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Alenia Spazio: Space Programs for Solar System Exploration

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Abstract. Alenia Spazio is the major Italian space industry and one of the largest in Europe, with 2,400 highly skilled employees and 16,000 square meters of clean rooms and laboratories for advanced technological research that are among the most modern and well-equipped in Europe. The company has wide experience in the design, development, assembly, integration, verification and testing of complete space systems: satellites for telecommunications and navigation, remote sensing, meteorology and scientific applications; manned systems and space infrastructures; launch, transport and re-entry systems, and control centres. Alenia Spazio has contributed to the construction of over 200 satellites and taken part in the most important national and international space programmes, from the International Space Station to the new European global navigation system Galileo. Focusing on Solar System exploration, in the last 10 years the Company took part, with different roles, to the major European and also NASA missions in the field: Rosetta, Mars Express, Cassini; will soon take part in Venus Express, and is planning the future with Bepi Colombo, Solar Orbiter, GAIA and Exomars. In this paper, as in the presentation, a very important Earth Observation mission is also presented: GOCE. All in all, the Earth is by all means part of the Solar system as well and we like to see it as a planet to be explored.

1. The past planetary science heritage: CASSINI-HUYGENS, ROSETTA and MARS EXPRESS

CASSINI (Fig. 1) is a major NASA/ESA/ASI mission to Saturn, ongoing since 1997. It is the most sophisticate and complete system for planetary exploration ever built, providing unprecedented amount of scientific data. Currently in its Saturn tour, it will complete 74 orbits of the ringed planet, 44 close flybys of the moon Titan, and numerous flybys of Saturn's icy moons. Recently, it has deployed the HUYGENS probe to descend through Titan's cloudy atmosphere and land on its surface. The role played by Alenia Spazio encompasses the project and the manufacturing of the 4 m multifrequency high gain antenna, (X, Ka, S and Ku bands), the RadioFrequency Electronic Subsystem of multi-mode radar, the RF Instrument Subsystem for the Radio Science experiment, the Huygens Data Relay Subsystem and Data Management System.

The RadioFrequency Electronic Subsystem of multi-mode radar was designed and built in collaboration with NASA- JPL. It is at the same time synthetic aperture radar, a radar altimeter and a radiometer, for the study

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Fig. 1. Cassini Huygens

of Titan through its thick cloudy cover. It is small, power economic and operates in Ku band at 13.8 GHz and represents a real step forward compared with analogous instruments used in previous interplanetary missions. The Radio Frequency Subsystem, together with the Antenna Subsystem, provides communication functions for the spacecraft to and from Earth. Part of the radio frequency subsystem is also used by the Radio Science Experiment, and for this reason the RF subsystem was built such to have unprecedented stability. For telecommunications, the radio frequency subsystem produces an X-band carrier at 8.4 GHz, modulates it with data received from Commands and Data System, amplifies the X-band carrier power to produce 20Watts from the Traveling Wave Tube Amplifiers (TWTA), and delivers it to the antenna subsystem. The parts of this subsystem used for the radio science instruments are: the High-Gain Antenna, the Ultra Stable Oscillator, the Deep Space Transponders, and the X-band Traveling Wave Tube Amplifiers. The brilliant performance of this instrument other than the S/C as a whole, made the relativity experiment (the determination of the light deflection parameter of gravitation theory) possible (Bertotti et al. 2004).

