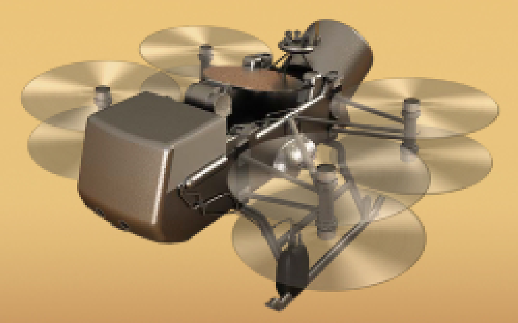
Titan's Surface from Dragonfly: Bridging the Gap Between Composition and Environment



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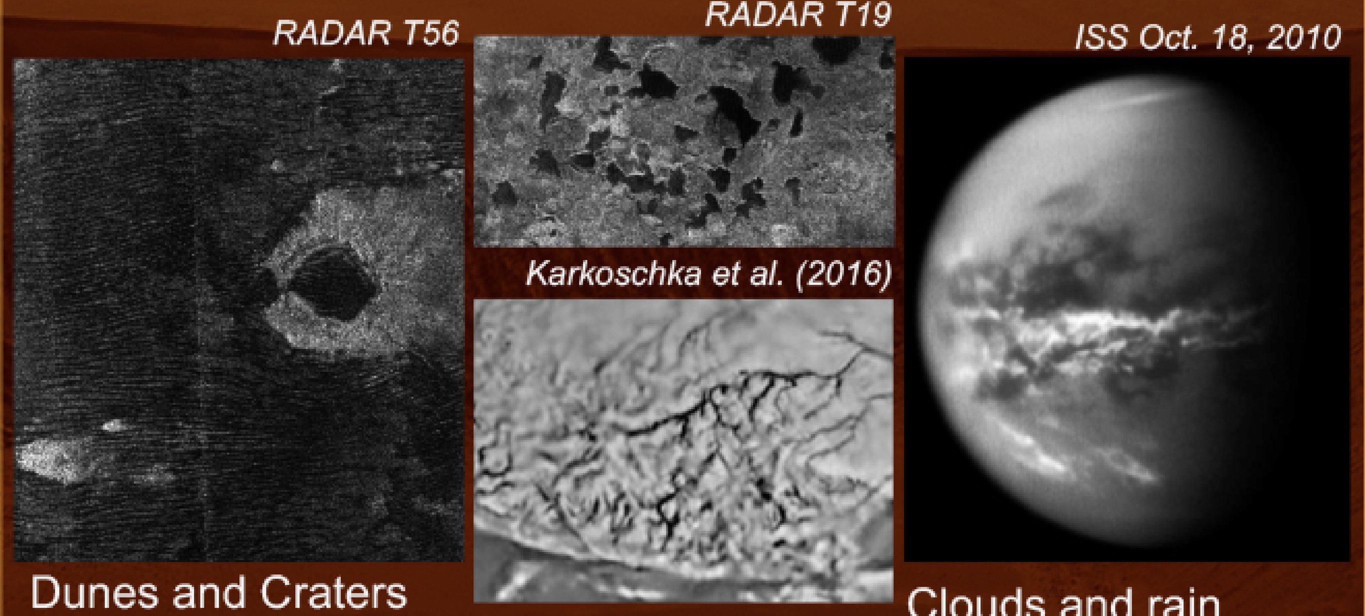
Dragonfly will provide the first *in situ* characterization of Titan's surface chemistry. (See Lorenz et al. 2018; Turtle et al. (2019) *LPSC 50* #2888)

