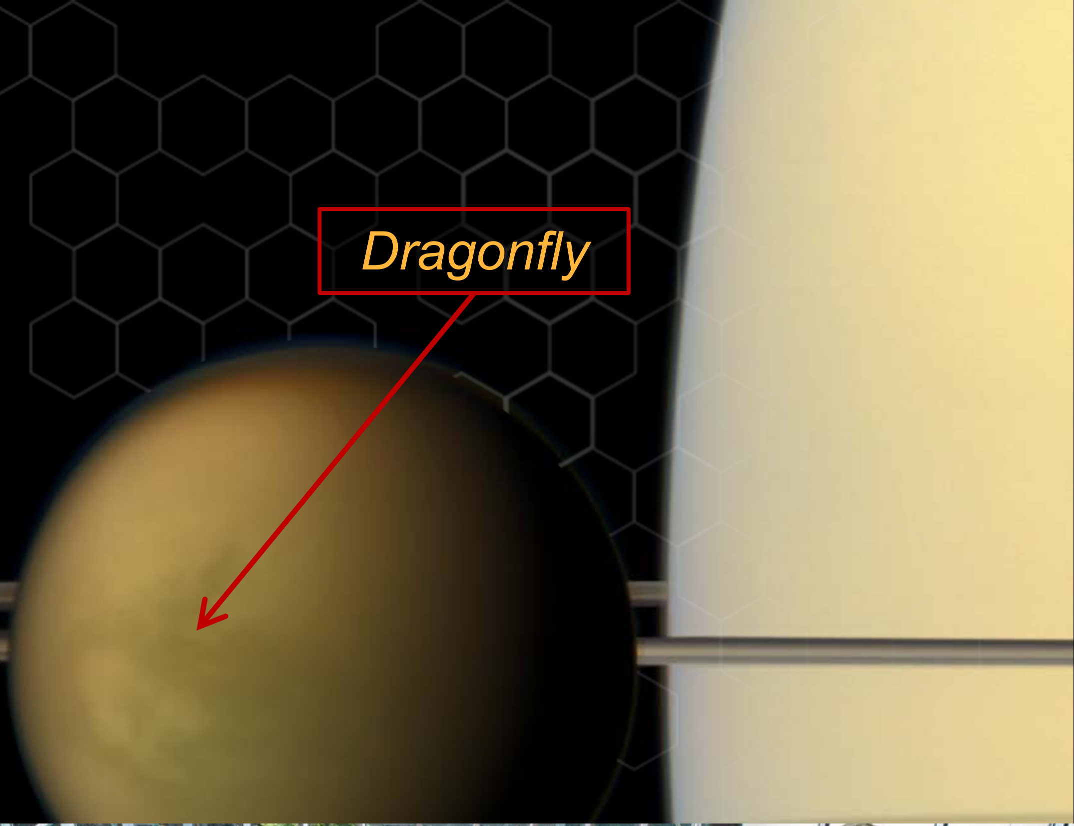
DRAGONFLY

A relocatable lander to explore Titan's prebiotic chemistry