IAC-12-D2.8.1

SPACE TRANSPORTATION IN ITALY - PAST, PRESENT AND FUTURE PERSPECTIVES

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The involvement of Italy in Space Transportation goes back to sixties when Luigi Broglio was the major actor in building the San Marco launch base in front of the coast of Malindi in Kenya. Thanks to a cooperation agreement with United States Air Force, a Scout launcher was adapted to the base and used. Italy became the third nation, after URSS and USA, putting a satellite into orbit.
After decades of involvement in the development of the Ariane family, Italy proposed the development at ESA level of the small launcher VEGA, that is a reality today.
Apart from the access to space strictly defined, since many years Italy is active on re-entry developments. Many studies have been conducted by industry and academia at national level, at ESA level and in bilateral cooperation with US and other international partners. The most concrete activities in the re-entry field are represented by the effort spent on the PRORA-USV managed by CIRA, and the leading participations in ESA programs like EXPERT and IXV.
The technology development associated to these systems is an important knowledge asset for both Italy and Europe. Aerothermodynamics, TPS and hot structures, advanced GNC, health monitoring and management, propulsion are fields in which Italy is active.
All this is paving the way toward the future of integrated evolutions of both the VEGA launcher and an IXV/USV re-entry vehicle.

1. Introduction

Space transportation sector involves a really great wide range of missions, projects and technologies, then making it a really multidiscipline world.

The present paper illustrates the activities, research, technologies, systems and products where Italy is expressing skills, competences and infrastructures, since the beginning of the space era.

2. The Origins: San Marco Launch Base

The Italian commitment on space activities was evident since the beginning of the space era, when Italy was the third country to put a satellite into orbit in 1964, with the SanMarco project promoted by prof. Luigi Broglio. The vision of prof. Broglio give the imprinting to the first 20 years of the story of Italy in Space. Thanks to his initiatives and capability of collecting interests from both civil and military communities, the operational base San Marco was realized in Kenya, in a very strategic position, being up to those days one of the nearest equatorial base in the world. It comprises the launch base, organized around three sea platforms, and the ground base equipped with TT&C (Tracking, Telemetry and Command equipments) and remote sensing stations. The base was active for about 20 years for satellites launches from the sea platforms, a concept later fruitfully commercialized by the company SeaLaunch; the last launch was in 1988. Today the San Marco base is still operative, being one of the strategic tracking stations of the European and international network, and particularly active are the ground stations carrying out support operations for many worldwide space agencies, launch and satellite providers (i.e. ESA, NASA, Boeing, Lockeed, ASI, Telespazio) and for satellite remotely sensed data acquisition.

Fig.1 – *Scout LV on S. Marco sea platform, in the '60s*

Fig.2 – *San Marco tracking station, today*

3. The history of European Launchers

In the same period, during the '80s, Europe was conceiving its proper identity in the space field, and the European Space Agency was funded; with respect to the American and Russian histories, the European fundamentals has always clearly been the pacific and exclusively civil and commercial use of space.

Starting from the beginning, the independent access to space has been among the main target of ESA.

The European strategy of access to space has been led up to now by two principles:

- *independent and affordable access to space*, in order to guarantees Europe access to new applications and new services offered by space systems; this is to be ensured by the availability of (a) launcher(s), launch base and corresponding industrial capabilities
- *commercial success on the world-wide market*, which is deemed necessary because of the small size of the European government market for alleviating the burden for governments to sustain independent access to space; this is ensured by a competitive range of launch services, continuously adapted to the market needs.

The Ariane Family

Being the Space Shuttle and the American launch vehicles committed on institutional government missions and in the realization of the International Space Station, while Soviet missiles were used strictly for national internal missions, the new adventure of European launcher family Ariane had an easy and quite monopole diffusion on the market of commercial satellites, bringing the Ariane launch vehicle, especially in the 1 to 4 versions, a technological and economic success precedent less.

At the end of '80s, projects for future space laboratories and forecast for new telecommunications satellites having largely increased dimensions and masses, lead the European community to start the design and development of a completely newly conceived launch vehicle: Ariane 5 born with the objective to accommodate the transfer of the large ATV European modules to the International Space Station and to maintain its leadership on the commercial market by means of double launch of big satellites. The original objective of transporting the manned capsule Hermes was soon abandoned; by the way, design choices already implemented forced in the following years to the necessity of new versions of the LV in order to optimize it for the proper purpose. In 1996 the first flight of Ariane5 ends a few seconds from lift-off, due to a destruction command forced by the uncontrolled change of the trajectory. The program was obviously hold off, it finally reached the success about one year later. In the following years, Ariane 5 had to face again an important failure, during the first flight of the ECA configuration in 2002, but it finally reached the full success with up to 30 launches fully successful, and now is leading the commercial market with a 50% of the market sharing.