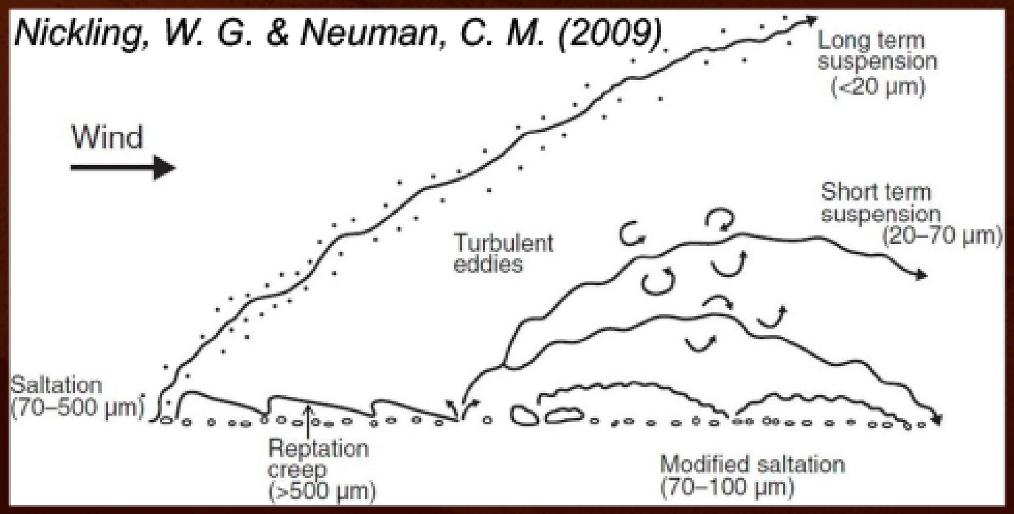
The Earth-like geological and atmospheric processes at work on Titan make understanding the geological context critical to evaluating the habitability potential of this ocean world.



Dunes and Craters — Lakes and Rivers — Clouds and rain

Modes of transport

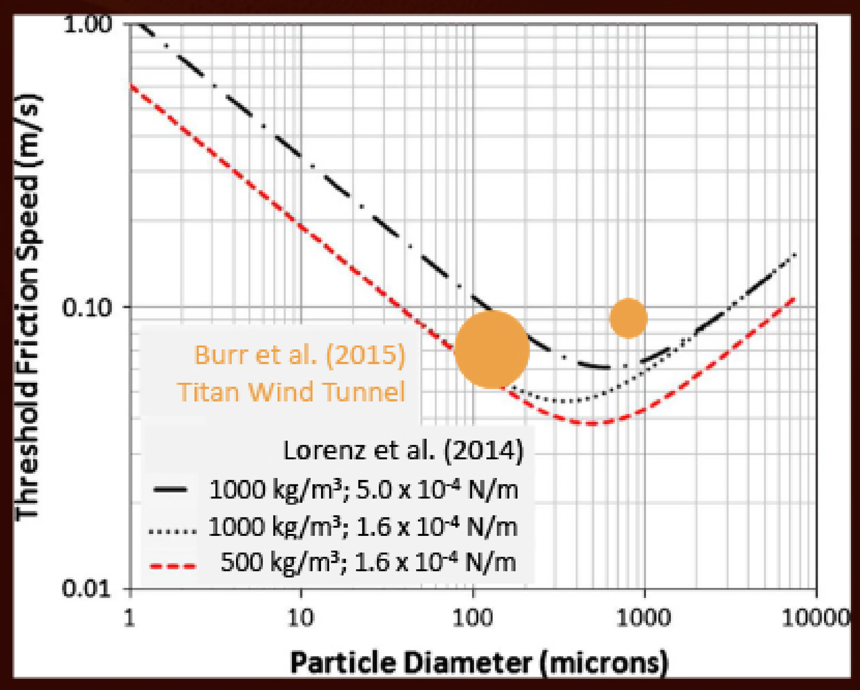
Coupling the following data with the compositional measurements will show what kinds of materials are redistributed across the surface via aeolian transport.



Dragonfly's cameras will reveal the distribution of grain sizes at each landing site.

