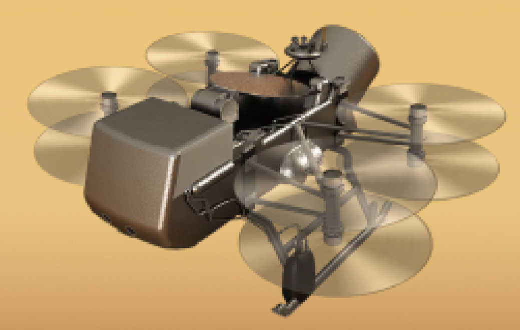
Titan Seismology with Dragonfly: Probing the Internal Structure of the Most Accessible Ocean World



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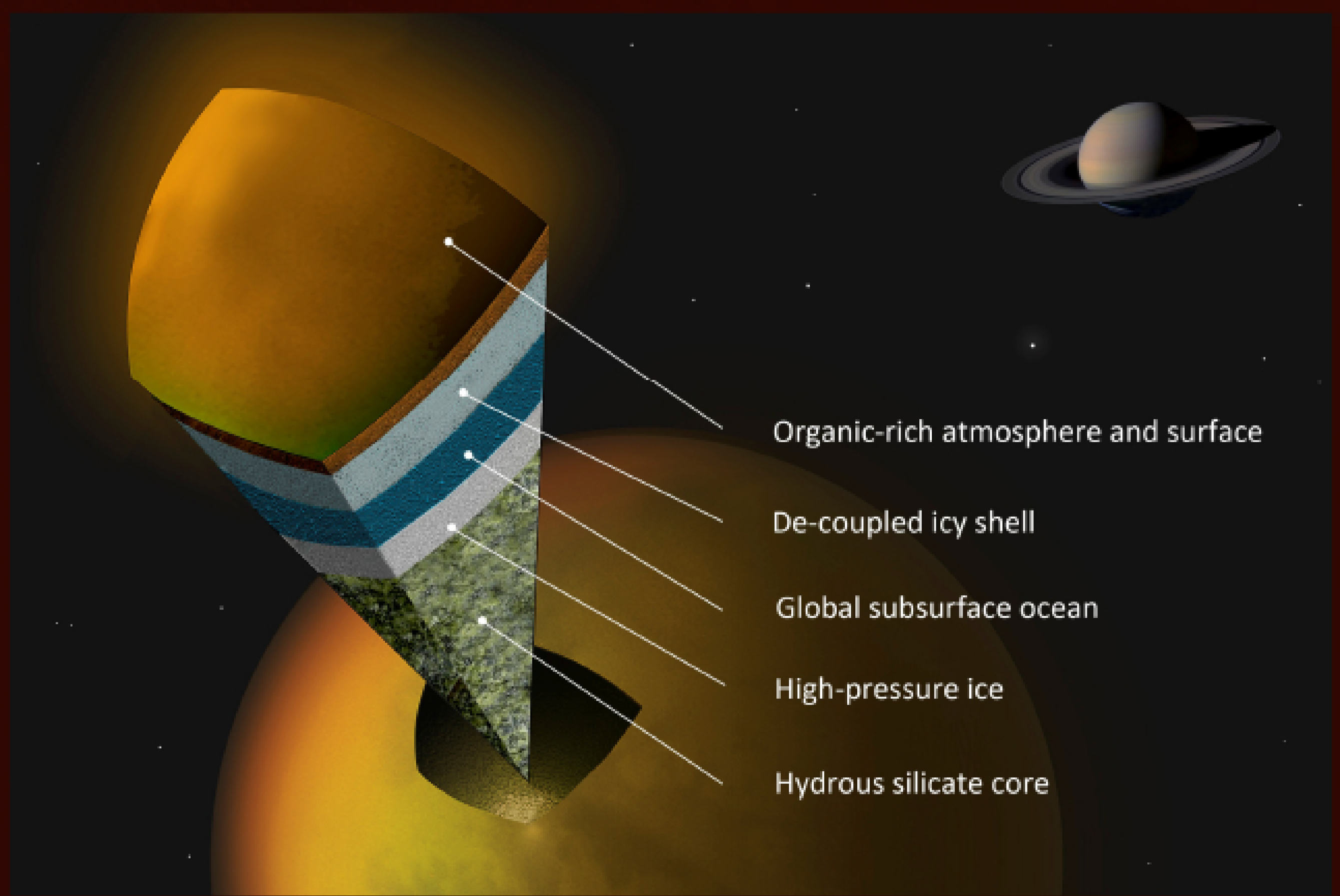
Dragonfly, proposed by APL (E. Turtle, PI) is one of two contenders for the NASA New Frontiers 4 mission competition. If selected (decision expected summer 2019), Dragonfly will be launched in 2025 to arrive at Saturn's moon Titan in 2034 to begin a >2 year mission of exploration. Dragonfly is a relocatable lander that would use 8 rotors to perform soft-landings at multiple sites on Titan's varied surface.