Italian contributions to the Ariane 5 program is 9,4% of the overall program, in the following fields: main responsibility of the lateral large SRM boosters, and the LOx turbopump of the Vulcain engine (and of Vinci upper stage in the future evolutions).

By the way, the worldwide scenario has drastically changed in the last decade, and new and very competitive actors are now on the scene, including in the last years some private company which has demonstrated the capability of affording the commercial market with very competitive prices. The governance of the launcher sector, then, needs the political sustainment of the overall industrial network, but this approach is now facing a serious critical revision, which will probably lead in the next years to an important change of the LV design approach.

Several programs are now analyzing different strategies for future evolution of the heavy lift European vehicle:

- Ariane 5 ME - the program provides for the qualification of the Vinci engine to be integrated in the new upper stage of the upgraded version of A5, leading to increase up to 12 tons the payload and to have full re-ignition capability of the upper stage
- A completely new vehicle, which configurations are under study by ESA (NGL) and by CNES (Ariane 6), with the objective to reduce/eliminate the public support to the exploitation: trade off among drastically different concepts (i.e. completely cryo configuration wrt prevalent solid) are compared in terms of performance, technology maturity, development investments, production const.

Fig.3 – *different strategies for the evolution of the European heavy lift vehicle*

<u>The last born: VEGA</u>

The Vega qualification flight took place last February 13, 2012, with great success, putting the new 'small' launcher of the ESA family available to the global market. This was the final step of a long story started more than ten years ago, when ASI decided to start a national program to develop those critical subsystems of a launch vehicle able to deliver small payloads, initially up to 1000 kg, in Low Earth Orbit, with the ambition to develop, in the medium-long term, an Italian leadership in this range of performances. Within this program, in the late '90, a new fully Italian solid rocket motor, **Zefiro 16,** has been developed and ground qualified.

In 1998 ASI proposed to ESA Member States the Europeanization of the Vega project, maintaining the Italian leadership. In 2000, after a deep revision of the technical and programmatic project requirements guided by the users' needs, the final approval of the programme was achieved with a slice approach:

- Vega launcher and ground segment in CSG, Kourou, with the following sharing: Italy (66%) France (15%) Spain (6) then Belgium, the Netherlands, Swizerland
- P80-FW, demonstrator, where the sharing is: France (66%) and Italy (over 10 including self-funded

contribution by industry), then Belgium, the Netherlands, etc.

Vega has been designed mainly oriented to earth observation missions, and generally to LEO missions: in particular it can achieve:

- Inclination between 5.2 degrees & SSO
- Altitude range between 300 and 1 500 km.
- Payload Mass range between 300 kg and 2500 kg

The reference mission performance is 1500 Kg @ 700 km circular Polar Earth Orbit

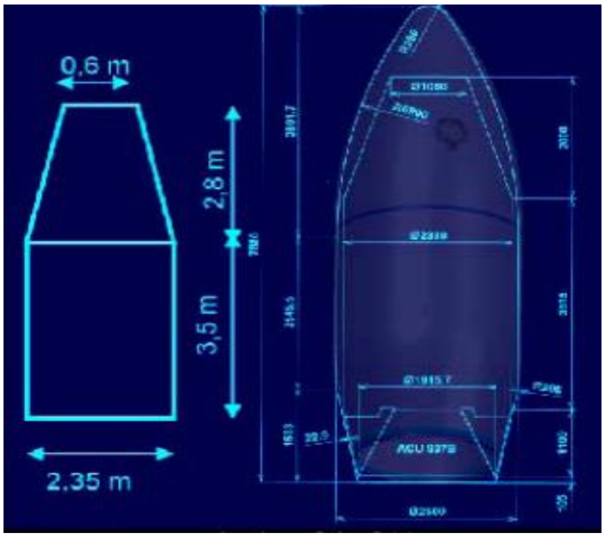

Fig.4 - *Payload usable volume that gives the limits of the static and dynamic dimensions of the satellites*

The analysis of the maiden flight data are confirming the full achievement of the expectations of the project.

