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Solar System exploration and SORA

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Abstract. Long Duration Balloons are usually considered a reasonably cheap and easy access to space. In this paper the interest of the Italian Space Agency, and in particular of the Observation of the Universe (OSU) unit, for the applications of LDB in Solar System explorations is highlighted. The direct use in planetary atmosphere of aerial robots (aerobots) is described and their use for surface and subsurface observation together with light landers and/or rovers release on extended areas. Furthermore, the recent studies for Mars, Venus and Titan planetary balloons are briefly described and the proposed TANDEM mission to Titan is emphasized. A secondary application field is the comparative planetology, and experiments in this area are currently included in Italian programs; after the successful HASI campaign, in the near future the SORA experiment will be performed and it could pave the way to an intensive balloons use for the flight of scientific space payloads.

Key words. Planetary exploration, aerobots, comparative planetology, sounding radar

1. Introduction

The main interest of space scientific community in balloons is connected to their capability to be used as platforms for space observation avoiding atmosphere filtering; therefore, the most involved disciplines are: IR/Sub-mm Astrophysics, Particle Astrophysics, Gamma Ray/X-Ray Astrophysics, Geospace Sciences, Solar and Heliospheric Physical and Upper Atmosphere Research (Israel et al. 2005).

Moreover LDB or SDB can also be included in Solar System exploration programs, and the first potential applications are in direct planetary exploration. Observing the time line of the exploration of Earth, depicted in Figure 1, it's clear that it started from the use of ground vehicles going to the space satellites and passing through aerial observations by means of balloons and montgolfiers. On the contrary, the history of planetary explorations followed the reverse order, but it at present still misses the intermediate stage of flying vehicles as balloons (the only applications are the soviet VEGA probes on Venus of the 1985).

Additionally, the balloons are an interesting support for the so called Comparative Planetology, the science that takes origin from the reciprocal analogies between Solar System's planets. From balloons can start the free fall to simulate the entry and descend phases of landers or entry vehicles and to collect data for the improvement of structures and instruments. Furthermore, payloads for observation, surface and subsurface analyzing and atmosphere examination can be carried around Earth and their results can be used to calibrate instruments and the related software for data acquiring, conditioning and analyzing.

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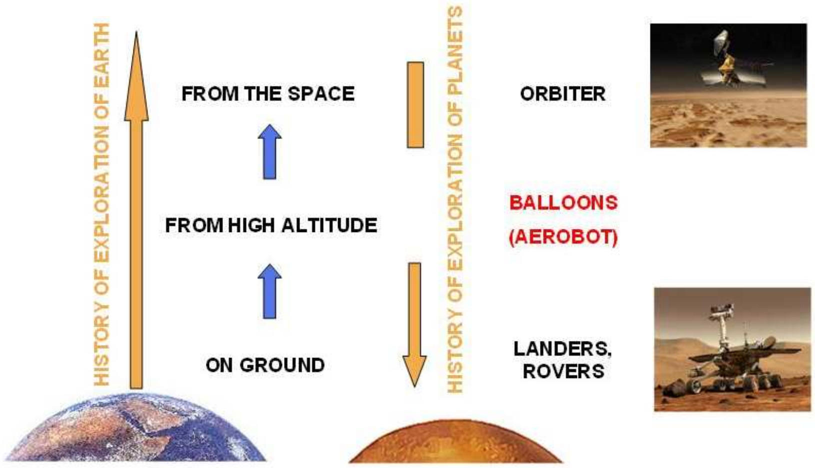

Fig. 1. Vehicles for planetary exploration.

2. Planetary balloons or aerobot (aerial robots)

For planets with atmosphere, planetary robot balloons or aerobots (J. Blamont 2007) are potentially very useful vehicles, carried by spacecrafts and then locally deployed, to inspect large areas in great detail for relatively low cost and light weight. The most relevant benefits are the larger observation area with respect to the one available by means of landers and rovers and specific flight altitude that can permit optimal distance for planetary observation, but also for atmospheric data collecting.

The consequent scientific areas of interest are: close-up image of planetary surface (geology, geochemistry, geophysics), in-situ observation of planetary atmosphere (meteorology, chemistry), remote-sensing (mineralogy). Besides permitting the overflights of observation payloads, they could also be used to transport and release small landers and rovers on a large area of the planetary surface.