and habitability



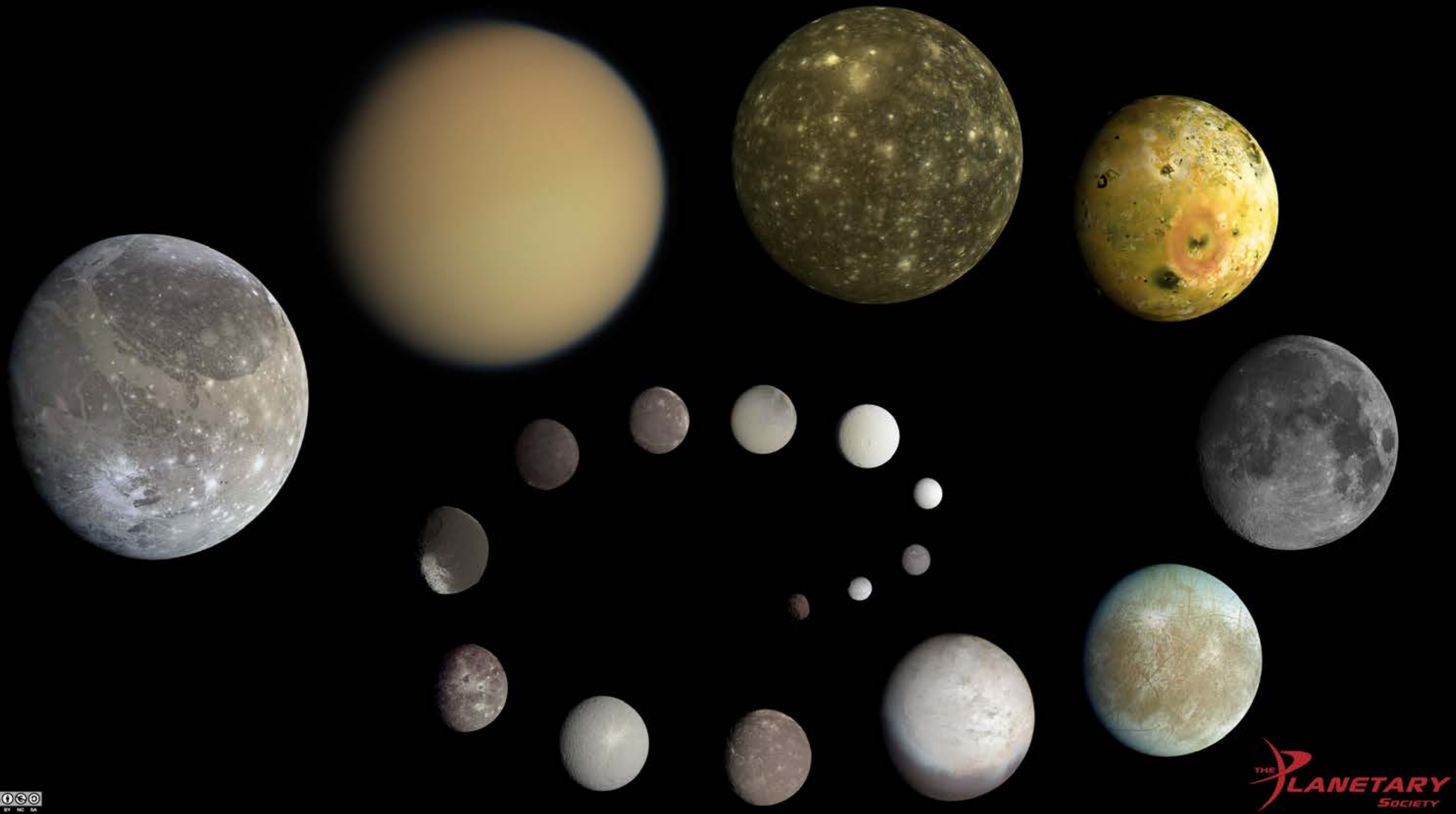
Science Opportunities at Titan: The Dragonfly Mission