Vega Evolutions

Vega provides today the launch of several types of missions, but some areas of the satellite market are still uncovered: for example, are not yet accessible at low cost missions of great interest in Europe as the orbits of the Galileo constellation, particularly given the operational phase and the periodic replacement targeted. In addition, there is the indication, given by market analysis, of a tendency of an increasing request of missions in LEO / MEO from institutional and governmental sides.

ESA has initiated preliminary studies of configurations that are expected to increase the performance of the lower stage: a modification of the first stage solid rocket motor (P-80) by about 89 tons of propellant to about 100 or 120 tons (P-100 or P-120). To this it would be added in longer term, also in function of a structural optimization of the vehicle, an evolution of the second stage from the current 23 tons of propellant Zefiro23 of up to 40 tons

Fig.5 – *the Vega Evolution as per ESA studies*

With regard to higher stages of the launcher, the first goal in verification is the 'Europeanization' of the fourth stage AVUM, which engine and tanks are now designed and manufactured in Ukraine and Russia,. In this direction are going some studies supported by the German DLR, and named Venus, which would enable Germany to find a way of integration in the Vega project, to which now Germany is not participating.

The Venus study, carried out by Astrium GmbH, has analysed the opportunities and problems associated with the possibility to equip Vega with a new upper stage, replacing Z-9 and AVUM, with an improved version of the existing motor Aestus, working with storable propellant, which is to-day used on Ariane 5 in the basic version ES to launch ATV, also in this case the launcher's performance in terms of payload would be increased to over 2 tons of reference orbit. In the same VENUS study it has been investigated the possibility to replace the only AVUM main engine with a new developed engine named BERTA, also this engine working with storable propellant, which would allow a lower increase of the performance of the launcher of about 300 kg.

Some more ambitious long term projects involve the replacement of the entire upper part of the launcher, that is the third stage Z-9 and fourth stage AVUM, with a new upper stage equipped with liquid propulsion.

Fig.6 – *the Vega Evolution as per Lyra project*

The Lyra project, started by ASI in 2005 with a feasibility study, is developing a 10 tons thrust LOx-methane test demonstrator engine, derived from an existing Russian Lox-H2 engine, in order to increase the performance of the launcher of about 30% at the same cost of the Vega standard version. This type of propulsion is currently not developed by any company or agency in the world, although several development programs in progress show a great interest in this type of 'clean' and high energy propulsion.

Fig.7 – *Mira engine – subscale development test*

Around this technological concept, Italy was able to convey both the industrial attention, with Avio, than those of the research world, thanks to a project led by the Italian Aerospace Research Centre of Capua, with the support of the Ministry of Research; as well as international cooperation, with two specific agreements with the Russian space agency Roscosmos and the Japanese JAXA

The second flight of Vega will be already a step in the direction of evolution, because the launcher will be 'guided' by a new flight programme software whose development was strongly supported by ASI and developed by Italian industry. The qualification flight, which took place very successfully last February, has been 'led' by a software developed by the French company Astrium, which has exclusive rights for over thirty years of this activity for European launchers. With the second flight of Vega, Italy has set itself the further step of acquiring full control and competence of Guidance, Navigation and Control, which constitute the very 'heart' of the launcher, and has decided to strongly support the development of a guidance system on which the Italian industrial architect can be fully responsible

RLV and Related Technologies

During the 90's a great interest was collected around the world in affording those technological challenges posed by the design of a future generation re-usable vehicle. While the Space Shuttle was fully committed to the construction of the ISS, it was believed that the right way to gain significant reduction of the recurrent launch cost (i.e. one order of magnitude with respect to STS-Shuttle) was to make the launcher partially or completely reusable and to greatly increase its reliability, while preserving its operability.

So, while NASA, then U.S. Airforce, made efforts on several technology demonstrator programs, in 1994, ESA started the Future European Space Transportation Investigations Programme (FESTIP), then followed in 1999 by the Future Launchers Technologies Programme (FLTP), in order to study possible RLV concepts and promote the development of the related technologies. Several launcher concepts were subsequently conceived, and a systematic effort was made to compare reusable and partially reusable launcher concepts against common defined requirements and on the basis of common design rules.

Semi-reusable concepts, whether Two-Stage-To-Orbit (TSTO), or multiple stage to orbit, were considered as technically feasible with the present technology. furthermore reusable launcher concepts using advanced air-breathing propulsion (i.e. ramjet, supersonic combustion ramjet or air liquefaction, etc.) were recognised to require technologies very far from implementation on operational vehicles.