Saltation threshold wind speeds will be determined via

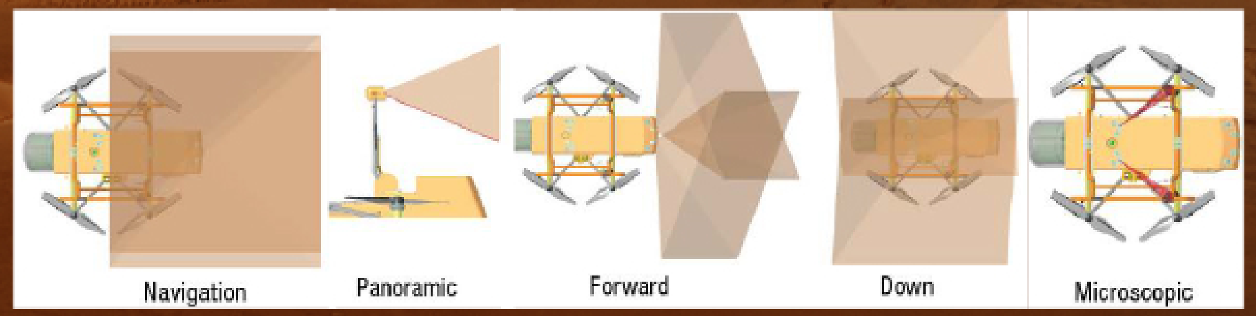
- passive observations similar to those made by *Curiosity* (e.g. Bridges et al. 2017)
- a controlled saltation threshold and transport rate experiment using a rotor (Lorenz et al. 2017)



(Above) The wind speeds necessary to initiate motion is a function of particle size, particle density, and interparticle forces.

Sample provenance

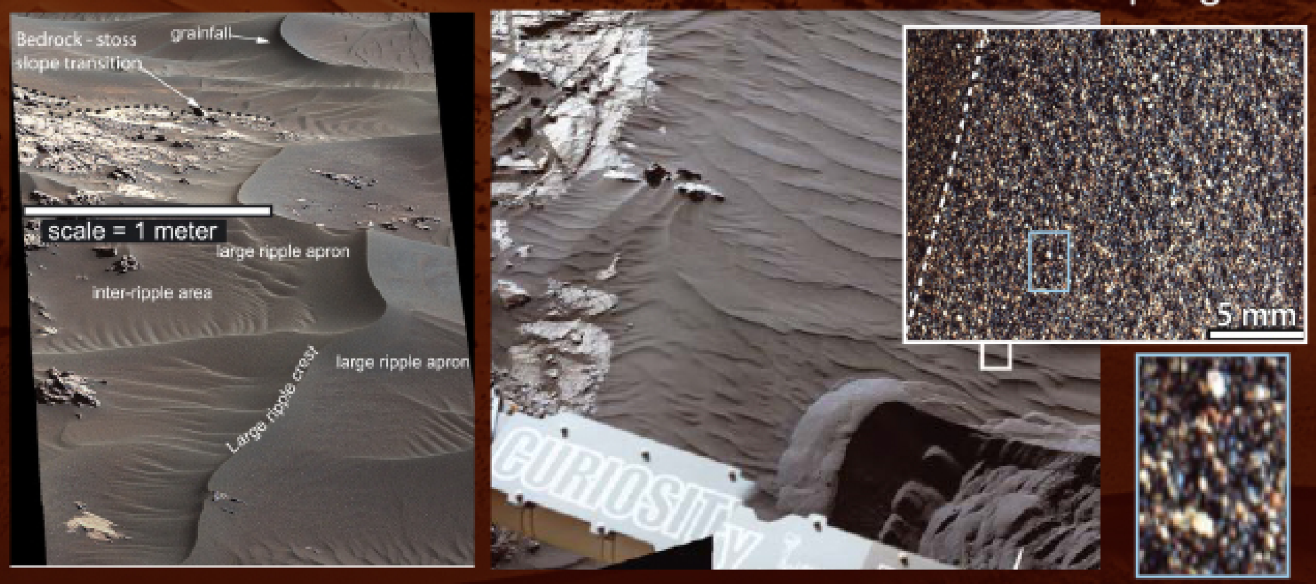
***Dragonfly*'s suite of cameras with nested fields of view provides context for where sampled material originates in the landscape.**



(Below) Curiosity images from Ewing et al. (2017) are a good analog for the scales at which Dragonfly will interrogate the surface.

