TITAN AERIAL EXPLORER: A MISSION TO CIRCUMNAVIGATE TITAN J.I. Lunine[1], K. Reh[2], C. Sotin[2], P. Couzin[3], A. Vargas[4]. [1]Univ. of Rome Tor Vergata, Via della Ricerca Scientifica 1, 00133 Rome, Italy, jlunine@roma2.infn.it, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, Thales Alenia Space, Cannes, France, CNES, Toulouse, France.

Introduction: The Cassini-Huygens mission revealed Titan to be a body with an active hydrological cycle involving methane, ethane and a variety of other organic molecules[1]. It found methane oozing from the surface at the Huygens landing site, and liquid organics residing in vast near-polar deposits whose extent rivals or exceeds the great lakes and seas on Earth. Cassini observed methane clouds forming as convective storms in the summertime south, as ghostly echoes superimposed on methane seas sheathed in late winter darkness, and as unexpectedly vast outbursts in the mid-latitudes as the Sun crossed the equator of Titan at equinox. The geologic history of the surface remains a mystery after six years of Cassini data. The variety of surface features and atmospheric phenomena seen only at moderate and low resolution by the orbiter tease us, because we know from nature of the one site visited *in situ* by the Huygens probe that hidden among the dunes and channels, the mountains and lake shores, is a complex history of climate change and chemical evolution tied to methane and its prodigious variety of organic products. We seek to understand this history by deploying at Titan the one type of vehicle that combines the mobility and coverage of the orbiter with the capability for high resolution and *in situ* observations demonstrated by the Huygens lander, and does so in an aerodynamically stable and low-risk fashion—an aerostat (balloon plus gondola).

Concept: The Titan Aerial Explorer mission has been proposed for study under the ESA Cosmic Visions 2010 opportunity. It utilizes a helium-filled super-pressure (or "pressurized") balloon, rather than a hot air (montgolfière) design, as in many previous studies. Strict limitations on technology readiness level, relative robustness of the inflation scenario and mission lifetime were factors that weighed in this decision. Its development leverages decades of previous experience as well as recent planetary balloon development advances of the French Space Agency (CNES) and Jet Propulsion Laboratory California Institute of Technology (JPL) inspired by the Titan Saturn System Mission (TSSM) study. The proposed design satisfies the Cosmic Vision call requirement which specifies that technologies are to be at a technical readiness level 5 or greater. The Advanced Stirling Radioisotope Generator (ASRG), assumed to be provided by NASA, would enable electrical power for all phases of the mission. The aerostat gondola would carry the instruments necessary to perform the measurements. The baseline communication scheme would be a direct-to-earth link using the aerostat's inertial stabilized 0.75-meter high gain antenna. TAE would be compatible with Saturn orbiting relay if one were in the Saturn system at that time.

The great advantage of the pressurized balloon is the maturity of its inflation and deployment scheme. Its disadvantage is relative sensitivity to the presence of small holes that could reduce dramatically the mission lifetime. Studies will be made of options to ensure integrity of the envelope and define onboard mitigations that can be exercised in the event of minor leaks.

Science: TAE science is organized around two themes, which emphasize the special nature of Titan and at the same time its important connections to studies of other planets and the Earth. These are (1) The presence of an atmosphere and liquid volatile "hydrologic" cycle, which implies climate evolution through time and (2) organic chemistry, which is pervasive through its atmosphere, surface, and probably interior. These in turn lead to five primary science objectives for a balloon-borne system, which then, through the science investigations that devolve from them, would be addressed through measurement objectives.

Science objective 1 is to determine the composition and transport of volatiles and aerosol particles in clouds, including hydrocarbons and nitriles, in order to understand the hydrocarbon cycle, as well as to quantify the climatological and meteorlogical variations of temperature, clouds and winds. Objective 2 is to characterize and assess the relative importance today and throughout time of Titan's geomorphologic processes: cryovolcanic, aeolian, tectonic, fluvial, impact and erosion. The third objective is to determine the internal differentiation and thermal evolution of Titan, including whether Titan has an internal ammonia-water ocean, a metal core and an intrinsic or induced magnetic field, and as well to quantify the extent and origin of geodynamic activity. The fourth is to identify geochemical constraints on bulk composition, the delivery of nitrogen and methane and exchange of surface materials with the interior. The final science objective is to determine the chemical pathways leading to formation of complex organics at all altitudes in Titan's atmosphere and their modification and deposition on the surface with particular emphasis on ascertaining the extent of organic evolution on Titan.