By the way, in the following years the international community left the idea of reusable vehicles, turning back to evolved expendable configurations.

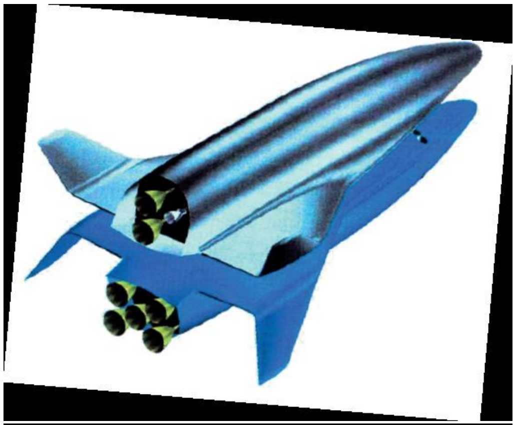

Fig.8 – A*n example of a Two Stage To Orbit concept (TSTO)*

4. Reentry Flying Test Beds and Technologies

PRORA-USV

The PRORA-USV program was conceived in 2000 as a technology-driven effort aimed at maturing a number of technologies and engineering tools considered enabling for future space access and slender winged re-entry vehicles. The major assumption was based on belief that future trip to space and back will be guaranteed by today aviation-like systems, and since the beginning the contamination between space and aeronautics know-how was of primary attention. Such re-entry “aeronautical” system are essentially characterized by a longer high altitude flight phase that can be obtained by a lift higher than the present blunt spacecrafts (capsule, Shuttle) and flying at angles of attack smaller that those employed up to now.

One of the main elements of the program was identified to be the flight testing, for the aim of which the development of a set of sharp flying test beds was included with the use of flight opportunities offered by other international programs as well.

USV is a national program that includes interactions and even integration with international activities and projects. Collaborations were indeed established in past years on specific topics as:

- CFRP cryogenic tanks technologies, with JAXA (NASDA at that time)
- air-breathing propulsion studies, with CIAM (Russia)
- Winged re-entry vehicle (USV_X) aerodynamics and system analysis, with ISRO (India).

The PRORA-USV program is timely defined by an in-flight experimental milestone approach. In this sense, it consists in the execution of a series of flight tests of increasing complexity, in terms of flight regimes and altitude envelope, with the aim of gradually achieving the final goal of an advanced re-entry capability.

USV is composed by the following three pillars:

- USV_1/2 to develop and use Flying Test Beds (FTB) launched by means of Stratospheric Balloons or rockets and dedicated to transonic flights (DTFT = Dropped Transonic Flight Tests), supersonic flights (DSFT = Dropped Supersonic Flight Tests), and hypersonic flights along suborbital trajectory (SRT = Suborbital Re-entry Test) or almost constant speed trajectory (HFT = Hypersonic Flight Test);
- USV_3 to develop and use a VEGA-launched high-lift FTB for sub-orbital (SRT) and orbital flights (ORT = Orbital Re-entry Test);
- USV_TECH dedicated to enabling technologies development with specific regard to
  - Aerodynamics/Aerothermodynamics
  - Sharp UHTC-based Hot Structures
  - GNC
  - CFRP Cryogenic Tank
  - I&IHMS, Intelligent & Integrated Health Management System
  - Air-breathing Propulsion
  - Adaptive Hypersonic Wing

  the first three of which with higher priority.

System and technology targets that are needed to achieve the final re-entry capability as above defined are grouped into three major classes of missions, characterized by an increasing complexity criterion in terms of flight regimes, technologies and launch systems.

The first class of missions covers flight and mission operation issues related to the low atmosphere part of a re-entry pattern, from about 35 km altitude down to land, the main focus being on aero-structural and flight control of a re-entry vehicle at transonic and low supersonic speed. Two twin units of the FTB_1 laboratory able to reach a Mach 2 maximum speed are dedicated to these missions, using a stratospheric balloon as launch system (first stage) and operated inside the military polygon of Salto di Quirra (PISQ) in Sardinia.

