Science at a Variety of Scientific Regions at Titan using Aerial Platforms, M.Pauken[1], J. L. Hall[1], L. Matthies[1], M. Malaska[1], J. A. Cutts[1], P. Tokumaru[2] , B. Goldman[3] and M. De Jong[4], [1]Jet Propulsion Laboratory, California Institute of Technology, MS 321-550, 4800 Oak Grove Drive, Pasadena, CA 91109, Michael.Pauken@jpl.nasa.gov, [2]AeroVironment, Monrovia, CA, [3] Global Aerospace, Monrovia CA, [4]Thin Red Line Aerospace, Chilliwack, BC

Titan's low-gravity, thick-atmosphere environment lends itself to exploration by atmospheric flight. Flight on Titan can also provide science with observational opportunities that would be achieved by orbiters and rovers on other planets and moons but which are not possible on Titan because of the obscuring atmosphere and hazardous terrains. This paper reviews past work and recent developments on aerial platform concepts for Titan and the contribution of aerial exploration to Planetary Science Vision 2050.

Scientific Motivations:

Titan has an abundant supply of a wide range of organic species and surface liquids, which are readily accessible and could harbor exotic forms of life. Furthermore, Titan may have transient surface liquid water such as impact melt pools and fresh cryovolcanic flows in contact with both solid and liquid surface organics. These environments present unique and important locations for investigating prebiotic chemistry, and potentially, the first steps towards life.

Aerial platforms are ideal for performing initial reconnaissance of such locations by remote sensing and following it up with in situ analysis. The concept of exploring at Titan with aerial vehicles dates back to the 1970s [1] and NASA initiated studies of Titan balloon missions in the early 1980s [2] and JPL conducted a studies and technology development in the 1990s and early 2000s [3], but it was the Cassini-Huygens mission arriving at Saturn in 2004, that gave a new impetus to aerial exploration of Titan.

Impact of Cassini Huygens Mission

When ESA's entry probe Huygens descended through the atmosphere of Titan it determined that not only was the atmosphere clear enough to permit imaging of the surface but also the surface had a rich variety of geological features. Winds were light and diurnal changes were minimal ideal for aerial platforms

These observations reaffirmed the notion that aerial vehicles were destined to play a key role in the future exploration of Titan for 1) remote sensing since many orbital signatures were obscured by the dense atmosphere, 2) mobility, since the lakes and dunes that covered many areas of Titan of would present hazards to surface vehicles and 3) surface sampling through controlled flight near the surface [4].

Here we review the various aerial platform concepts for Titan that have been proposed since the landing of Huygens in Dec 2004, the technology development that has been undertaken and the role that these vehicles can plan in a Planetary Science Vision 2050.

Lighter Than Air (LTA) Concepts

***TSSM Montgolfiere Balloon*:** In 2008 NASA and ESA jointly developed a concept for a Titan Saturn System Mission (TSSM) which included a Montgolfiere balloon for which altitude control is provided by heating of ambient gas with radioisotopically derived waste heat [5]. TSSM competed with a concept for a mission to the moons Europa (NASA) and Ganymede (ESA) which ultimately was selected on the basis of technical maturity in Feb 2009. A joint CNES JPL technical effort on balloon development continued addressing issues of buoyancy stability and control and deployment.

Titan Helium Balloons Rise Again: Selection of Montgolfiere balloons using RPS waste heat for Titan mission was based on their ability to float for many years in the Titan atmosphere and to change altitude with minimal energy use. However, subsequent work on helium balloons has shown that these features can also be obtained in a much more compact and easily controlled helium balloon. Life-limiting diffusion of helium through balloon envelopes at Titan temperatures was shown to be reduced by 4 orders of magnitude from that at Earth ambient [6]. Altitude control of helium balloons was shown to be feasible with very modest amounts of energy by either pumped compression or mechanical compression (Figure 1 and [7]).

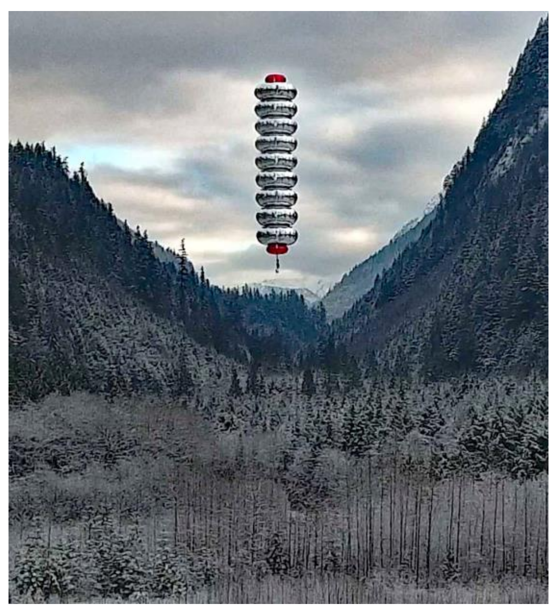

Figure 1 Mechanical Compression Altitude Control balloon is comprised of a number of segments that are compressed by shortening a tether that runs down the axis of the balloon. Release of the tether allows the balloon to rapidly ascend

Concepts for achieving lateral motion and control of the lighter than air vehicles have also been developed such as the Titan Winged Aerobot (Figure 2) was investigated in NASA's 2016 Phase 1 SBIR program.