Instruments: The TAE mission would acquire extended *in situ* measurements of Titan's troposphere (only briefly sampled by Huygens) and conduct imaging and sounding of the surface and subsurface at high resolution. Three remote sensors—a camera (VISTA-B), near-infrared spectrometer (BSS) and radar sounder (TRS)—and three *in situ* experiments—an aerosol collector and analyzer (TCAA), meteorology package (ASI/MET), and a device for measuring electric and magnetic fields and conductivity (TEEP-B) would comprise the instrument suite. In addition, tracking of the balloon's radio signals would allow for determination of atmospheric circulation patterns at cruising altitude. The selected instruments all have a TRL level at or exceeding 5, and some are as high as 8.

All the instruments would be integrated in the aerostat gondola. The instruments would have different modes of operation. While VISTA-B and BSS would acquire data when the surface is illuminated, the ASI/MET, TEEP-B and TRS instruments could take measurements at any time. The TCAA would operate when aerosols or cloud droplets are detected on the collector plate. Communication to Earth would be possible during half of Titan's sol (~16 Earth days), when the balloon could see the Earth, which mostly occurs when Titan is illuminated. The total amount of data that could be downlinked to Earth is on the order of 150 Mbits per Titan sol. The proposed procurement approach for all instruments is that they would be provided by member states or other countries. A call for instruments and a selection process would be conducted according to ESA rules.

Mission: The proposed baseline mission would begin with a Soyuz-Fregat launch in 2022 followed by a 9-year interplanetary cruise (Earth-Venus-Earth-Venus-Earth-Titan) of the combined Carrier and Descent Modules (CM/DM). The DM would include the aerostat encased in a Huygens-like entry and descent system. When the CM nears Titan, it would point and release the DM onto the pre-determined entry, descent and inflation trajectory. The DM would enter Titan's atmosphere south of the equator, deploys a parachute, releases the aeroshell heat shield and backshell, initiates balloon inflation, releases the helium tanks and establishes neutral buoyancy at ~8 km altitude.

The arrival of the aerostat would be in April 2032 at Ls = 270°, which is the southern summer solstice on Titan. At this time of year winds in the lower troposphere of the summer hemisphere are predicted to blow toward the west at the aerostat's operating altitude. The zonal wind most likely does not change direction at a given altitude and latitude within the same season, but the altitude of transition between eastward and westward wind is somewhat uncertain; staying below 10 km maximizes the chance that TAE would have a steady zonal wind to the west. By putting the balloon into the southern hemisphere, with an entry point biased to the east of the Huygens landing site, it would have a reasonably high probability of drifting over and imaging the features observed there 25 years earlier by the Huygens probe, providing an opportunity to examine landscape evolution on a spatial scale small enough for changes to plausibly have occurred.

The most likely aerostat trajectory is a wavy path along a line of constant latitude, with an excursion north and south of amplitudes typically a few degrees latitude. The typical zonal wind speed in the altitude range of the balloon is roughly 1 m/s, so one circumnavigation of Titan at the equator would require roughly 6 months. The threshold science mission would be achieved after a 3-month long navigation halfway around Titan, while the goal is a complete circumnavigation. For the bulk of the mission, the mission operations for TAE would take place from ESA's European Space Operations Centre. Data would be archived at both the PDS and the ESOC node.

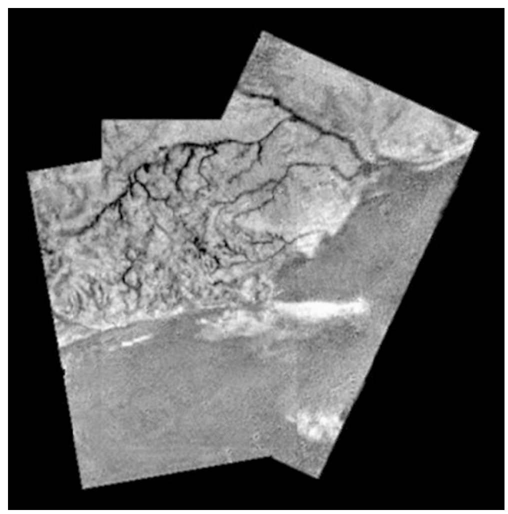

Fig. 1. Huygens images of dendritic features on Titan at 30 m resolution. TAE could take hundreds of images at finer resolution from ~8 km altitude. ESA/NASA/JPL/U. Arizona.

The entry conditions, design of the descent system and the EDS operation sequencing would be set such that the Huygens heritage could be used to the maximum extent possible. Other key components also have strong heritage from previous missions, such as the superpressure balloon approach (Vega 1985 balloons), but modified to work in the Titan environment. Although the trajectories studied are for 2022, the mission could be readied for launch as early as 2020.

References: [1] Lunine, J.I. and Lorenz, R.D. 2009. *Ann. Rev. Earth. Planet. Sci.* 37, 299-320.