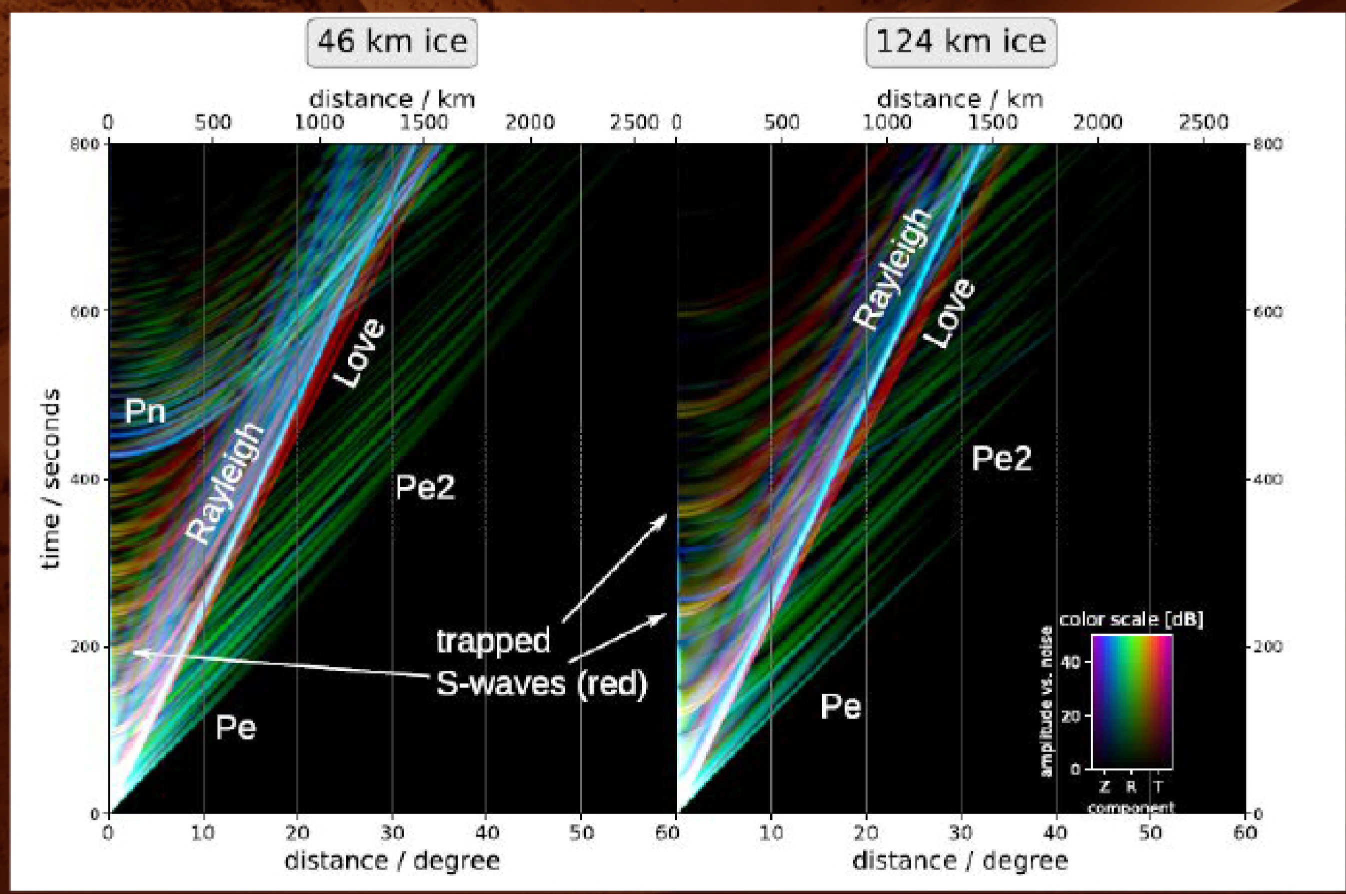
Like other large icy moons, Titan has an internal water ocean, as revealed by Cassini measurements of rotation and of tidal deformation, and by Huygens observations of a possible Schumann resonance (an electromagnetic wave trapped between the ocean and ionosphere). Estimates of the ice crust thickness overlying the ocean range from ~50 to 150km. The ocean, several hundred km thick, may have abundant solutes such as sulfate salts and/or ammonia. Tidal forcing by Titan's eccentric orbit around Saturn will drive seismic activity in addition to impacts and possible endogenic processes.

