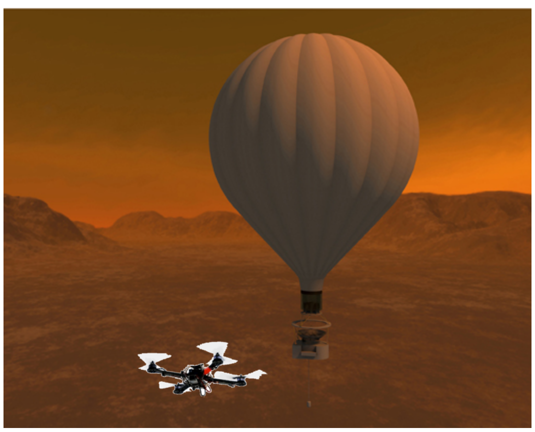
TITAN AERIAL DAUGHTERCRAFT (TAD) FOR SURFACE STUDIES FROM A LANDER OR BALLOON. L. Matthies[1], P. Tokumaru[2], S. Sherrit[1], and P. Beauchamp[1], [1]Jet Propulsion Laboratory, California Institute of Technology, [2]AeroVironment, Inc.

Introduction: Titan's rich organic chemistry makes it an important target to explore prebiotic chemical processes, with high priority on characterizing organics on the surface. At the same time, the diversity of its surface features suggests that long-range mobilty is important for Titan exploration[1]. It has been challenging to identify mission architectures that achieve these goals affordably. Recent rapid progress on autonomous navigation of micro air vehicles (MAVs) for terrestrial applications[2,3] opens new possibilities for a small (approximately < 10 kg), highly autonomous aerial vehicle that could deploy from a lander or balloon to perform close-up surface studies over large areas. With vertical take-off and landing (VTOL) capability, this includes potential to acquire liquid and/or solid samples from the surface and return them to the mothership for analysis. Including the ability to dock with the mothership and recharge from an RTG on the mothership could enable multiple sorties by the daughtercraft. This would enable global surface access from a balloon that itself stays at a safe altitude, or regional surface study with sampling of solids and liquids from one landing near a lake.



Aerodynamics, Rotor Configuration, and Sizing: Prior studies have shown the basic feasibility of rotorcraft flight in Titan's thick atmosphere[4,5]. We are evaluating quadrotor helicopter configurations due to their mechanical and control simplicity and the ability to incorporate rotor guards to increase in-flight safety close to the mothership and the surface. Preliminary sizing study has considered deployment from a balloon For total TAD mass of 10 kg, this suggested feasibility of descending to the surface and returning to a balloon at 10 km altitude, with 30 cm diameter rotors, 100 Wh/kg battery specific energy, and keeping up with a balloon drifting at 2 m/s, with a few kg available for payload and margin. Larger daughtercraft or lower altitude for the balloon would of course provide more payload and margin. Lander scenarios have not been examined, but the balloon case suggests that sorties of several km from a lander are quite possible for this size daughtercraft.

Avionics and Navigation: Terrestrial MAVs have demonstrated highly accurate navigation with just a down-looking camera and an IMU[2]. Lightweight UHF radios are possible that provide communication, bearing, and range between the mothership and daughtercraft. Lidar or radar-based altimeters with adequate range for safe near-surface navigation are possible in a few 10s of grams or less[6]. Docking could be mediated with active optical targets on the mothership. This concept requires a high degree of autonomy, which requires substantial onboard computing resources. The necessary performance can be achieved with processors for smartphones[7,8]; architectures with redundant copies of these processors and microcontrollers designed for automotive safety systems may provide adequate radiation tolerance for the Titan environment. Adequate thermal control appears to be possible with a few cm of aerogel insulation, a small heater, and heater power from the mothership when docked.

Science Payload: While a variety of sensors are desirable and possible in a lightweight payload, the high payoff and significant challenge of sampling from such a platform makes sampler design our current focus. We consider a mothership instrument suite with a high resolution mass spectrometer, which needs about 100 mg of material. We are examining a 1-2 kg, spring-driven mechanism that drives a sample tube into the surface, with potential to acquire several samples.

References: [1] *Vision and Voyages for Planetary Science in the Decade 2013-2022*. [2] Weiss, S. et al. (2013) *Journal of Field Robotics, 30(5)*, 803-831. [3] Johnson, A., Montgomery, J., and Matthies, L. (2005) *IEEE Int'l Conf. Robotics and Automation*, 3966-3971. [4] Lorenz, R. D. (2000) *JBIS, 53*, 218-234. [5] Young, L. A. and Aiken, E. W. (2001) 27th European Rotorcraft Forum. [6] Sarabandi, K. et al. (2011) *Proc. SPIE Vol. 8031*. [7] Goldberg, S. and Matthies, L. (2011) *Embedded Computer Vision Workshop*. [8] Li, M., Kim, B. H., and Mourikis, A. I. (2013) *IEEE Int'l Conf. on Robotics and Automation*.