31 March 2020

Zibi Turtle, Dragonfly Principal Investigator

Johns Hopkins Applied Physics Laboratory

Titan's unique environment



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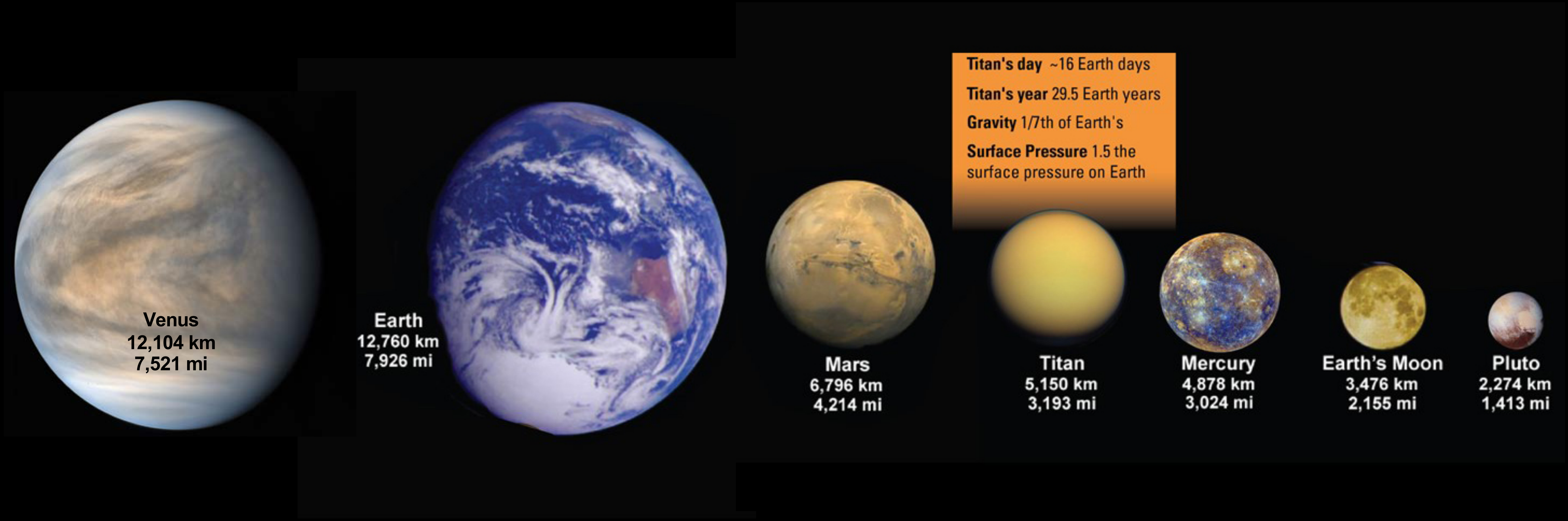
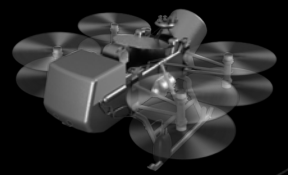
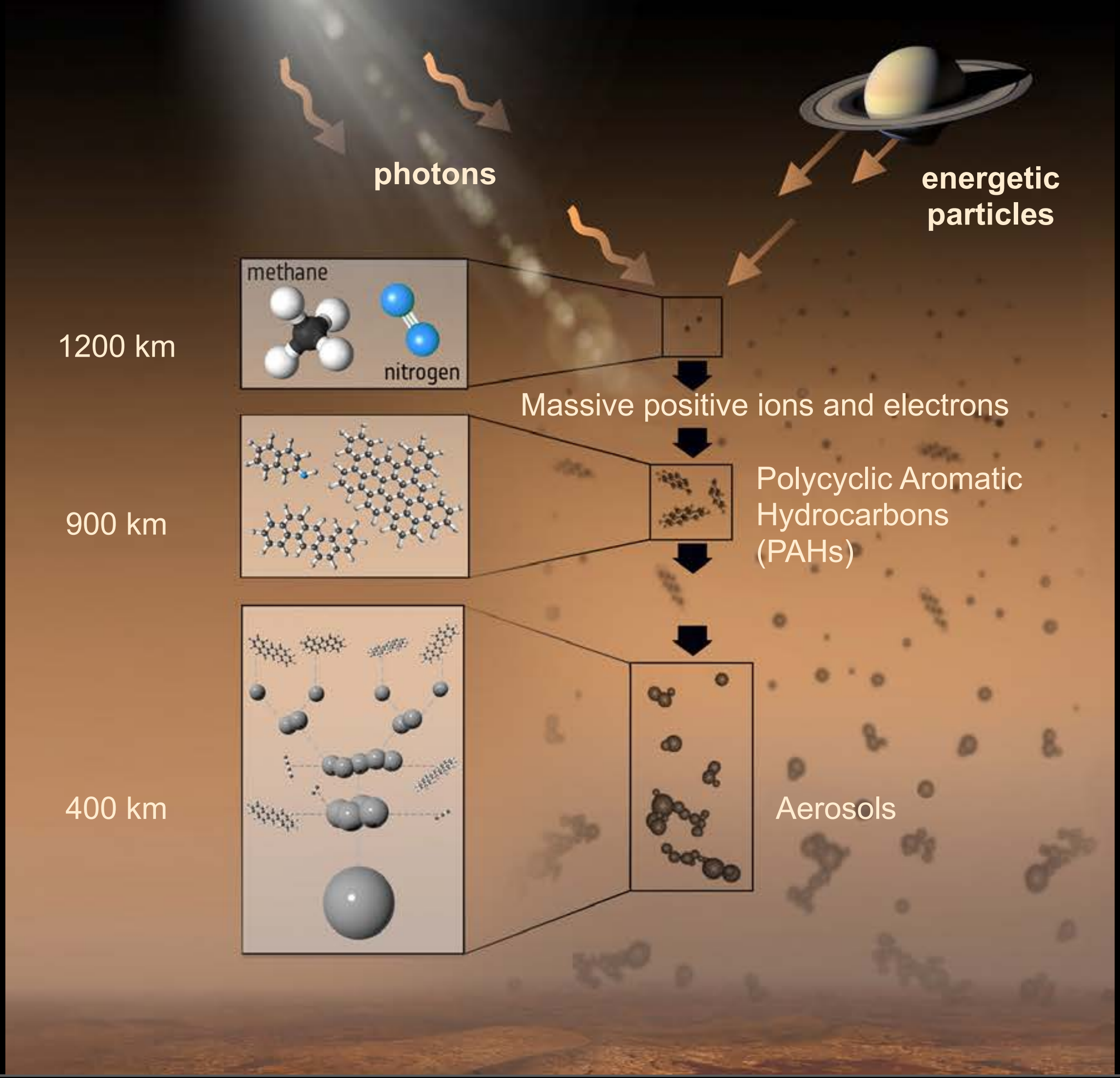


