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Italian space agency space transportation activities and programs

Marta Albano[1]*, Rocco Carmine Pellegrini[1], Roberto Bertacin[1], Simone Ciabuschi[1], Simone Illiano[1], Rocco Maria Grillo[1], Enrico Cavallini[1]

[1]Italian Space Agency (ASI), Italy

marta.albano@asi.it

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Abstract Space transportation systems are the key elements for the space exploitation thought space-based services (for telecommunication, navigation and earth observation) and space exploration. As more government and commercial players show interest in effective and sustainable space transportation systems and services, affordable, regular and resilient transportation systems have become increasingly important for sustainable space services. Italy, thought the activities of the Italian Space Agency, is increasingly investing in the space sector and it confirms to be one of the top players on the international scenario. The paper presents an overview of the activities of the Italian Space Agency in this sector, both through national and European framework.

Introduction

The Italian Space Agency has the role to promote and coordinate the space activities at national and international level. The main space transportation activities and programs will be presented in this paper showing the complexity and the variety of the Italian investments in this sector. The activities cover three main areas. Launchers: Italy thought ASI, as National Space Agency with the aim of maintaining the national leadership in the sector participates to ESA launchers activities, such as VEGA family and develops, thorough ASI national programs, critical subsystems such as liquid and hybrid engines, avionics systems etc. Re-entry vehicles: Italy, throught ASI, is the main contributor in Europe for the development of the first European re-entry and re-usable vehicle that will enable new type of services for institutional and commercial customers through Space Rider, based on the experience gained in IXV program. Sub-orbital, hypersonic and stratospheric flights: with the aim to perform missions, develop a national capacity in the specific sectors promotes collaboration with European entities for balloon borne launch campaigns, participates to European working groups dedicated to suborbital law and activities, works on the realization of a national hypersonic demonstrator.

Launchers

Italy, throught the Italian Space Agency supports the development and exploitation of European launchers through its participation in ESA Programmes. The main support is to the VEGA family launchers (VEGA, VEGA-C and VEGA-E) where the leadership is Italian and the prime contractor is AVIO S.p.A. In particular, based on the successful development and exploitation of VEGA launch system entered into service in 2012, Italy has supported the development of the VEGA-C launcher[13] up to its maiden flight occurred in July 2022 with the successful release in orbit of LARES2 satellite (developed by ASI itself) and six CubeSats. After the successful maiden flight, Italy is now supporting the return to flight of VEGA-C after its failure on its second flight in December 2022, and its ramp-up in the stabilized exploitation phase, through a dedicated program aiming also at providing improved robustness to the Launch System in view of its commercial exploitation. Italy has also supported since long time the future evolution of VEGA, starting with ASI national Programs such as Lyra, fostering the introduction of a larger liquid propulsion upper

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stage exploiting LOX-CH4 propellant combination substituting Z9 and AVUM. In the frame of Lyra program, the basis for mastering this technology have been set up through a collaboration with Russia leading to the firing test of a 10 ton class engine demonstrator called MIRA [7]. Those achievements have been the basis for introducing within the ESA programmes the VEGA Evolution Preparatory Program aimed at developing VEGA-E that, starting form VEGA-C configuration, will substitute Z9 and AVUM+ with a new upper stage making use of M10 engine, developed in the frame of the same program. M10 [12] first development model (DM1) has been already successfully fire tested at engine level in the SPTF test facility located in Sardinia in 2022, while the second development model (DM2) will undergo a complete firing test campaign in the coming weeks. Italy has also a leading role in the P120C Solid Rocket Motor development program which constitutes a common element for the future VEGA and ARIANE launcher families, guaranteeing the synergy between the two launchers. P120C, indeed is used as first stage on VEGA-C and as strap-on booster on Ariane 6 in its version with 2 or 4 boosters. This will also allow higher production volume and cadence for the P120C production line, contributing to lowering the exploitation costs though an economy of scale and building blocks approach. In order to improve ARIANE 6 performances to allow the deployment of large constellations a further development of this SRM has been started in 2021 and then confirmed at the last Ministerial Conference 2022, for a more powerful version of the rocket called P120C+ (or P160C) with an extended length allowing to load a higher mass of solid propellant, increasing the overall total impulse of the motor.

Figure 1 First VEGA C -Lares 2 mission -courtesy of ESA.