Fig.9 - FTB_1 “Polluce” vehicle

Fig.10 - FTB_1 before lift off

The second class of missions is dedicated to hypersonic flight in the range of Mach 6-8. The project is being developed on the bases of cooperation with University of Queensland, Australian DSTO and DLR focusing on a 2 meter class glider vehicle, initially accelerated by one of the launchers used within the HIFiRE program.
The vehicle would guarantee some 15-20 seconds of hypersonic experimental flight either along a unsuppressed ballistic trajectory (SRT mission), or following what is indicated as a semi-suppressed trajectory (HFT mission).

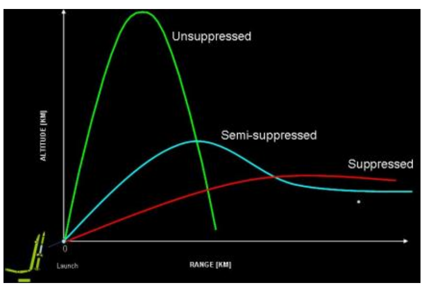

Fig.11 - FTB_2 possible trajectories: unsuppressed SRT and semi-suppressed HFT

The third class of missions is designed to cover all the flight regimes interested by a complete re-entry pattern, from LEO/MEO orbit down to land. These missions are supposed to be accomplished with the FTB_3 laboratory, using VEGA as reference launch system. The FTB_3 mission envelope is defined in order to respond to the major requirement to investigate in flight enhanced re-entry profiles (low wing-load and high-lift), as compared to conventional either non-lifting (capsules) and lifting (Space Shuttle) profiles, in terms of vehicle maneuverability, flight pattern
The major experimental target of such a class of missions consists in the validation and qualification of aero-thermodynamics, GN&C and hot structures, with special focus onto their capability to withstand high thermal loads (heat flux as high as 2-3 MW/m2 and temperatures up to 2000°C) associated to advanced re-entry flight patterns (moderate angle of attacks, below 20°, and flight duration longer than 1 hour).

Major achievements of the program up to these days are as follows.
The USV Program reached its flight readiness DTFT_1 in just four years, with the vehicle named “Castore”. On 24 February 2007 flight more than 80% of the fixed objectives were achieved, even if the vehicle itself was lost because of a parachute failure.
One year after, the DTFT_2 was ready to take place (March-April 2008 launch window) with the twin vehicle named “Polluce”. Adequate launch conditions were not reached, however, and the flight was definitively postponed. DTFT_2 has been run on 11 April 2010.

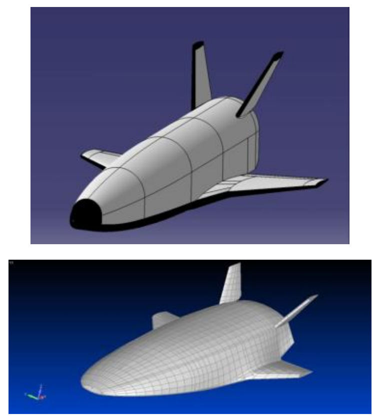

Fig.12- Design evolution of the flying laboratories from USV_1 to USV_2 (scale is disregarded)

The vehicle, tagged FTB_4, is based on FTB_1 preserving a number of its characteristics. The vehicle phase A final configuration is of spatular type in view of a possible accommodation of an air-breathing engine air-duct experiment. The design evolution of FTB_4 is generically shown in Fig. 8 wrt the Flying Test Bed of the USV_1 project, in which the scales are not true (FTB_1 length of about 9 m, FTB_4 length less than 2 m).

SHARK

SHARK (Sounding Hypersonic Atmospheric Re-entering ‘Kapsule’) is a technology demonstrator of an autonomous ballistic capsule with an UHTC-nose test, 20kg in mass and 30 cm in diameter, launched by the ESA sounding rocket MAXUS 8 (Fig. 10) on a 700km apogee suborbital trajectory, on 26th March, 2010. It is the first European real flight experiment of a component realized in Ultra High Temperature Ceramic (UHTC),

but this is just one of the many peculiarities of this interesting experiment.
The capsule, accommodated between the booster stage and the payload stage of the rocket, was released just after the burnout, during the ascent phase, at a velocity close to three kilometers per second. While the main payload performed its flight, the capsule flow on a parallel parabola, reaching 700km altitude in a 15 minutes long flight.
The internal systems of the capsule, activated at the release, acquired data during the extra atmospheric part of the flight and during the challenging reentry phase, measuring 40g load factors and temperature that exceeded the 1000°C on the sharp ceramic nose tip, when the capsule was flying at about Mach 10 at 30km altitude.

