Probing the Internal Structure of the Most Accessible Ocean World: Titan Seismology with Dragonfly

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Introduction: Among the Ocean Worlds (OW), Titan is both large and organic-rich. Titan's thick atmosphere makes it the easiest OW surface to which in situ instrumentation can be delivered, permitting the nature of the ice crust, and possible processes allowing exchange of material between the ocean and the surface, to be diagnosed directly by seismic measurements. NASA is currently evaluating two candidates for the New Frontiers 4 mission, to launch circa 2025: one of which is a Titan lander, Dragonfly [1].

In situ exploration of Titan: Using a set of rotors, the Dragonfly "dual-quadcopter" can traverse tens to hundreds of kilometers to seek areas of potential prebiotic synthesis (e.g. cryovolcanic flows or impact melt sheets, where liquid water may have interacted with the abundant surface organics). Important context for these astrobiology studies [2] is how thick Titan's ice crust may be and what composition the ocean might have: Cassini/Huygens data suggest a 50-150 km ice crust, and models have considered ammonia-water oceans, or water with abundant sulfate. Dragonfly will attempt to constrain these properties, via seismic means (as well as by observations of the Schumann Resonance, and by measurements of Titan's rotation state).

Titan Seismology: The rich range of propagation modes through ice crusts, internal oceans, possible high-pressure ice phases etc. demands a new taxonomy of seismic waves [3]. Simulations (fig.1) show how measurements at a single station can be used to determine source direction and distance, as well as diagnose interior structure. Indeed, elements of the waveforms can indicate not only the thickness of the overlying ice crust, but can even probe the presence or thickness of a high pressure ice layer at the ocean floor [3]. Estimates of icy moon seismic activity [4] due to tidal excitation (rather stronger than that at our own moon) suggest events may be rather common.

Instrumentation: Two sets of geophones, one mounted on each skid, record motion in three axes. A single-axis seismometer (a shock-tolerant unit unit qualified by JAXA for the Lunar-A mission [5], with a ~1Hz sensitivity hundreds of times better than the geophones) can be lowered to the ground with a wind shield. The records of the skid geophones will allow this disturbance to be subtracted from the seismometer signal. Additionally, as on InSight, continuous wind and pressure measurements can be used to identify and decorrelate meteorological effects Testing has shown good sensor electrical operation at 94K (in fact, sensitivity increases slightly, due to the drop in resistance of the coil windings.)

Measurement Approach: Dragonfly only flies a small fraction of the time (~1%) and spends two Titan days or more at each landing site. These long stays permit recording of seismic activity and background noise at different tidal phases (local solar times) and locations, Dragonfly can perform continuous monitoring, with triggered events flagged for data downlink. Ample onboard storage permits later retrieval of events determined to be of interest.

Beyond passive seismic monitoring, Dragonfly has rotary-percussive sampling drills which can provide seismic excitation of the near-surface.

Conclusions: If Dragonfly is selected by NASA in summer 2019, its seismological investigations will provide a new window into Ocean World interiors.