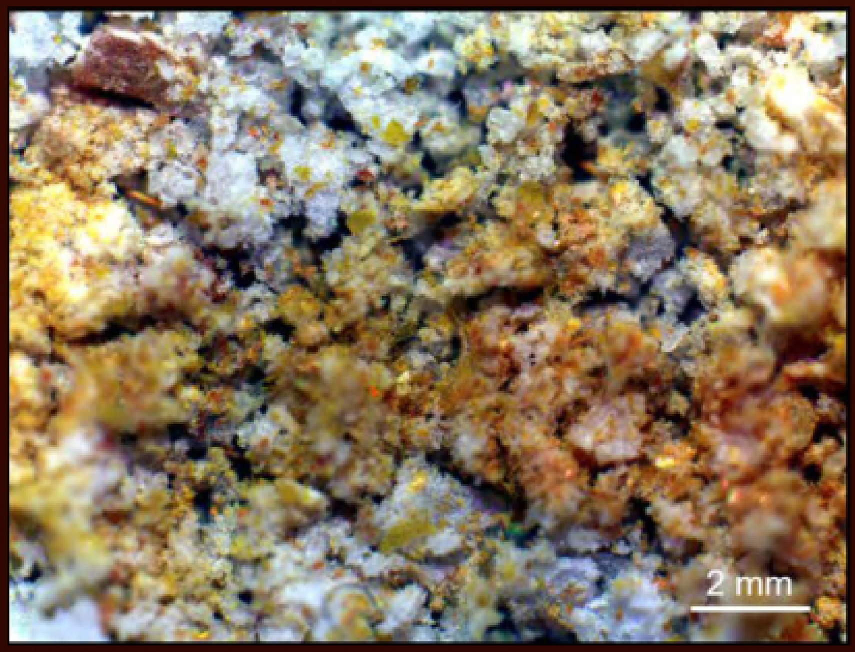
A landing site

In front of the lander — Below the lander — At the sampling site



Extrapolating between these scales facilitates building hypotheses concerning the geological provenance of the samples and thus the processes responsible for distributing and reworking compounds for prebiotic (or potentially even biotic; e.g. Neish et al. 2018) chemistry.

Illuminating the surface with specific wavelengths in the visible-near-infrared enables *Dragonfly* to distinguish water-ice-rich and organic-rich materials at the microscale.



R,G,B = 0.935, 0.770, 0.455 µm
pixel scale ~ 6 µm; FOV ~14 x 10 mm
Tholins generated by He et al. (2017)

In this false-color image

- tholins made with 5% methane in nitrogen (yellow)
- tholins made with 10% methane in nitrogen (orange)
- Water ice (white)

are distinguishable with a 2% linear stretch.

See also Núñez et al. (2019) LPSC 50 #3004.

Material properties

Observations of the interactions between the rotorcraft and the surface can also provide evidence for deducing the physical properties of the regolith, much like the investigations by *Viking* and *Phoenix* [e.g. Moore et al. 1997; Shaw et al. 2009].

Observation	Property	Example Interpretation
texture and morphology of drill cuttings and hole walls	cohesion angle of repose	Liquid methane can increase soil cohesion and therefore reduce transportability (Lorenz 2014; Yu et al. 2017).
monitoring the drill current applied during drilling	bulk hardness	Simple organics (e.g. acetonitrile, a potential evaporite) have lower hardness than water ice. (Lorenz et al. 2018)

(Left) Dragonfly prototype drill at Honeybee Robotics imaged with FOV (4.7°) representative of Dragonfly's microscopic imager.

