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Geological context from *Dragonfly* for determining Titan's habitability potential

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Cassini-Huygens found that photochemistry in Titan's atmosphere produces haze particles that range from simple hydrocarbons like methane, ethane, and benzene (e.g. Vuitton et al., 2007; Cui et al. 2009) to more complex ion species up to 10,000 Da/q (Coates et al., 2007, 2009). Products that make their way to Titan's surface can then be reworked and redistributed by a variety of Earth-like physical and chemical processes. Titan is thus a unique, natural laboratory for studying prebiotic chemistry similar to that of early Earth (Trainer et al. 2006), potentially habitable niches in transient liquid-water environments (Neish et al. 2018), and potential habitable conditions for hydrocarbon-based life (McKay & Smith 2005).

Dragonfly is a mission concept selected for Phase A study designed that would determine the chemical composition of a variety of surface materials at different geological settings (Lorenz et al. 2018; Turtle et al. 2019). It is a rotorcraft lander equipped with a mass spectrometer (DraMS), a gamma-ray neutron spectrometer (DraGNS), a camera suite (DragonCam), and a meteorology/geophysics package (DraGMet). Due to the diversity of modification processes on Titan, geological context will be key to informing the astrobiological and/or habitability significance of the compositional analyses.

Reworking: On Titan's surface, transient liquid-water environments could facilitate aqueous chemistry and production of biologically relevant molecules like amino acids (e.g. Neish et al. 2008). Identifying whether a water-ice-rich surface sample is a cryovolcanic deposit or impact melt will require geological interpretation of images captured by DragonCam. Bulk elemental composition measurements by DraGNS will also provide information for discerning material history.

Redistribution: The rates at which materials are deposited into and removed from an environment directly affect the habitability of the environment.

Across the surface: Wind and liquids redistribute sediment on Titan. Dunes formed by saltating organic sands dominate the equatorial region of Titan (e.g. Barnes et al. 2008, Le Gall et al., 2011). Like *Curiosity* (Bridges et al. 2017), *Dragonfly* will conduct passive monitoring for grain movement. However, since *Dragonfly* has the capability of creating its own wind, initiation of saltation induced by controlled rotor activation will also be monitored with DragonCam. This

is especially important at Titan where winds above the saltation threshold may not be common at the time of year when *Dragonfly* arrives.

DragonCam is also equipped with an LED array for illumination at UV-visible wavelengths. Such spectral data provide microtextural, compositional context, creating a bridge between the sample-scale measurements of DraMS to lander- and landing-site-scale images taken by other DragonCam cameras on the surface and in flight.

In the near subsurface: Several lines of evidence from *Cassini-Huygens* (e.g. Lorenz et al. 2006; Turtle et al. 2018) suggest the presence of near-subsurface liquid hydrocarbons. Such a reservoir has an important effect on the methane cycle (e.g. Mitchell & Lora 2016). DraGMet will monitor the near surface methane humidity and constrain the porosity of the surface.

Downward: It is not known whether organics from Titan's surface are transported to the subsurface ocean, providing an influx of organics. Some of the uncertainty lies in the poorly constrained thickness of Titan's crust (50-150km). *Dragonfly* will monitor ground motion with two skid-mounted geophones and a deployable seismometer (Lorenz et al. 2019); the direction and amplitude of observed waveforms provide information about the level of seismic activity and the ice crust thickness (e.g. Vance et al. 2018).

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