According to their base technology, aerobots can be classified as:

- Solar, or infrared (IR) Montgolfiere: hot-air balloon where the envelope is made from a material that traps heat from sunlight, or from heat radiated from a planetary surface, with the advantages of easy deployment than a light gas balloon, no tank of light gas for inflation, relatively forgiving of small leaks of internal gas;
- Reversible fluid balloon: consisting of an envelope connected to a reservoir, containing a fluid that is easily vaporized and condensed during the different phases of the flight in order to change the altitude of buoyancy;
- Aerostat: balloons that could also be anchored to maintain a fixed position, especially with the aim to perform atmospheric observations.

3. Studies for exploration missions involving aerobots

The space community have recently expressed a deep interest in aerobots and their applications, so producing a lot of theoretical and experimental studies, mission proposals, technology demonstrations.

The most involved agency is without doubt the US NASA, which has found the dedicated Balloon Program Office, working also on the idea of planetary aerobots for missions to Mars, Venus, Saturn's moons, and the Outer Planets (Figure 2). The first preliminary studies were: ALICE (Altitude Control Experiment), that flew since 1993, and PAT

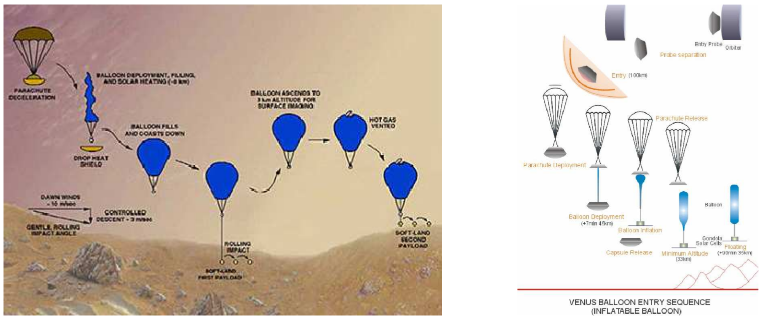

Fig. 2. Mars and Venus aerobot mission proposed architectures.

(Planetary Aerobot Testbed) which developed in 1996.

Two balloon types are today under investigation for Mars exploration (J. A. Jones et al. 2005): Montgolfieres (zero pressure) and Helium Superpressure (pumpkin and spherical shaped). Both designs are utilizing aerial deployment and inflation of the balloon envelope while descending in the Martian atmosphere. The limitation for montgolfiere is connected to their lifetime, that is of several hours and make them suitable for polar exploration, while the second can fly for hundred of days. Specialized NASA program for Mars was MABVAP (Mars Aerobot Validation Program), started on 1997 and focused on the deployment and inflation of super-pressure ballons and development of materials and structures suited to a long-duration Mars mission. Within the program the developed experiments are: MABTEX (Mars Aerobot Technology Experiment), MGA (Mars Geoscience Aerobot), and MASEPA (Mars Solar Electric Propelled Aerobot).

Programs for Venus exploration by aerobots are dedicated to samples acquisition for subsequent in-orbit analyses or return to Earth and atmospheric data acquisition of chemical composition, for the development and validation of geological and climatic evolution models. A New Frontiers mission candidate is the Venus In-Situ Explorer (VISE), whose architecture includes balloons flight, rendezvous and sample return. The proposed Venus Aerostatic-Lift Observatories for in-situ Research (VALOR) mission consists of a couple of helium-filled balloons, flying at a 56 km altitude in tropical and polar latitude, carrying scientific payloads for rare gases and their isotopes detection and environmental measurements for Venus climatic (circulation, greenhouse, chemical cycles) phenomenon's.

A dense atmosphere, 1.5 times more than on Earth and 400 times than on Mars but with a very cold temperature (about -180 C), can be encountered also on Titan. While JPL is intensive working on the first aerobot prototype with autonomous navigation during one year mission in Titan's atmosphere, the European Space Agency in October 2007 has selected the proposal TANDEM, in the framework of the 2015-2025 Cosmic Vision Plan for studies as an L-class mission to explore in situ Saturn's natural satellites Titan and Enceladus. The scientific targets of the mission are: surface composition and geological structures study, liquids detection and atmosphere/surface interaction, space environment analysis (atmosphere, ionosphere and exosphere as well as its plasma and magnetic field environment).

