Dragonfly: In Situ Exploration of Titan's Organic Chemistry and Habitability

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Titan's abundant complex carbon-rich chemistry, interior ocean, and past presence of liquid water on the surface make it an ideal destination to study prebiotic chemical processes and document the habitability of an extraterrestrial environment (Hand *et al.* 2018; Neish *et al.* 2010; Chyba *et al.* 1999; Raulin *et al.* 2010). In addition to the level of organic synthesis that Titan supports, opportunities for organics to have interacted with liquid water at the surface (*e.g.*, sites of cryovolcanic activity or impact melt (Neish *et al.* 2018)) increase the potential for chemical processes to progress further, providing an unparalleled opportunity to investigate prebiotic chemistry, as well as to search for signatures of potential water-based or even hydrocarbon-based life.

The diversity of Titan's surface materials and environments drives the scientific need to be able to sample a variety of locations, thus mobility is key for *in situ* measurements. The dense atmosphere (4x that at the surface on Earth) and low gravity (1.35 m/s^2), make heavier-than-air mobility highly efficient (Lorenz 2000, 2001; Langelaan *et al.* 2017), and recent developments in autonomous aircraft make such exploration a realistic prospect: a vehicle with aerial mobility can access different geologic settings 10s –100s of kilometers apart. *Dragonfly* is a dual-quadcopter rotorcraft lander mission concept currently being studied in Phase A under NASA's New Frontiers Program that would take advantage of Titan's unique natural laboratory to understand habitability and how far chemistry can progress in environments that provide key ingredients for life (Lorenz *et al.* 2018).

Compositional measurements in different geologic settings will reveal how far organic chemistry has progressed on Titan. Sites where transient liquid water may have interacted with the abundant photochemical products that litter the surface (Neish *et al.* 2018; Thompson & Sagan 1992) are of particular interest. At each landing site, bulk elemental surface composition can be determined by a neutron-activated gamma-ray spectrometer (Lawrence *et al.* 2017). Surface material can be sampled with a drill and ingested using a pneumatic transfer system (Zacny *et al.* 2017) into a mass spectrometer (Trainer *et al.* 2017, 2018) to identify the chemical components available and processes at work to produce biologically relevant compounds. Meteorology and remote sensing measurements can characterize Titan's atmosphere and surface (Wilson & Lorenz 2017; Stofan *et al.* 2013; Lorenz *et al.* 2012) –Titan's Earth-like system with a methane cycle instead of water cycle provides the opportunity to study familiar processes under different conditions. Seismic sensing can probe subsurface structure and activity (Lorenz & Panning 2018).

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