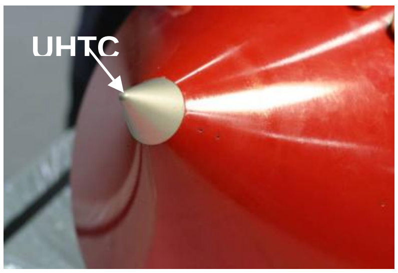

Fig.13- Shark capsule, with UHTC cone

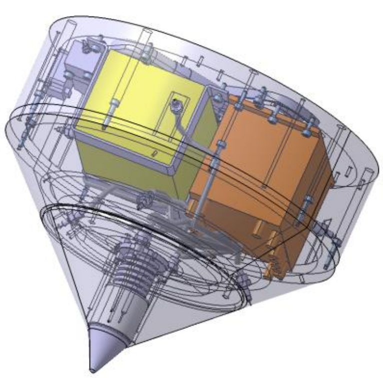

Fig.14- Shark internal accomodation

This small capsule, 30cm, diameter and 20 kg mass is a remarkable summary of some of the most valuable expertise available in Italy. The UHTC tip is the heritage of the millenary Italian experience in ceramics fabrication, the cutting edge of decades of scientific research of the Italian National Council for Research (CNR) in the field of the advanced ceramics and the result of years of engineering efforts from the Italian Aerospace Research Center, trying to apply the UHTC in the aerospace field, for the realization of the future hypersonic vehicle.
SHARK genesis is peculiar by itself. The Europen Space Agency (ESA) needed to test a sort of black box in a siple and economic way. ESA conceived the idea to board a capsule on MAXUS-8 and asked to CIRA if it was possible to set up design and build something in less than 6 months.
In the activities the CIRA was the prime contractor of the many subsystem providers and machining companies that realized the structures of the capsule. SHARK was equipped with 16 temperature transducers, 10 pressure ports, 6 inertial sensors, on board computer and data acquisition and storage systems, autonomous power ans beacon transmitter. Once recovered, in July, all the data have been recovered, and analyzed.

The data management system was not supposed to survive the landing, but the robust design allowed the system to acquire data even after the 300km/h impact with the ground.
The recovered data are the first measures executed by an Italian vehicle in the hypersonic flight regime at altitude that are very relevant for future hypersonic vehicles.
These data are original, we own the raw data, before any treatment and conditioning, this is the first time that this is available in Italy and is an important element for the future development of Italian hypersonic technologies.

EXPERT

The ESA EXPERT ballistic capsule is almost ready to fly (2011), and CIRA is participating in a number of technical areas such as: (i) aerothermodynamics; (ii) scientific coordinator of all 15 experiments coming from all over Europe; (iii) principal investigator of 3 of those 15 experiments, dedicated to natural and roughness induced transition, shock wave boundary layer interaction upstream the open flap, and UHTC Sharp Winglets; (iv) post-flight analysis.
The Winglets mission objective is, in particular, to test UHTC structures and ceramic/metal IF in real re-entry flight condition, and in particular:

- Expose UHTC hot structure to high energy conditions (10 MJ/kg) to which high heat fluxes (5 MW/m2) correspond
- Study the thermal behavior of the structure (by 5 embedded thermocouples) and the aerodynamic surrounding the winglet (4 pressure ports).

The Winglets shall sustain the mechanical loads imposed by the Russian launch vehicle VOLNA (8g static, 7.7grms random, 1000g shock). Then, when the material will be heated by the thermal load, the Winglet will sustain the 15g deceleration of the re-entry phase. The innovative nature of the payload and materials used, the roughness of the operative environment, imposed an accurate design, supported by complex non linear CFD, FEM and statistical analysis.