Several different studies about balloons for Titan have been recently performed. In J. A. Jones and J.J. Wu (2007) a Radioisotope Power Source heated Montgolfiere was described and tested, mission scenario was analyzed while environmental data were acquired and compared with results of simulations. Other proposed missions under investigation are (R. D. Lorentz 2007): PASTA (PASsive TitAn balloon), ZORBA (ZOnal Recon Balloon), TABI (TiTAn Balloon Investigation), TALE (Titan Airship Latitude Excursion).

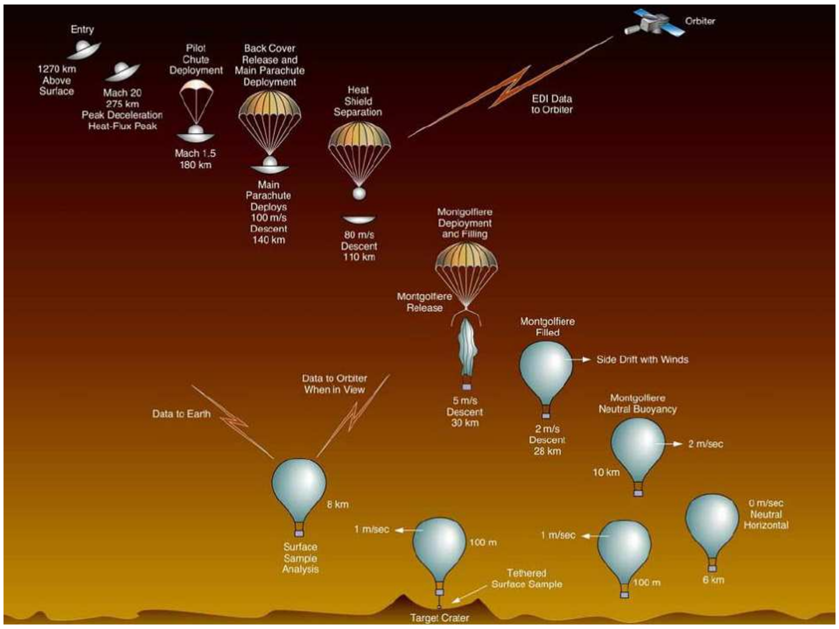

Fig. 3. A Titan Montgolfiere entry, descent and inflation possible scenario (R. D. Lorentz 2007).

4. Comparative planetology

While accurate monitoring the international activities about planetary balloons, the Italian Space Agency is directly involved in balloon's based experiments, using Earth environment as a natural laboratory to test the interaction of probes with local atmosphere or with the overflight lands, with the aim of instruments and software calibration, attitude and trajectory control and shielding during descent phase, observation payloads testing.

In this field, a very successful example is the Huygens Atmospheric Structure Instrument (HASI) experiment (M. Fulchignoni et al. 2004); this multi-sensor package was designed to simulate the measurements and data acquisitions the of the physical properties (temperature, the pressure, the turbulence, the atmospheric conductivity) performed by Huygens probe, of the Cassini-Huygens NASA-ESA-ASI mission, during its descent in Titan's atmosphere. The experimental campaign was performed from the ASI Milo base in Trapani (Italy) on 2002, when the mock up descending and landing from an altitude of 35 km was monitored during the 45 minutes of the flight. In Figure 4 the experimental set up and the TEM temperature time history chart of the described test are shown.

5. SORA: rada sounding on arctic

The OSU-ASI unit is currently involved in the SORA (SOunding RAdar) experiment, that is a part of more complete program for radar sounding testing and improvement in order to consolidate the italian scientific and technological know-how in the development of radar for Solar System exploration, acquired with MARSIS and SHARAD instruments.