The internal ocean may be habitable, and the probable exposure of surface organics to transient liquid water (either via cryovolcanism or in impact melt sheets) can drive the formation of prebiotic compounds such as pyrimidines and amino acids. Internal structure measurements provide important context for these environments and the possibility that surface-interior exchange processes may be active today

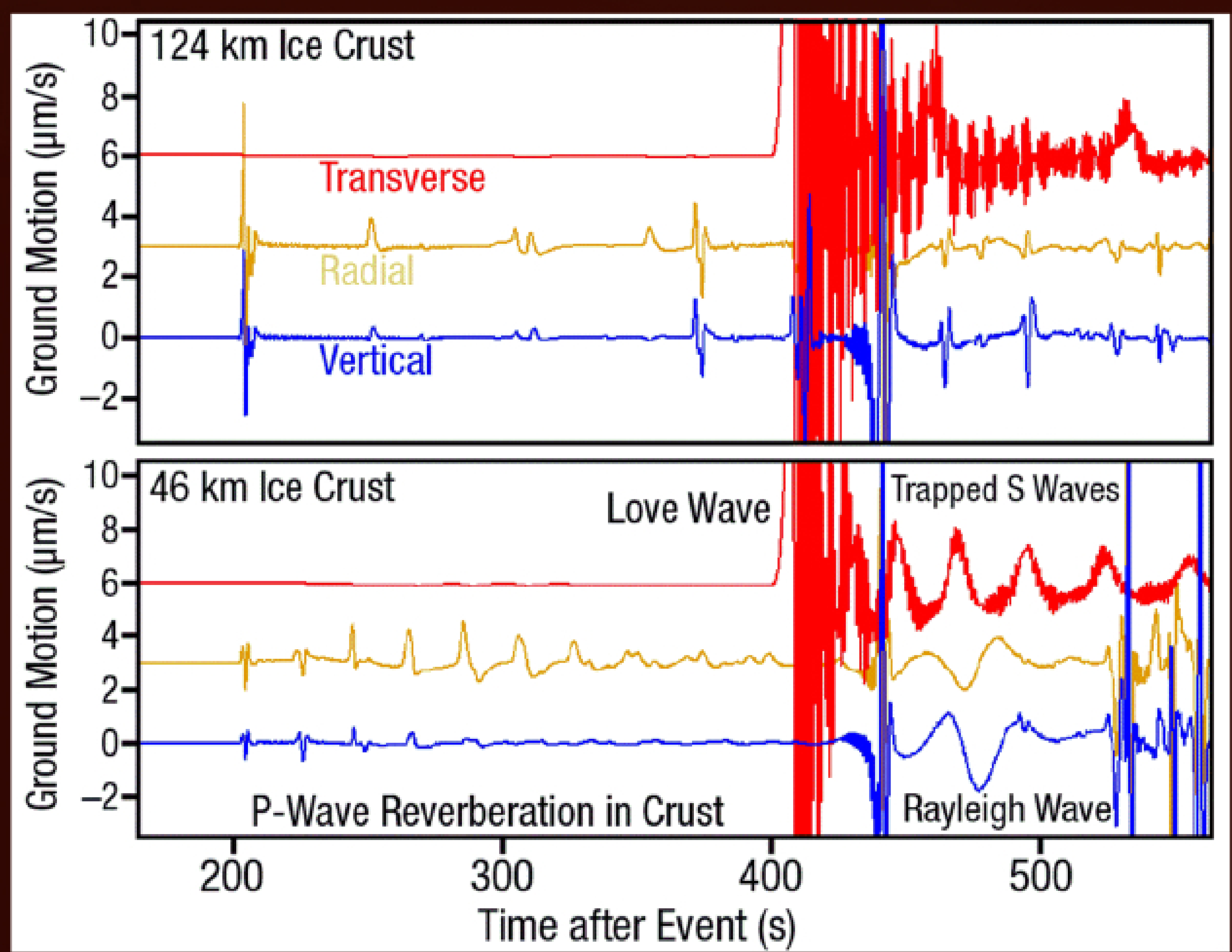


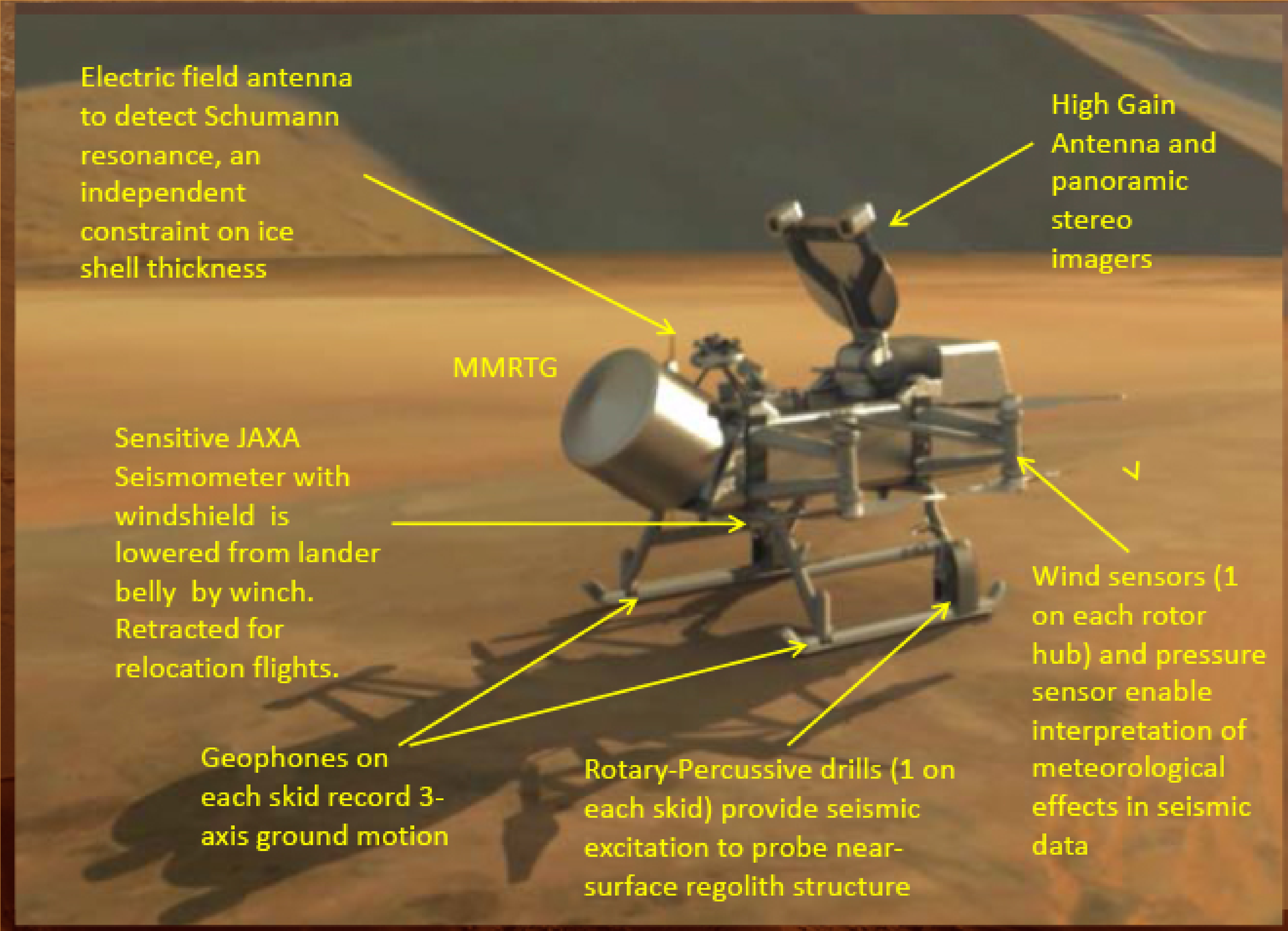
Seismology provides a new window on the structure of icy moons/ocean worlds. The ice crust/water ocean/rock core (or possibly for Titan, ice crust/water ocean/high pressure ice layer/rock core) structure demands a new taxonomy of seismic waves to describe the rich array of propagation modes.

Although measurement of the ice crust thickness is the most important (and easiest) result simulations show that seismic propagation can reveal e.g. the presence of a high pressure ice layer at the base of the ocean. Seismic data, coupled with geochemical information (e.g. presence of salts or ammonia in the ice crust) will provide important constraints on Titan's formation and evolution.



Simulated ground motion (not corrected for instrument transfer function) at an 18 degree distance (~800km) from a Magnitude 4 event. The early P-wave reverberation, and the character of the trapped S-waves, are directly diagnostic of the ice shell thickness. The value of 3-axis measurements is evident. The Love and Rayleigh waves have amplitudes that may permit detection with the geophones as well as the more sensitive seismometer.





Geophysical and Meteorological instrumentation is integrated in a single package ("DraGMet") to facilitate synchronization and co-analysis of data from different sensors. Direct wind loads on deployable seismometer are eliminated by a wind shield, and lander noise can be decorrelated from seismometer signal by geophone records.

Rugged seismometers (qualified by JAXA to 2000-g for both the former Lunar-A mission and for terrestrial application) confirmed tolerance of Titan temperatures in tests at National Observatory of Japan in 2018. COTS geophones have similarly been tested in LN2 at APL and demonstrate excellent operation (minor damping change).

Further information :

Lorenz, R. D., E. P. Turtle et al.,. 2018. Dragonfly : A Rotorcraft Lander Concept for Scientific Exploration at Titan, Johns Hopkins Technical Digest, 34(3), 374–387

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http://dragonfly.jhuapl.edu