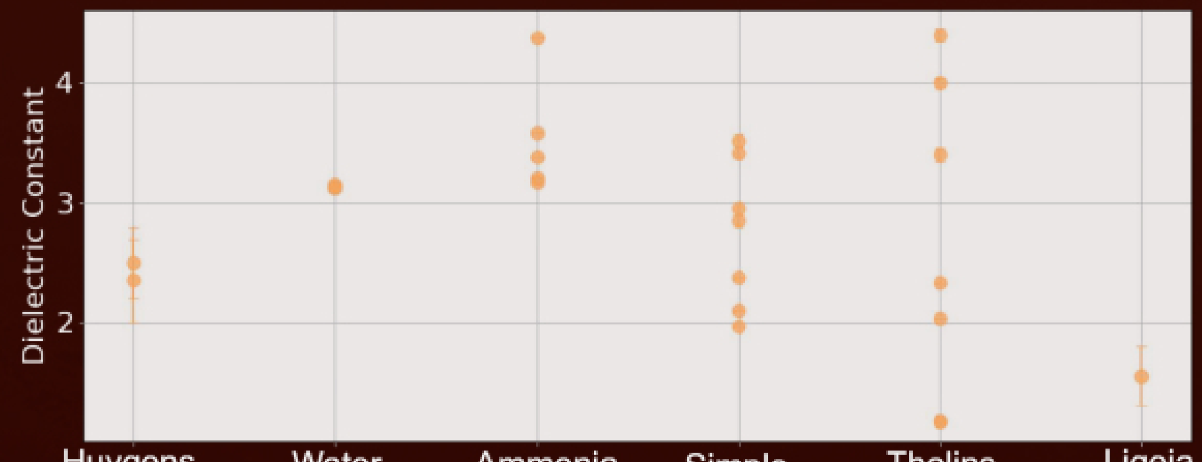
Understanding the physical properties of the material is also important for evaluating whether to ingest material for analysis with the Dragonfly Mass Spectrometer.

(Right) Cryogenic lab tests with Titan analog materials with a range of material properties show that the drilling system is capable of generating and transporting sufficient volume of tailings for sampling and analysis.

The Dragonfly Geophysics and Meteorology package includes several commercial, off-the-shelf sensors for measuring

- Dielectric constant
- Thermal properties
- Methane humidity

} regolith dampness, porosity, and composition



Data from: Huygens PWA-MIP/HASI (Hamelin et al. 2016), Cassini RADAR (Le Gall et al. 2016), and lab measurements (Paillou et al. 2008; Le Gall et al. 2008,2016; Lethullier et al. 2016).

Burr, D. M. (2015) *Nature*, *517*(7532), 60.
Bridges N. T. et al. (2017) *JGRP* 122.10 (2017): 2077-2110.
Ewing, R. C. et al. (2017) *JGRP*, *122*(12), 2544-2573.
Hamelin, M. et al. (2016) *Icarus*, *270*, 272-290.
He, C. et al (2017) *The Astrophysical Journal Letters*, *841*(2), L31
Karkoschka, E., & Schröder, S. E. (2016) *Icarus*, *270*, 307-325.
Le Gall, A. et al. (2016) *JGRP*, *121*(2), 233-251.
Lethuillier, A. et al. (2018). *JGRP*, *123*(4), 807-822.
Lorenz, R. D. (2014) *Icarus*, *230*, 162-167.
Lorenz R. D. (2017) *Fifth Intl Planetary Dunes Workshop* 1961. 3043.
Lorenz R.D. et al. (2018) *APL Tech Digest 34*, 374-387.
Moore, H. J. et al. (1977) *JGR*, *82*(28), 4497-4523.
Nickling, W. G., & Neuman, C. M. (2009). *Geomorphology of desert environments* (pp. 517-555). Springer, Dordrecht.
Neish C.D. et al. (2018) *Astrobiology 18*, 571-585.
Núñez et al. (2019) *LPSC 50* #3004
Paillou, P., et al. (2008) *GRL*, *35*(18).
Rauleder, J. & Leishman, J. G. (2013) AIAA *journal* 52.1 (2013): 146-161.
Shaw, A. et al. (2009) *GRP*, *114*(E1).
Turtle E. P., et al (2019) *LPSC 50* #2888
Yu, X. et al. (2017) *Icarus*, *297*, 97-109.