Contribution to the prospective workshop on
"Earth and Space Sciences in Europe using CNES balloons"

Pau, September 22-24, 2008

A. Coustenis,
B. LESIA, Observatoire de Paris

Studies for a hot-air (Montgolfière) balloon for in situ exploration of Titan

Executive summary

The Titan Saturn System Mission (TSSM) is currently studied by ESA and NASA as part of the Outer Planet mission program. This mission is in a short-term competition with EJSM (Europa Jupiter System Mission) and a downselection is expected by the end of 2008.

A mission to return to Titan after Cassini-Huygens is a high priority for exploration, as recent Cassini-Huygens discoveries have further revolutionized our understanding of the Titan system and its potential for harboring the "ingredients" necessary for life. These discoveries reveal that Titan is rich in organics, contains a vast subsurface ocean of liquid water, surface repositories of methane, ethane and other organic compounds, and has the energy sources necessary to drive chemical evolution. With these recent discoveries, interest in Titan as the next scientific target in the outer Solar System is strongly reinforced. Cassini's discovery of active geysers on Enceladus adds a second target in the Saturn system for such a mission, one that is synergistic with Titan in understanding planetary evolution and in adding a potential abode in the Saturn system for life as we know it.

In order to respond both to the NASA Decadal and the ESA Cosmic Vision Themes as defined in the 2007 calls and studies, TSSM would have to return new science insights — among other — on chemical composition and structure, meteorology, dynamics, geology, geophysics, hydrology, solar system physics. To do so, the in situ exploration is a key player in this mission, as was demonstrated by the Huygens probe within the Cassini-Huygens mission and as is also clearly shown in the current study.

One overarching goal of the TSSM mission is to explore *in situ* the atmosphere and surface of Titan. In the current mission architecture, TSSM consists of an orbiter (under NASA's responsibility) with a large host of instruments which would perform several Enceladus and Titan flybys before stabilizing in an orbit around Titan alone, therein delivering in situ elements (a Montgolfière, or hot air balloon, and a probe/lander). The latter are being studied by ESA, in collaboration with CNES (balloon division in Toulouse). The Titan balloon will circumnavigate the satellite above the equator at an altitude of about 10 km for several months. The probe will descend through Titan's atmosphere and land on a liquid surface (at the North pole, in a lake according to the current design).

The mission concept consists of a NASA-provided 1600 kg orbiter with ESA-provided in situ elements : a 180 kg short-lived probe and a 588 kg Montgolfière balloon. Launch is scheduled for 2020, and a 9.5 year trip is foreseen before Saturn Orbit Insertion (SOI). During

the first Titan flyby (~100 days after SOI), the orbiter would release the lander (Mare Explorer) to target Kraken Mare, and the Montgolfière balloon system toward the equator.

Although an orbiter-alone mission to return to Titan and the Saturnian System, would bring exceptional new insight on very exciting objects, *in situ* investigation would enable the assessment of Titan science features which are not feasible from the orbiter. A Montgolfière hot-air balloon that can circumnavigate Titan carried by winds, exploring with state-of-the-art new instrumentation, in combination with a probe lading in a Northern-hemisphere lake and with orbiting observations is a powerful and, for Titan, unprecedented opportunity for synergistic investigations—synthesis of data from these extensively-studied selected instrumentation suites is the best current way to understanding this complex body.Titan's thick lower atmosphere and low gravity make the deployment of *in situ* elements vastly easier than at any other solar system body, as indicated by CNES studies. *In situ* elements will give direct access to atmospheric and surface sampling and analysis. They will also enable powerful techniques such as seismology and subsurface sounding to be applied to exploring Titan's interior structure.

Instruments aboard the balloon would provide high resolution vistas of the surface of Titan as the balloon cruises at 10 km altitude, as well as make compositional measurements of the surface, detailed sounding of crustal layering, and chemical measurements of aerosols. A magnetometer, unimpeded by Titan's ionosphere, would permit sensitive detection of induced or intrinsic fields.