SORA experiment main goals are: the validation of the algorithms and data calibration of the sounding radars for planetary exploration (especially for SHARAD and MARSIS); the investigation of ice covered surface in polar regions, to improve climatic models and ice-monitoring satellites. The observed regions include ice sheets, glaciers, permafrost areas, plutonic to sedimentary rocks, and sedimentary natural environments. Sea ice will be prob-

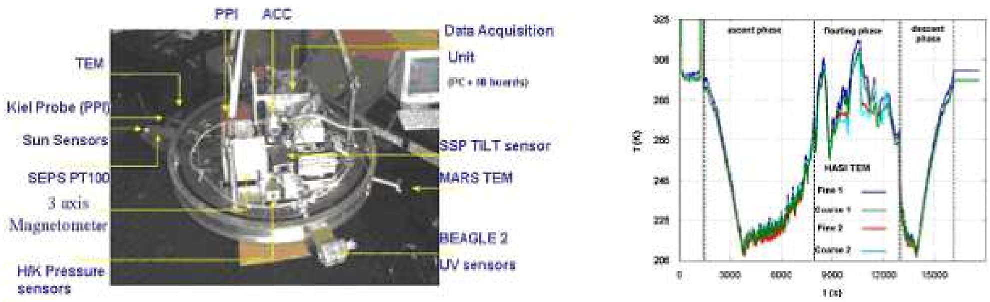

Fig. 4. Instruments of the HASI probe and results of the experimental campaign.

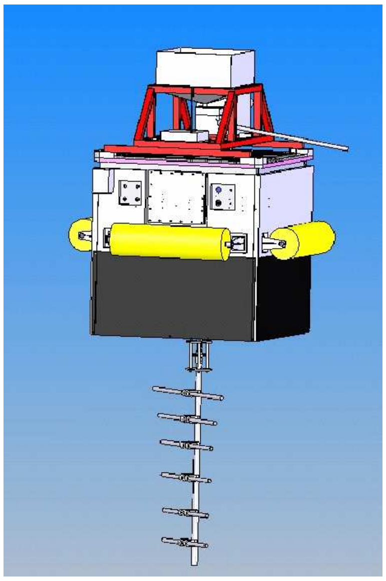

Fig. 5. SORA gondola and payloads.

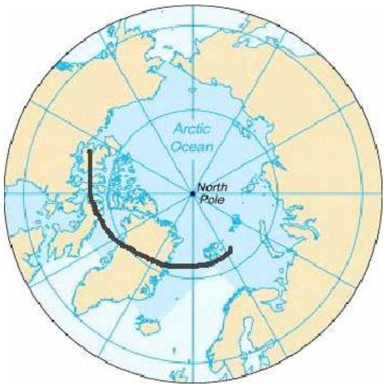

Fig. 6. SORA predicted trajectory from Svalbard islands.

ably too thin to be detected by the instrument. The chosen regions can be correctly considered as Terrestrial analogue of Martian polar morphologies, because of the presence of similar geological structures.

In order to achieve this scientific targets CORISTA developed a low-frequency synthetic aperture radar altimeter (central frequency 163 MHz, pulse duration 3 μsec) capable of ice sheets sub-surface mapping, with a vertical resolution of 15 m. The emitting antenna is a Yagi constituted by 6 elements and a gain of 13 dB. The gondola structure, showed in Figure 5 and designed by CISAS to survive the flight and the landing even in extreme environmental conditions and/or in water, is realised in aluminium alloy with stainless steel structural components. Inside the layered modular gondola the other subsystems, as main CDMU unit, telemetry equipment, power distribution unit, are allocated. The flight equipment, including balloon but also ballast, parachute and its subsystems, is directly provided by ASI and integrated in the Milo base.

The mission consists of a circumpolar flight about one week long, at the latitude of about 79 N and altitude of about 35 km, starting from Svalbard Islands, flying over lands of Greenland and with a probable recovery target area in the Canadian Arctic Archipelagos (Figure 6).

6. Conclusions

The balloons are not only a budget wise cost affordable support for space observations form Earth over a wider spectral range, but also a very promising vehicle, with high mobility, capability to deploy landers and extended observation areas, for planetary exploration. Because of this, a lot of studies within various space agencies programs about mission architectures that include the use of aerobots are currently under investigations. The Observation of the Universe unit of the Italian Space Agency is very sensible to this field of research, is continuously looking for scientific and technical proposals and it's today directly involved in the SORA experiment, that will hopefully start a new period of intensive activities and experimental campaigns by Long Duration Balloons.

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