The large Antenna Subsystem, extremely advanced in terms of design and technology, consists of the High-Gain Antenna (HGA) and two Low-Gain Antennas (LGA-1 and LGA-2). The primary function of the high-gain antenna is to support communication with Earth. It is also used for S-band Huygens Probe Science, Ku-band RADAR, and Ka-band Radio Science. The high-gain antenna is a Cassegrain antenna consisting of a 4-meter parabolic primary reflector, a sub-refractor mounted in front of the focal point of the primary reflector and the fee horn between the two. It is one of the most complex and sophisticated ever developed for space up to date. The Huygens Command and Data Management Subsystem (CDMS) provides the monitoring and control of all probe subsystems and payload activities. Specifically, the CDMS performs the following functions: Timing of the 22-days coast phase to Titan and switches the probe "on" just prior to atmospheric entry; Controls the activation of deployment mechanisms during the descent to Titan's surface; Distributes telecommands to the engineering subsystems and science instruments; Distributes to the science instruments a Descent Data Broadcast providing a timeline of conditions on which the instruments can base the scheduling of mode changes and other operations; Collects scientific and housekeeping data and forward the data to the orbiter via the umbilical cable (during the cruise phase) or the Probe Data Relay Subsystem (during the descent phase)

The Probe Data Relay Subsystem (PDRS) provides the one-way probe-to-orbiter communication link and includes equipment on both the probe and the orbiter. The elements that are part of the probe support equipment (i.e. on the orbiter) are the probe system avionics and the Radio Frequency Electronics, the latter including an ultra-stable oscillator and a low noise amplifier. The probe carries two redundant S-band transmitters, each with its own antenna. The telemetry in one link is delayed by about four seconds with respect to the other link in order to avoid data loss if there are brief transmission outages.

ROSETTA (Fig. 2), the ESA Cornerstone mission was originally scheduled for launch in 2003 towards Comet Schwassman Wachman, aimed to study the origin of comets and of the Solar System, and the relationship between cometary and interstellar materials. After comet Schwassman Wachman 3 was ruled out, Comet Wirtanen was selected for targeting, but, due to launcher reliability problems, the spacecraft suffered 1 year launch delay. This caused the selection of a different object, Comet 67P/Churyumov- Gerasimenko, and a big problem of maintenace of the spacecraft for the time of the delay, which was successfully managed by Alenia Spazio. ROSETTA is now en route to the comet, will orbit around it as it journeys towards the Sun and it will fly by at least one asteroid. Alenia Spazio had responsibility for system AIV other than the On-board S/X - band Deep Space Transponder. The AIV phase of ROSETTA is to be listed amongst the most difficult integration activities one could think of in the field. Seven months only in a very tight schedule were available before the first launch campaign, for both assembly and integration of all the scientific instruments, including functional and electric tests. After one more year of testing and verification at ESTEC facilities, ESA decided to carry on the launch campaign under Alenia Spazio responsibility. At the moment of launch in 2004, Alenia Spazio had experienced two launch campaign and 1 year maintenance of a spacecraft which had, by the way, several scientific instruments substituted with new ones, after integration was already completed, while maintenance phase was under way.

MARS EXPRESS (Fig. 3). It is the first European spacecraft orbiting Mars. The main mission objectives include searching for subsurface water and performing global high resolution photo-geology, mineralogical mapping and analysis of atmospheric composition and circulation. The mission though deprived of its lander, is continuing with the research carried out by the orbiting element As with the Rosetta scientific probe, Alenia Spazio has taken on responsibility as main contractor to ESA for the assembly, integration and testing of the satellite and has defined and provided the related ground support equipment.

Fig. 2. Rosetta at Alenia Spazio's facility in Torino

Moreover, on behalf of the Italian Space Agency and in collaboration with La Sapienza University of Rome, the Company has designed and built the MARSIS (Mars Advanced Radar for Subsurface and Ionospheric Sounding) instrument capable of detecting the presence of water up to a depth of over 5 km beneath the surface, thereby contributing to one of the main objectives of the mission. The instrument was halted at the very beginning of the mission operations for safety -related problems, but the European Space Agency has recently given the go-ahead for the deployment of MARSIS on the first week of May this year. The innovation in the MARS EXPRESS mission consisted in a new approach of a space project in terms of working organisation and programme management: the spacecraft was developed and built in record time and at considerably lower costs then ever. A further contribution by Alenia Spazio to MARS EXPRESS concerns the construction of the

