from VCCT, whose parameters, GIc and GIIc, are usually available in the frame of a standard experimental characterization campaign on a material system.
To overcome these difficulties, a practical approach to set up the parameters governing the debonding behaviour of CZM based elements, is introduced and demonstrated. Indeed, this practical approach, implemented in the ABAQUS FEM code, uses VCCT based models to setup CZM debonding parameters.
The procedure, starting from Double Cantilever Beam (DCB) and End notched Flexure (ENF) experimental curves allows to determine proper mesh and the time step of VCCT based FEM DCB and ENF models. These models are adopted to set up the CZM parameters, knowing GIc and GIIc material properties, simply performing a trial and error procedure between the VCCT based DCB and ENF models and CZM based DCB and ENF models. Once the optimal CZM parameters have been found for fracture mode I (DCB model) and mode II (ENF model), for a material systems, they can be applied directly to other complex CZM based FEM models without the need of further CZM parameters tuning and further experimental data. Furthermore, once set the VCCT based FEM DCB and ENF models, they can be used to determine CZM parameters for other material systems without the need of additional experimental data.
This approach has the advantage to allow the use, for complex structures, of CZM FEM models, which do not suffer from mesh and time-step dependency, with a physically based choice of CZM parameters derived by GIc and GIIc material properties.
The numerical simulations of the traction and "T-Pull" tests performed adopting the CZM formulation offered the chance to study the influence of loading conditions on the onset and evolution of damage at any location of the skin stringer interface. Results on debonding onset and propagation are presented, discussed and compared to experimental data.

Modelling, Testing and Design Considerations of a GOX/GCH4 Igniter for a HYPROB-SSBB single injector thrust chamber

F. Battista[1], P. Natale[1], M. Ferraiuolo[1], A. Martucci[1], M.Fragiacomo[1], D. Ricci[1], P. Roncioni[1], A.French[1], V. Salvatore[1]

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This paper discusses design, test results and preliminary numerical rebuilding of the GOX-GCH4 igniter for a subscale experimental "breadboard" (SSBB) LOX/Methane rocket engine in the framework of the HYPROB-BREAD project. The igniter architecture takes into account different literature efforts [2] and Figure 1 summarizes the design where main body, inlets and nozzle are depicted. A spark plug is used to ignite the propellants. The simulations (by FLUENT®) have been carried out in order to obtain heat loads and pressure distributions for the thermo-structural analysis, by means of axi-symmetric FEM model. The former analysis has been carried out (ANSYS®) in order to evaluate igniter life cycles. Finally, ECOMSIMPRO® analyses have been accomplished to validate the design performances [3].
The results from the performed calculations demonstrate that the design methodology employed is satisfactory.
Main results from the first experimental campaign as long as preliminary numerical rebuilding analysis are shown. Results are quite satisfactory and confirm the effectiveness of the design methodology and verification analyses.

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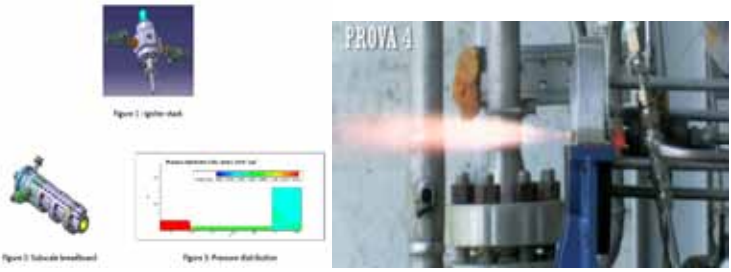

Figure 1: Igniter stack and firing test in AVIO/ASI FAST2 facility

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