Complex organic chemistry



- Photochemistry in upper atmosphere produces complex carbon molecules
- Rich organic material covers the surface
- Potential for organic compounds to have mixed with liquid water for extended periods of time at the surface

Titan is a singular destination for understanding the chemical processes on our own planet that supported the development of life



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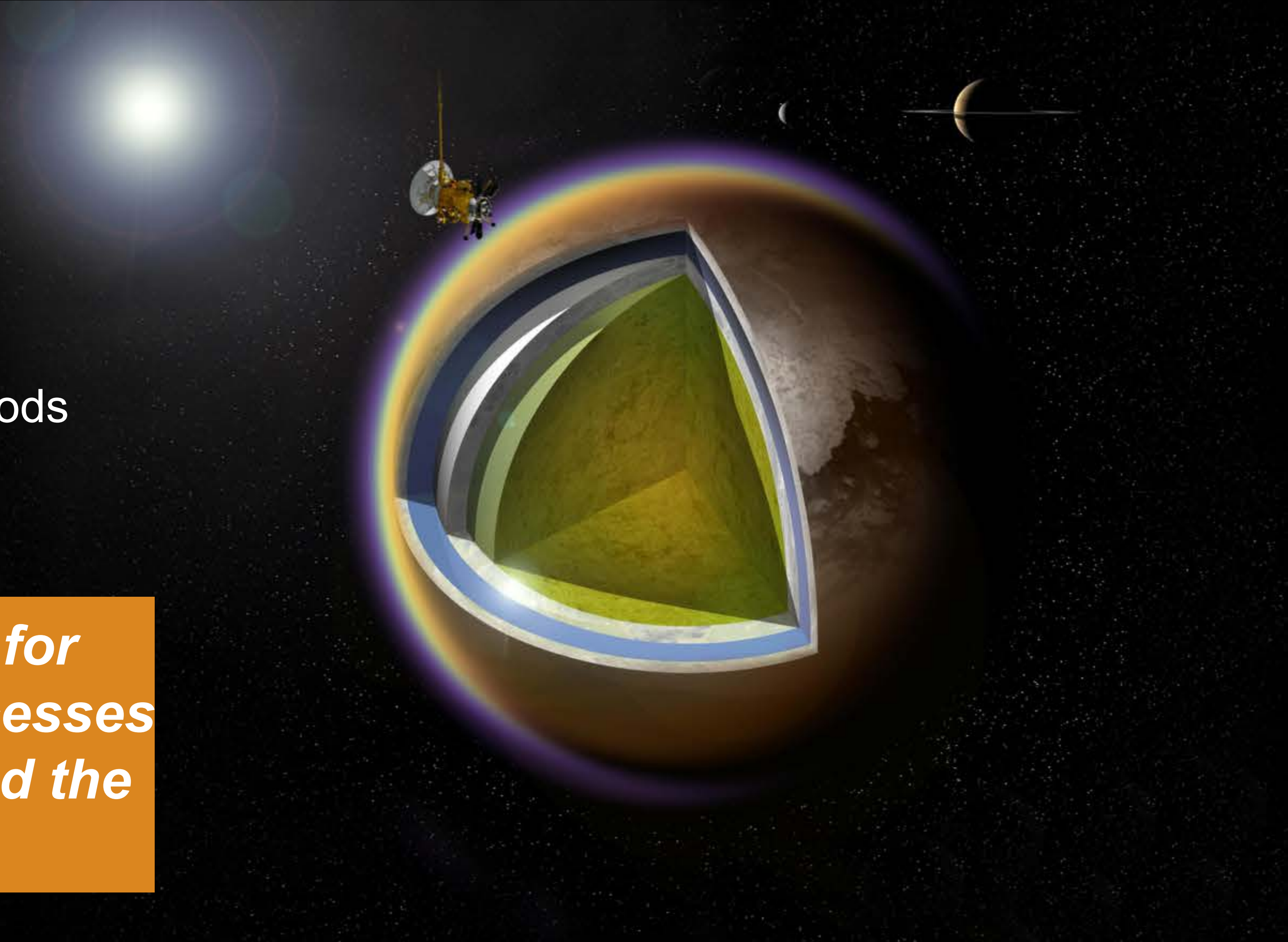
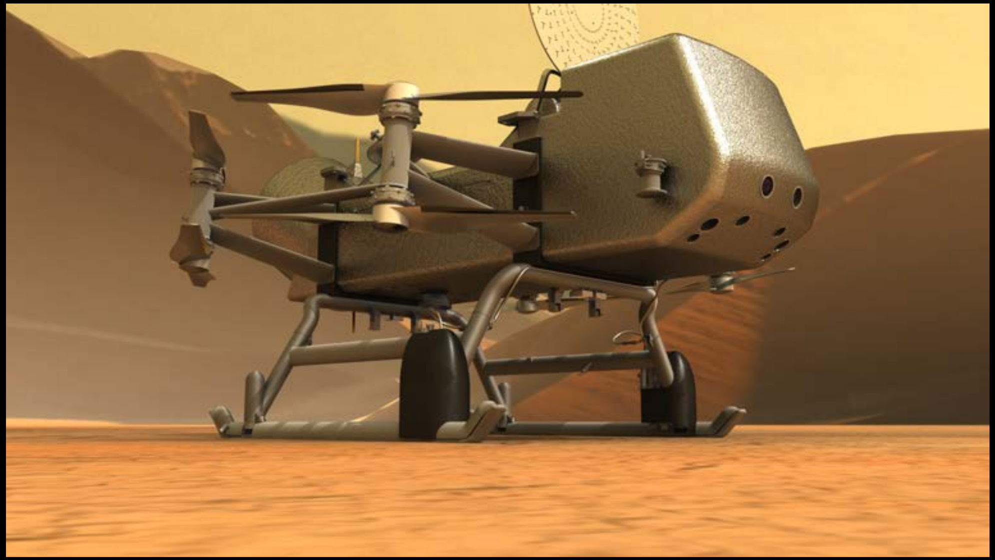


Following from Cassini-Huygens' discoveries, Dragonfly takes the next steps to answer fundamental questions

What makes a planet or moon habitable?

What chemical processes led to the development of life?