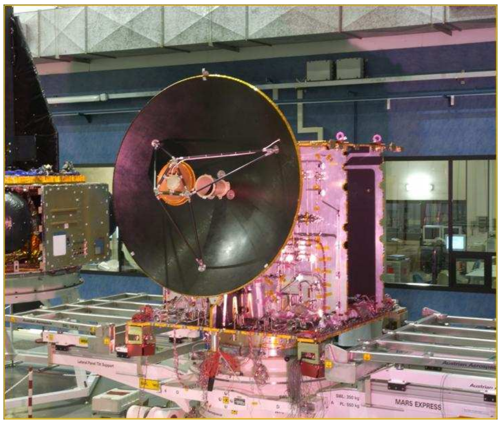

Fig. 3. Mars Express at Alenia Spazio's facility in Torino

two satellite S/X-band Deep Space transponders for the link between Mars Express and Earth.

2. Planetary Science today: VENUS EXPRESS and GOCE

VENUS EXPRESS (Fig. 4) will be the first European mission visiting Venus, built on the same design as Mars Express, (with minor modifications due to the mission objectives and different planetary conditions) by the same industrial team, same organization and programme management on a very tight schedule: 4.5 years from call for proposal to launch. The scientific equipment comprises instruments mainly aimed at studying the Venusian atmosphere and thick clouds, and make global maps of the surface temperatures.

As with the Rosetta and Mars Express scientific probes, Alenia Spazio has taken on responsibility as main contractor to ESA for the assembly, integration and testing of the satellite, making it quicker and cheaper to develop and has defined and provided the related ground support equipment.

A further contribution by the company concerns the construction of the two satellite S/X-band transponders for the link between Venus Express and Earth. The launch window for VENUS EXPRESS is open from October 26th to November 25th 2005. On a 150-days

Fig. 4. Venus Express at Alenia Spazio's facility in Torino

Fig. 5. GOCE

cruise it will be put in orbit around Venus for mission duration of 2 sidereal years. In the planetary science mission, we like to include also GOCE (Fig. 5). The Gravity Field and Ocean Circulation Explorer is the ESA's first and most important mission for the scientific exploration of the Earth. Developed as part of the "Living Planet" Earth Observation Programme, is aimed to produce the first high-resolution global map of the terrestrial gravity field, by a combination of local gravity gradient measurements by an on-board gradiometer, and satellite - to - satellite tracking measurements by a pair of sophisticated GPS receiver.

The gradiometer is equipped with six tri-axial electrostatic accelerometers arranged in three mutually orthogonal pairs, with a separation of 0.5 m within each pair. The accelerometers are supported by an ultra-stable structure maintained at a constant temperature by a multi-layer thermal control system. The mission performance is determined by the concurrent operation of the instruments and the satellite systems, which must suppress disturbing linear and angular accelerations. With the very stable, 4.9 m - long satellite, GOCE will recover gravity anomalies to better than 1 milligal (> 1 micro-g) and geoid heights to better than 2 cm, all over the earth's surface with a half-wavelength resolution of 100 km, unprecedented accuracy and resolutions.

Alenia Spazio is prime contractor for GOCE. It is responsible for design, construction, integration, testing and in-orbit commissioning of the satellite, for designing all the pointing control and drag free attitude control and implementing algorithms for the compensation of the braking effect of air molecules in the operational orbit; Alenia Spazio is then responsible for developing a functional simulator able to reproduce the generation of scientific data and scientific performance prediction. Moreover the Company also designs and constructs the first level ground processing algorithms for the scientific data produced during the mission. GOCE launch is scheduled on August 2006 from Pletzek base in Russia on a Rockot vehicle; the spacecraft will be put into circular sun-synchronous orbit at only 250 km altitude, and is expected to produce scientific data for 2.5 years lifetime.