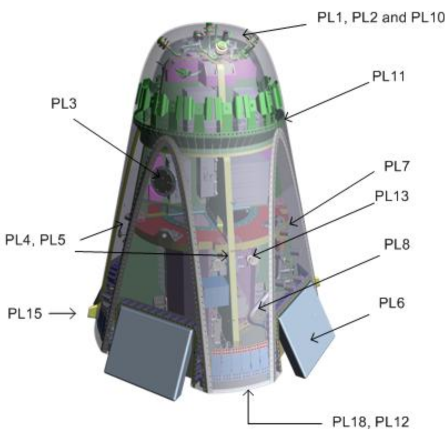

Fig.15 – Expert capsule, with allocation of experiments

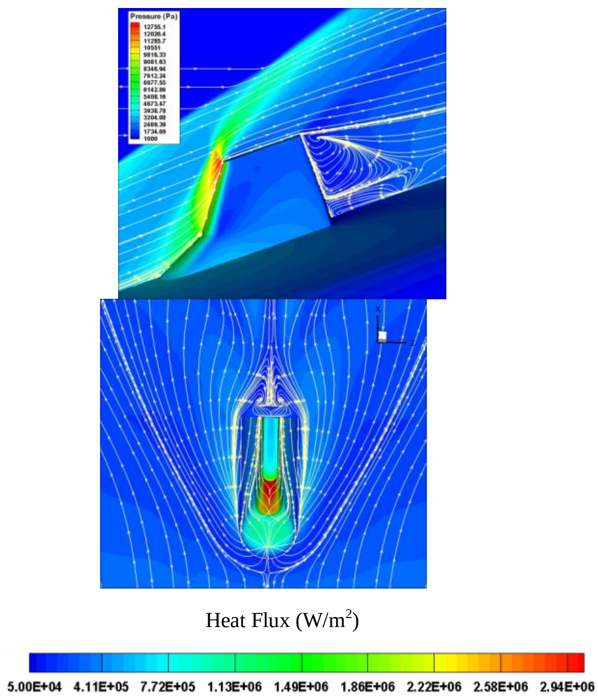

Fig. 16. 3D CFD non-equilibrium flow field

Also the instrumentation on the fins is challenging. One winglet is instrumented with 3 thermocouples, while the other is equipped with 4 pressure ports and 2 thermocouples. The realization of the pressure ports was tectonically challenging, for the realization of the pass through holes and for the connection with the pressure transducers.

In order to prepare for the next UHTC in-flight experiment on board EXPERT, a full design loop was run up to the qualification during a PWT campaign (Fig. 14) and subsequent comparison with numerical simulation that was very good. In particular, Fig. 15 shows a comparison between wall temperature distribution on the model holder and the winglet as measured during the PWT test by means of thermography and as computed by non-equilibrium CFD code.

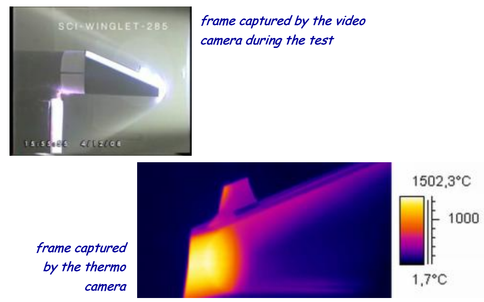

Fig. 17. Winglet ready for thermal qualification in SCIROCCO (top) and run execution (bottom)

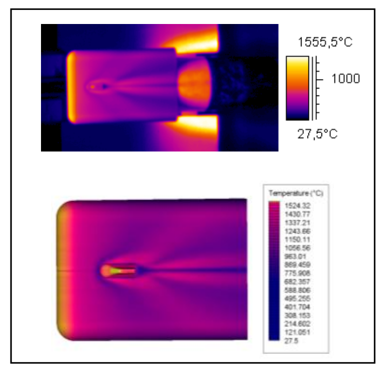

Fig.18 - I/R thermography acquisition during the test (top) and predicted CFD wall temperature under test conditions (bottom)

At present CIRA has delivered two UHTC fins, qualified and accepted for flight on the European capsule EXPERT. The design passed both PDR and CDR review guided by ESA. A qualification model has been qualified for the mechanical environment (vibration and shock) and has been tested in SHIROCCO.

Once the qualification model have passed the Qualification Review the flight models have been realized, tested for the flight mechanical environment and then accepted by ESA. The integration of the capsule has been accomplished and the flight is planned for the next summer (2011).

EXPERT flight will have a lower apogee if compared to SHARK, but the flight will be much more energetic, entering the atmosphere at about 5 km/s.

IXV – Intermediate Experimental Vehicle

The atmospheric re-entry domain is a cornerstone of a wide range of space applications ranging from the planetary exploration, the sample return, the future launchers, the space planes, the crew and the cargo transportation, and several other innovative applications in the field of robotic on-orbit satellite monitoring, servicing, repairing and disposal.

Since several years significant importance was given to the development of the critical re-entry technologies through several basic research and technology preparatory programmes. Today, the inflight verification of such technologies is considered an important European programmatic objective to be pursued within ESA short-term undertakings.

Since its beginning, the IXV was conceived as a technology platform.