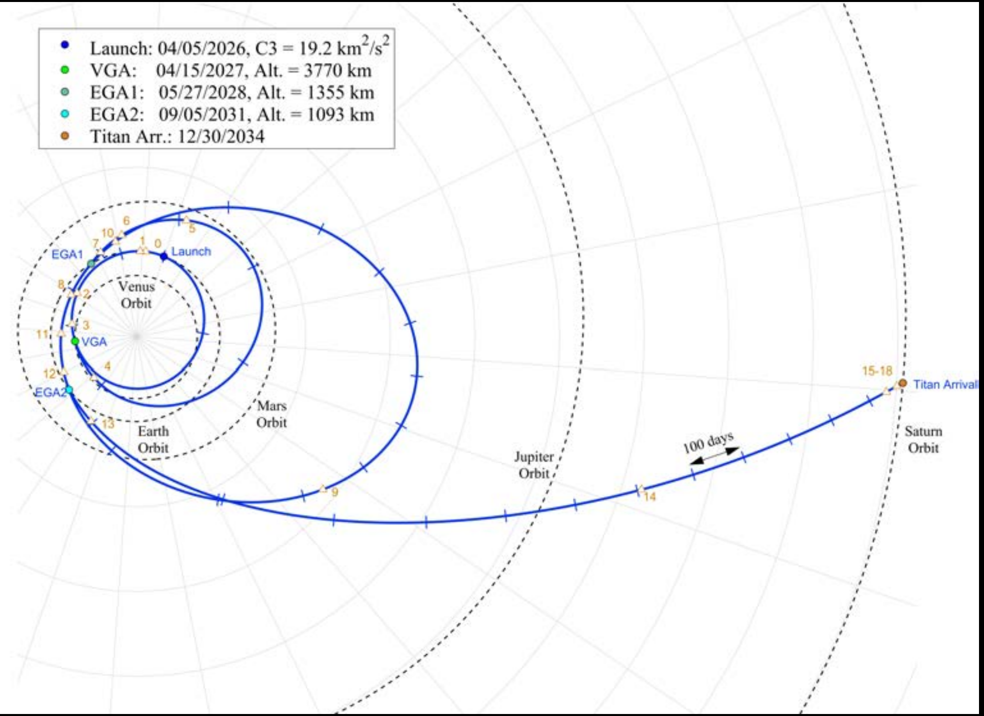
Has life developed elsewhere in our solar system?

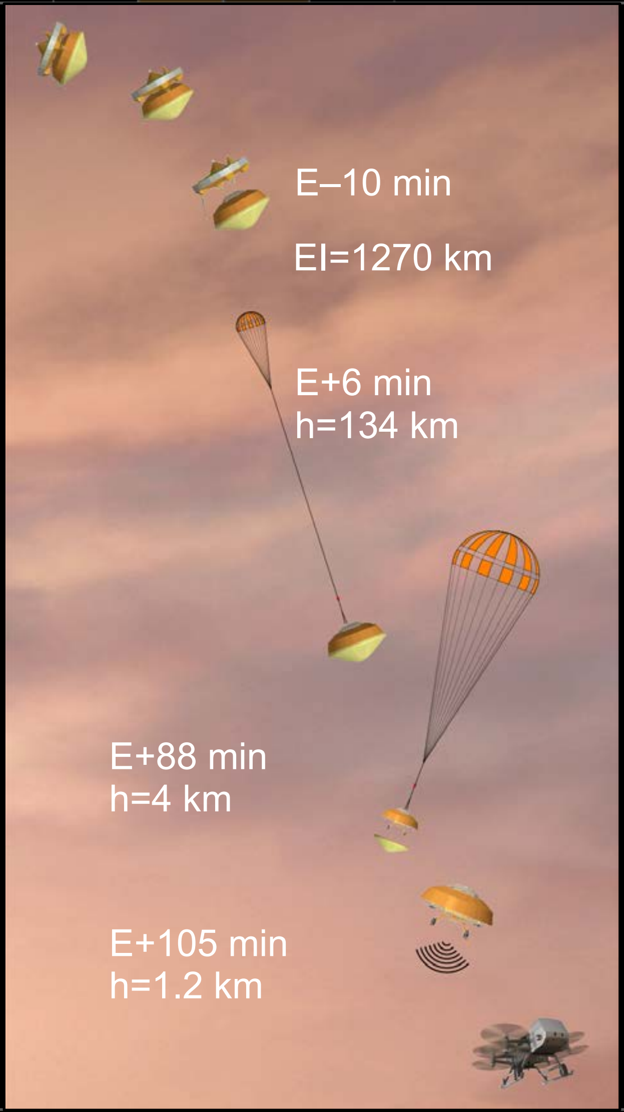


Aerial mobility enables access to Titan's diverse surface materials and environments with different geologic histories