In the logic of the P120C, the P120C+ (or P160) will maintain its characteristic of common building block of Ariane and Vega European family of launchers, increasing also the performance of Vega launchers, VEGA-C and VEGA-E. ASI conceived within the National PNRR and today supports the implementation of the so-called PNRR-STS project, funded by EU in the framework of the Italian PNRR. The project will be dedicated to the technology pushing towards the new generation of liquid propellant LOX-CH4 launchers, through the in flight testing and demonstration of the innovative LoX-methane propulsion, based on M10 engine developed in the frame of VEGA-E Program, and the development of critical and enabling technologies. Those critical technologies consist of composite material cryogenic tanks, non-pyrotechnic separation systems and integrated avionics systems based on low-cost hardware. In addition, in the frame of the National PNRR funds, the development of a larger thrust class liquid rocket engine with respect to M10 has been started in the frame of an optional ESA Programme fully funded by Italy, so called Hight-Thrust Engine. This High thrust Engine (HTE), in the class of thrust and performance complementary and synergic with M10 and with Prometheus will constitute the base for future building blocks to be used in the next generation of European launchers fully based on Lox-Methane propulsion.

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Avionic systems for Launchers

The development of future generation launchers is strongly characterized by the efficiency of the service offered both in terms of performance and competitiveness. This requires technological innovations aimed at improve the services provided on the market. The growing amount of data to be managed on board requires new concepts of avionic architectures. To innovate these systems, worldwide, various actions are undertaken such as the improvement of the hardware with the development of new on-board computers, the creation of new architectures such as for example the modular approaches or the implementation of new procedures aimed at streamline integration and ground testing activities with the use, for example, of wireless technologies or real-time simulations of environmental stimuli (rotation of the earth, gravity, sloshing of propellant tanks, temperature and thrust, weather conditions, etc.) . It should also be considered that avionics systems account for approximately 20-25% of the cost of the launch service and they are a fundamental element of innovation for the management of on-board data, launcher safety and state recovery. Therefore, avionics systems constitute a key element in order to place the launch service on the market in a strategic way. In order to promote the innovation and to consolidate the role of Italy in the launcher sector, avionic systems are in development through national programs. Wireless systems will allow to facilitate the ground procedures and the launcher design. Different GNC systems are in phase of study both for the re-entry of the launcher stages and for optimization of GNC systems itself by the means of data fusion. Neutralization systems are also in development phase in order to assure the safety of the flights. Communication systems based on Flexible TTEthernet are in early stage of development in order to lower the costs guaranteeing high reliability of those systems.[1]

Green Innovative propulsion and Technology Developements

Funded by EU in the framework of the Italian PNRR, ASI has contracted in April 2023 a major project to design, develop and on-ground qualify an innovative Multi-Purpose Green Engine (MPGE) to be exploited as "*building-block"* for the future Space Logistics scenarios, as element shared between the Space Transportation roadmap and the In-orbit servicing roadmap whose MPGE is part of. Thanks to an intrinsic versatility, mainly related to its throttability, MPGE will be able either to operate as propulsive module of orbiting platforms for next generation in-orbit services, also in reusable configurations (e.g. Space Rider), and to power the upper stages of VEGA-class launchers.

This kilo-Newton class engine will be designed to operate with an innovative combination of green liquid propellants, characterized by long-term storability. Main drivers of the project will be also the wide use of additive manufacturing processes, to optimize the layout and minimize the overall mass, and of a fast prototyping approach, by use of a large number of test campaign and development/qualification models.

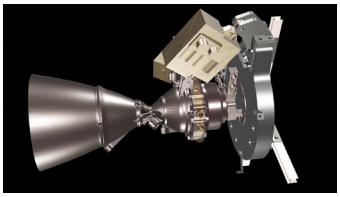

Figure 2 First draft of MPGE.

In the field of Hybrid Propulsion, ASI has set up the PHAEDRA Program (Paraffinic Hybrid Advanced Engine Demonstrator for Rocket Application) [5] with the aim to gather the main Italian competences in the field of hybrid propulsion both in industry and in Universities and Research Centers in order to develop a technological demonstrator in relevant scale to be fire tested at the beginning of next year. The Demonstrator will devote particular attention to the re-ignition characteristics and throttling capabilities, adopting paraffin-based fuel in solid form as a single

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port grain and oxygen peroxide (HTP) as liquid oxidizer. ASI has also funded research activities on solar sails propulsion with the aim to create highly specialized skills in various technological areas relating to the main issues of solar photonic propulsion such as mission analysis, materials development for membrane substrate and reflecting coating depositions, deployment structures (telescopic booms or memory form material booms) and attitude control system relying on photochromic materials. The activities on solar sails technologies are carried out in collaboration with some university departments and with specialized laboratories at Italian research institutes[3]. As a result of the activities carried out, material production processes have been set up, several samples at laboratory scale have been produced and characterized, both for the membrane substrate, reflecting coating optical properties, and boom subscale prototypes [6]. ASI participated also to project called "MAGIC", funded by the Regione Lazio, which has developed enabling technologies aimed at the full industrialization of additive manufacturing processes (Additive Layer Manufacturing - ALM) of alloys and superalloys of nickel and copper for the production of aerospace components, complementary joining technologies, with a particular focus on laser welding, and certification and qualification protocols through Non-Destructive Testing (NDT). In particular components for the propulsion systems have been developed. ASI has supported the development of technologies for propulsion systems such as the study carried out for segmented solid rocket motor cases using composite materials culminated with the mechanical characterization tests of a sub-scale model applying this technology that can be of interest also for the application on inter-stage joints manufactured in composite materials with the aim to guarantee a more reliable and lightweight overall launch system.