3. Planetary Science in the future: BEPI COLOMBO, SOLAR ORBITER AND EXOMARS

BEPI COLOMBO (Fig. 6, 7 and 8) is a large-scale (cornerstone) European mission to Mercury, in collaboration with Japan. It is dedicated to remote sensing of the planet, exploration of its gravity field, magnetosphere and exosphere, and experiments in relativity. It will feature the first major application of Ion Propulsion in a planetary mission, the first low-altitude Mercury Orbiter and a Magnetospheric Orbiter in a high eccentricity orbit. The two modules are to be launched together in stack configuration and will be separated on arrival at Mercury, where they will perform their missions in coordinated fashion. The mission is indeed one of the most challenging long-term planetary projects: for the environmental constraints, for the scientific requirements, and for the technological development advancement which are demanded, both on systems' and scientific instruments' sides. The technological challenge of Bepi Colombo includes a range of technologies designed to cope with high temperatures and intense sunlight, the development of solar electric propulsion, solar array, antenna system technologies, radiation protection technologies, TT&C and AOCS technologies and many others.

Bepi Colombo is planned for launch in April 2012 on Soyuz-Fregat, in a 4-year cruise to Mercury by ion propulsion and gravity assists. The on-orbit operations are planned to last 1 +1 year at Mercury. Alenia Spazio is involved in the project since 1997, at the time of the Assessment Study. Currently Prime Contractor in one of 2 on-going Definition Studies is candidate Prime Contractor for the Implementation Phase, starting early 2006.

SOLAR ORBITER (Fig. 9) will, for the first time, study the Sun from close-up (45-50 solar radii, or 0.22 AU), fly by the Sun, tuned to its rotation, and examine the solar surface and the space above from a co-rotating vantage point, and provide images of the Sun's Polar Regions from heliographic latitudes as high as 38. The mission is planned for launch in November 2013, for a 3 year cruise, 3 years operations and 3 years lifetime. Alenia Spazio is partecipating in on-going Assessment Study, with responsibility for the RF system, the Thermal Control, and the commonality with Bepi Colombo.

EXOMARS, (Fig. 10) the first Flagship mission in the frame of AURORA Programme, is part of Europe's strategy for space, endorsed by the EU Council of Research and the ESA Council 2001. It is conceived to be the next ESA mission to Mars and has two key objectives: the characterization of the Martian biological environment, (including the geological context of the rover site and identify promising

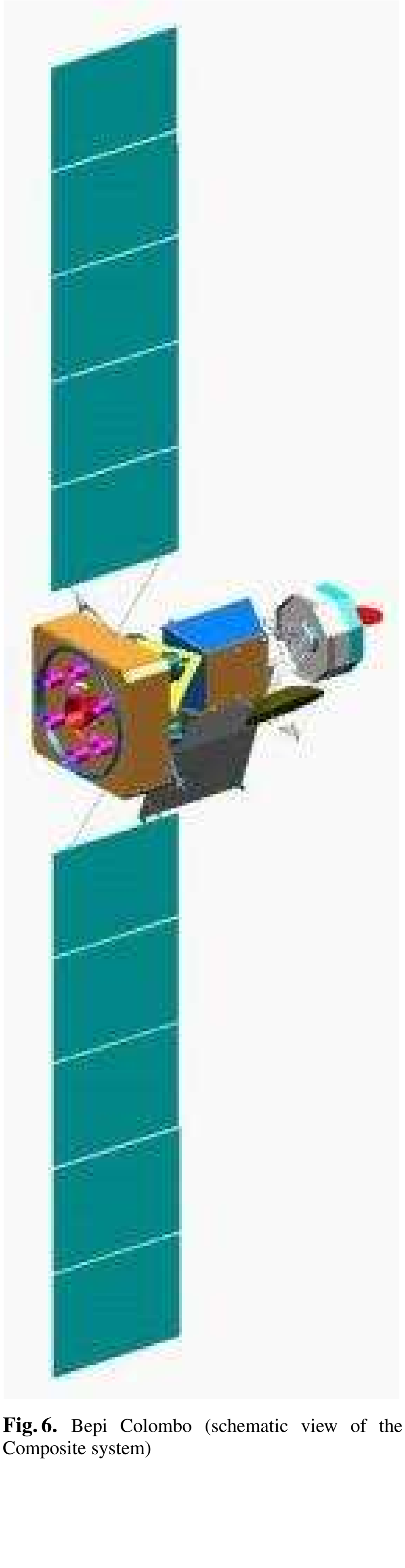

Fig. 6. Bepi Colombo (schematic view of the Composite system)