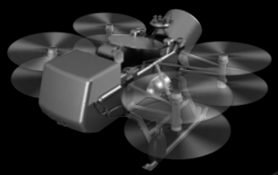
Dragonfly mission timeline

- Launch in 2026 → Titan arrival in 2034
  - Direct atmospheric entry
  - Similar latitude and same time of year as descent of *Huygens* probe

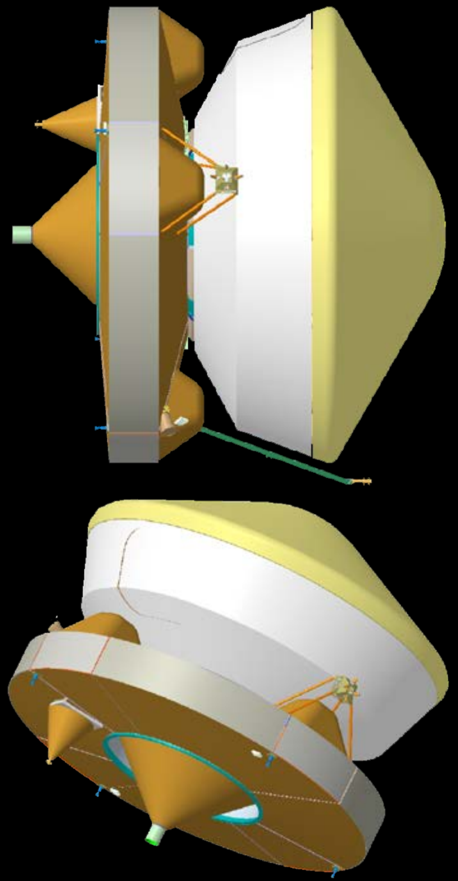




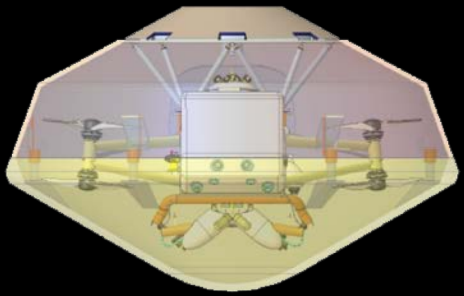
Dragonfly mission elements

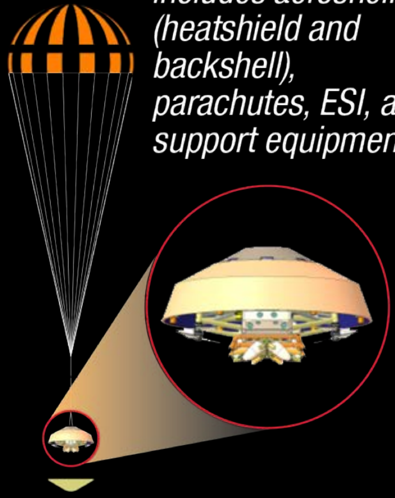


Spacecraft =
Cruise Stage + Entry Vehicle



Entry Vehicle =
EDL Assembly + Lander



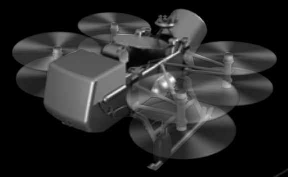


EDL assembly includes aeroshell (heatshield and backshell), parachutes, ESI, and support equipment.