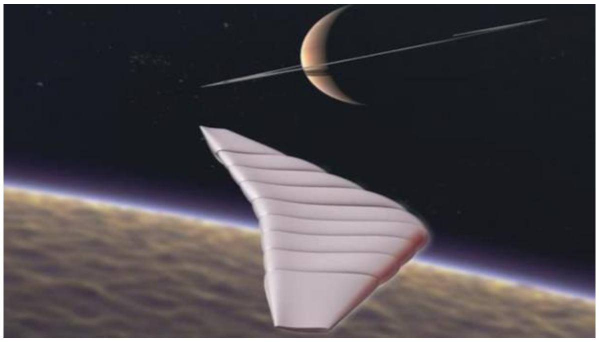

Figure 2 Concept for a Titan Winged Aerobot a hybrid balloon glider that does not require significant power either to stay aloft or to achieve lateral motion

Heavier Than Air (HTA) Concepts

Concepts have also been developed for both fixed wing and rotorcraft for Titan. Both take advantage of the favorable conditions on Titan for flight [5].

Fixed Wing Vehicles: Concepts for fixed wing aircraft on Titan have been developed by Lemke [8]. Despite the poor specific power of radioisotope power sources, the combination of the density of the Titan atmosphere and the very low gravity makes it practical to achieve sustained flight on Titan. The AVIATR—Aerial Vehicle for In-situ and Airborne Titan Reconnaissance [9] involved a study to fully explore the capabilities of a fixed wing aircraft.

While a disadvantage of the fixed wing aircraft is that scarce electrical power must be subdivided between the needs of staying aloft and propulsion. AVIATR addresses this by a novel 'gravity battery' climb-then-glide strategy to store energy for optimal use during telecommunications sessions. However, AVIATR cannot descend to the surface for sampling.

Rotorcraft: The dramatic expansion of drones capable of controlled descent has spurred interest in applying the same concept at the planets. A Mars Helicopter drone is currently under development at JPL targeted at flight on the Mars 2020 mission. Concepts using two coaxial counter-rotating rotors appear to provide the best thrust to weight ratio, which is crucial for feasibility in Mars thin atmosphere. In Titan's thick atmosphere and lower gravity, multicopters are feasible and offer simpler mechanical and control system designs (Figure 3 and [10]. Like the Mars Helicopter, this would be powered by a rechargeable battery which permits only short flights of the order of an hour before recharging. However, unlike Mars where the helicopter could land and recharge using a solar panel, the Titan Aerial Daughtercraft (TAD) must recharge from an RPS which is located on a Mothercraft – either a lander or a balloon.

Figure 3 Concept for a Titan rotorcraft flying over a Titan lake. The vehicle is powered with a rechargeable battery and must return to a mother craft to recharge.

Aerial Platform and Planetary Science Vision 2050

As NASA formulates a plan for Planetary Science Vision 2050, aerial platforms at Titan should play a key role. Both LTA and HTA concepts are clearly practical and can offer unique contributions to exploration of this fascinating world. They bring the unique ability to perform synoptic coverage from altitude and in situ measurement when they descend to the surface. Aerial platform will perform a large part of the role that both orbiters and rovers have served at Mars. When the time comes for sample return aerial platforms will also perform the critical role of lifting samples from the surface to a high enough altitude from which they can be injected into space. Planetary Science Vision 2050 must include a strategy for aerial platforms at Titan.

References

[1] Blamont, J., in D. M. Hunten and D. Morrison (eds), *The Saturn System*, NASA Conference Publication 2068, 1978. [2] A.L. Friedlander, *JBIS*, **37**, pp.381-387, 1984, [3] J. A. Jones and M. K. Heun, "AIAA, Paper No. 97-1445, 1997 [4] Cutts, J.A. J.L. Hall and E. Kolawa, IPPW-5, 2007 [5] Reh, IPPW-010, [6] Pauken, M and J.L. Hall IPPW-11, 2014, [7] De Jong, M. and J.A. Cutts, IPPW-12, 2015 [8] Lemke, L.G.: IPPW-7,2008 [9] J. Barnes AVITR plane report. Exp Astron (2012) 33:55–127 DOI 10.1007/s10686-011-9275-9, [10] Matthies, L.H, P. Tokumaru and S Sherritt, IPPW-11, 2014

* IPPW is International Planetary Probe Workshop. Presentations and papers can be accessed at the IPPW archive http://solarsystem.nasa.gov/missions/ippw