Development of a cryogenic Titan seismometer for the Dragonfly relocatable lander

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Dragonfly is a relocatable lander that would use dual-quad rotors to perform soft-landings at multiple sites on the Saturn’s largest moon, selected as the 4th mission in NASA’s New Frontiers Program. The Dragonfly spacecraft will be launched in 2026 to arrive at Titan in 2034 to begin a 2.7 year mission of exploration. The Geophysical and Meteorological package (“DraGMet”) onboard Dragonfly is a suite of sensors to monitor the Titan surface/subsurface environment. It includes a single-axis (vertical) sensitive seismometer, as well as two sets of small geophones, which are installed on the lander skids, together with temperature and pressure sensors, anemometer for wind speed/direction, measurement of thermal/electrical properties of surface material, and methane and hydrogen sensors.

Like other large icy moons (Europa, Ganymede, Callisto, Triton), Titan should have an internal ocean. Estimates of the ice crust thickness overlying the ocean range from 50 to 200 km, constrained by geodetic measurements from Cassini flybys. The ocean, several hundred km thick, may have abundant solutes such as sulfate salts and/or ammonia. Titan’s eccentric orbit around Saturn will drive seismic activity by tides in addition to impacts and possible cryovolcanism. Internal structure measurements provide important context for these environments and the possibility that surface-interior exchange processes may be active today. Seismological investigation on Titan may provide our first direct insights into the structure of icy moons/ocean worlds.

According to the current scenario, the seismometer will be lowered to sit on the ground by a winch at each landing site and protected from the wind loads using a streamlined shield. During the seismic observation, the above-mentioned meteorological sensors should be simultaneously operated. Beyond passive seismic monitoring, Dragonfly has actuators which can be used to probe the near-surface mechanical properties, analogous to hammering by the ‘mole’ on the InSight lander on Mars. Specifically, ground stimulation by Dragonfly’s rotary-percussive sampling drills (one on each skid) can be sensed by the geophones and/or seismometer.

The original seismometer is a short-period electromagnetic type developed for the prospective LUNAR-A penetrator mission; the output is proportional to the relative velocity between a moving coil and an internal magneto-static field. Though the principle of sensing is the most traditional type as a short-period sensor, its size is much smaller than sensors used in terrestrial seismology, whereas the sensitivity is much higher. As a feasibility study for application to Dragonfly mission, a series of laboratory/field tests are conducting using qualified seismometer models. During these tests, a temperature dependence of sensor characteristic and its performance to measure natural ground motion (what is called ‘microseism’) were investigated at a tunnel of the domestic seismic observatory. The tolerance of Titan’s environment, where the surface would be extremely cold at 94 Kelvin, has been confirmed and several key parameters are clarified to modify the current model for implementation on Dragonfly. In this paper, the outline of seismic experiment and results of ultra-low temperature tests will be described.

Keywords: Titan, Dragonfly, seismometer, icy moon