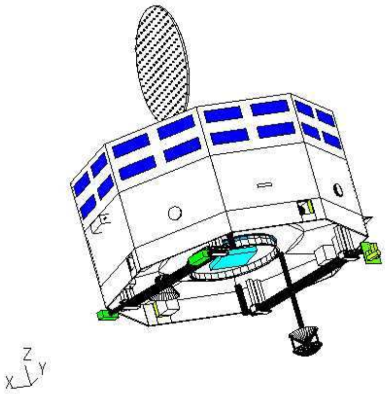

Fig. 7. Bepi Colombo (schematic view of the Magnetospheric Orbiter)

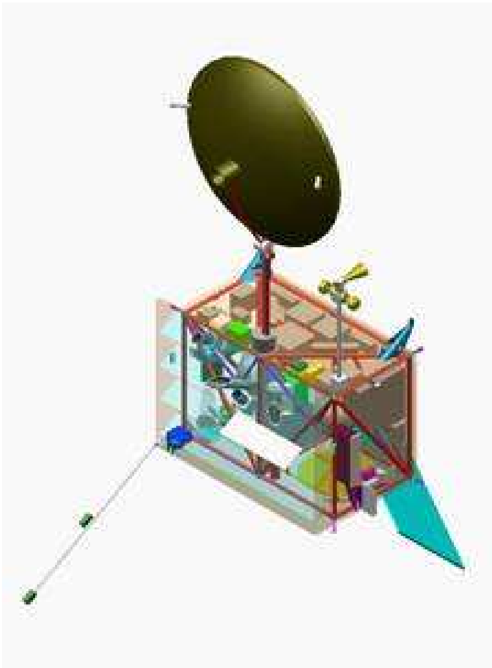

Fig. 8. Bepi Colombo (schematic view of the Planetary Orbiter)

targets from which to obtain samples for analysis; to accurately detect signs of life and/or organic molecules present in the collected samples and evaluate hazards to humans), and validation of landing capability. The mission also

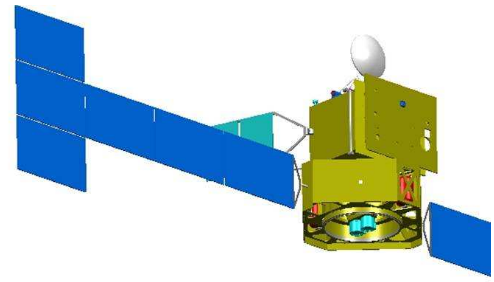

Fig. 9. Solar Orbiter (schematic view)

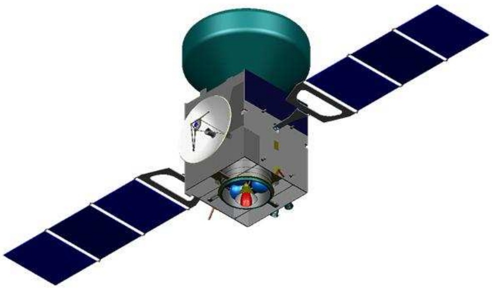

Fig. 10. EXOMARS (schematic view)

includes an in-orbit rendezvous experiment (RVE) in preparation for a Mars Sample Return mission. The mission architecture consists of Orbiter (including RVE), Descent Module, and 200 kg - class Rover. The key of the project is indeed the innovative technology: from rover system to precision navigation and landing, from inflatable braking device to power supply

EXOMARS is, for the moment being, still planned for launch in 2011, with a possibility of back-up in 2013.

Alenia Spazio is Leader of one of 3 parallel, almost completed Phase A studies, and is supposed to be Prime Contractor for the B1 phase, supposed to start this year (2005).

References

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