Since 2000, the European studies on experimental vehicles for re-entry technologies underlined the need for Europe to gain relevant in-flight experience on enabling re-entry systems and technologies, to consolidate its position and ambitions in the area of space transportation.

The concept down-selected for the IXV was a lifting re-entry body, to be launched and injected on a re-entry path by the ESA VEGA launcher via an equatorial trajectory, able to perform a set of dedicated maneuvers prior to land in the Pacific Ocean for recovery and post-flight inspection and analysis.

The technological objectives of the IXV mission are met by flying a large number of experiments that have been chosen among a wide range of European proposals. The main areas of investigation are:

- TPS, for verification and characterization of thermal protection technologies in representative operational environment;
- AED-ATD, for understanding and validation of aerodynamics-aerothermodyamics phenomena and improvement of design tools (i.e. CFD and WTT);
- GNC, for verification of guidance, navigation and control techniques in representative operational environment (i.e. re-entry from LEO);
- Flight dynamics, to validate the vehicle model during actual flight, focused on stability and control derivatives (VMI experiment).

An extensive Post Flight Analysis (PFA) is planned to ensure the fulfilment of the IXV in-flight demonstration and experimentation objectives, and to allow the concrete/measurable reduction of uncertainties for future space system designs.

SHS/ASA – Hot Structures

The research in the frame of the hot structures is suitable for an implementation in the architecture of future re-entry vehicle comes as a possible answer to peculiar mass and safety problems such vehicles will have to face, the hot structure being here intended as a thermo-mechanical system effective in sustaining both thermal and mechanical loads, integrating hence the functions presently devoted to the TPS and to the primary structure of the reusable or re-entry vehicles flown so far In this frame the Italian Space Agency contracted the design and manufacturing phase of a program oriented to the development of the capabilities available in Italy on the hot structures for re-entry vehicles and awarded Thales Alenia Space Italia with the leadership of a pool of industries/research centres collecting the best capabilities available in Italy in order to study, develop, manufacture and test a wing segment realized with use of different technologies emerging as the most promising from the past studies and experiences performed by all the participants to the program.

The test article to be manufactured and integrated was in fact conceived as an opportunity of testing all the hot-structures-related technologies presently under development in Italy, regardless the final use foreseen for each technological topic.

Such a program was named **ASA** (Advanced Structural Assembly) and the various system and sub-systems were defined as follows:

- Thales Alenia Space Italia - Prime Contractor, Responsible for the system design; the actively cooled leading edge; the internal structure and the joinings;

- CIRA, Responsible for the USV-derived environment definition; for the UHTC (Ultra High Temperature Ceramics) leading edge and for the Scirocco testing facility

- Università di Roma “La Sapienza” - Responsible for the Leeward panel made in hybrid material

- CSM, Responsible for the windward panel made in advanced MMC (Metal Matrix Composites) and for the UHTC material development

The ASA program passed through a sub-assy development concluded by a test campaign in order to validate each element of the assembly for the Plasma test (Scirocco being the PWT -Plasma Wind Tunnelfacility to be later used).

Therefore reduced-scale hot test were performed on the materials developed. In parallel the activity at system level for the test article and the test condition definition proceeded starting from the available environment and geometries coming from the USV trans-atmospheric mission

Four PWT test were performed simulating (and in reality enveloping) a long re-entry from LEO (plateau of max applied heat flux for a duration of 20 min, against the 12 min normally required for a LEO entry).

Fig.19 - *First ASA PWT Test into Scirocco. Effective duration: 15 min (due to plasma instability leading to the arc shut-off), Max heat flux: 410 kW/m2*

Fig.20 - *Test article into the Scirocco PWT after the first PWT test*

5. Conclusions

Italy is historically active in the Space Transportation field since the beginning of the space era, this sector representing an asset for the Italian national positioning within European cooperation programs.

The success of the Vega maiden flight is the last demonstration of Italian national capabilities to gain front line roles as System Industrial Architect, so as technological subsystem leader, as it is in propulsion.

National R&D programs are mostly oriented to the experimental demonstration of concepts and technologies in a short-medium term, focusing on enabling aspects and representative scale demonstrators.

Actually, the most important national programs are focusing on LOx-Methane propulsion and on re-entry vehicles, taking benefits from both national investments and international cooperations.

The overall results of the above mentioned activities will be available to the Launchers community, in order to promote fruitful cooperation in view of future European and international programs.

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