Re-entry vehicles and technologies

Re-entry environment is the upmost challenging condition for a space vehicle. ASI has promoted over the years the development of technologies and system competences for re-entry. The national programs allowed Italy to have one of the most relevant European competence in this sector. Italy, thought ASI, funded also ESA programs such as IXV, which successfully flew in 2015 and now is supporting with a primary role Space Rider.

The overarching objective of the Space Rider program is to develop a reusable, fully autonomous European space transportation system service, providing a European independent capability to routinely access and return from orbit with precise landing capability and a space vehicle serving as a platform for experimentation, in-orbit demonstration and validation with application missions in Low Earth Orbit. The Space Rider program is capitalizing the IXV experience and technological baseline qualified in flight. The Space Rider system is composed of two modules: the Re-entry Module (RM) and the Orbital Module (OM). The RM, being developed under the Design Authority of TAS-I, is a lifting body and it will be designed to embark experiments and payload inside a cargo bay and to return to Earth for landing and re-flight. The OM, under the Design Authority of AVIO, consists of the ALEK (AVUM Life Extension Kit) and acts as service module during the orbital phase of the system. The overall system is completed by a ground segment under the responsibility of ALTEC and TELESPAZIO and a landing site. The system has in orbit lifetime for a minimum duration of 2 months with the following applications: Micro-gravity experimentation laboratory, In-Orbit Demonstration and Validation for a wide range of technologies (e.g. Earth monitoring, satellite inspection, etc.). The vehicle shall be able to perform a high precision soft landing on ground on the landing site. The Space Rider system shall be designed to fly for 6 times. [10][11]

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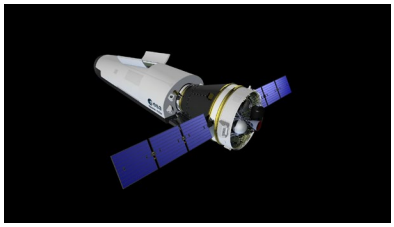

Figure 3 A possible configuration of Space Rider [2]

Suborbital, hypersonic and stratospheric flights

Complementary to classical space transportation topics, the Italian Space Agency funds and promotes national technological and research projects in the field of sub-orbital flights, meant as non-orbital, including support of their mid-stream component i.e. the spaceports, stratospheric platforms and suborbital-hypersonic vehicles. Stratospheric flights are operated by the means of platforms such as balloons at variable altitudes up to about 40km. ASI promoted these activities by its participation to the European project Hemera which developed technologies for the flight train and offered flights to the scientific community. ASI is continuing to keep in contact with the main European actors which participated also to the Hemera project[9]. Agreements and possible future European projects are ongoing. Suborbital flights have become over the years an interesting opportunity for both new space transportation services and research and development activities and a viable option for access to Space of nanosatellite systems. A suborbital flight usually does not exceed 100 km in height and will not orbit the Earth. In this sector ASI participate to discussions on the regulation of these flights. together with ENAC and to the European Commercial Spaceport Forum (ECSF), which brings together several European countries active in light spacecraft launch and suborbital flights. Hypersonic flights are performed by vehicles able to fly at Mach over 5. These flights conditions are typical of re-entry vehicles (winged such as the space shuttle or the aforementioned Space Rider or not winged such as Carina, ARD etc.) and of airbreathing cruise and acceleration vehicles (such as Sanger [4]). The last category, named also as CAV, is objective of many European studies in the recent years. Based on the high experience cumulated on these studies, the Italian Space Agency promoted a dedicated national agreement with CIRA in order to develop a small-scale propelled demonstrator. The project will develop the system and the necessary technologies focused on the propulsion[8].

Conclusions

Space transportation vehicles and technologies are of increasing interests at European and international level. ASI supports the development of the national capacities in order to maintain the strategic position of Italy in this field and to support though its national and ESA programs the European strategic independent access to space for Europe Space Program, both with its role in the frame of the ESA European launchers family and their exploitation and evolution in the European cooperation framework, and through R&D activities through its national programs. In this paper, a general overview of the main programs carried out at national and ESA level has been provided for the main lines of developments in the fields of Space Transportation, including Launchers, re-entry vehicles, suborbital, hypersonic and stratospheric flight and related technologies.

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