Rotorcraft Lander
Flight configuration with HGA stowed

- MMRTG power
  - Charge battery used for flight and science activities
  - Waste heat maintains nominal thermal environment in lander
- Direct-to-Earth communication
  - HGA articulation used to target cameras to build up panoramas of surrounding terrain
- Measurements on surface and in flight
  - Aerial imaging
  - Atmospheric profiles

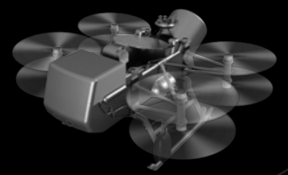
Dragonfly is driven by specific science questions about prebiotic chemistry and habitability



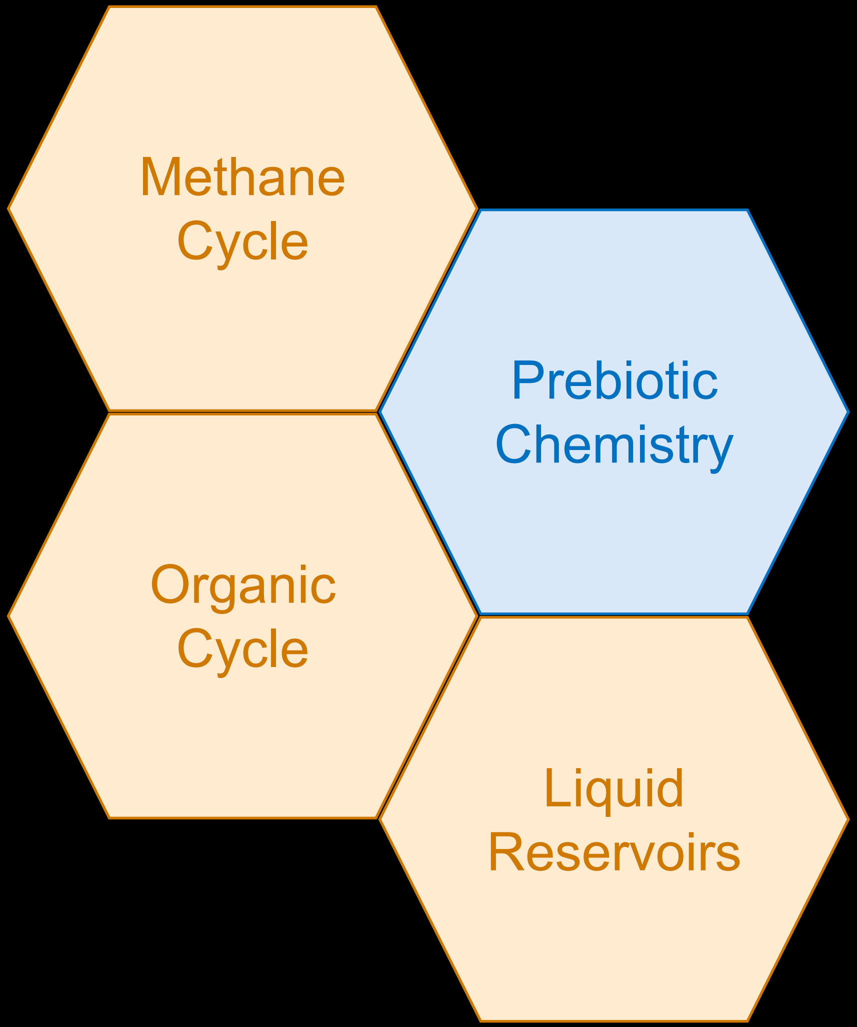
- What chemical components and energy-producing chemical pathways exist on Titan that could drive prebiotic chemistry?

Prebiotic Chemistry

Dragonfly is driven by specific science questions about prebiotic chemistry and habitability



- What chemical components and energy-producing chemical pathways exist on Titan that could drive prebiotic chemistry?
- What CH_4 sources and sinks exist in Titan's equatorial regions, and what are the implications for methane transport?
- How are materials, especially organics, transported on Titan's surface and in its atmosphere?
- Where and how has liquid water been in contact with organic material?



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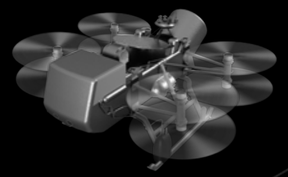

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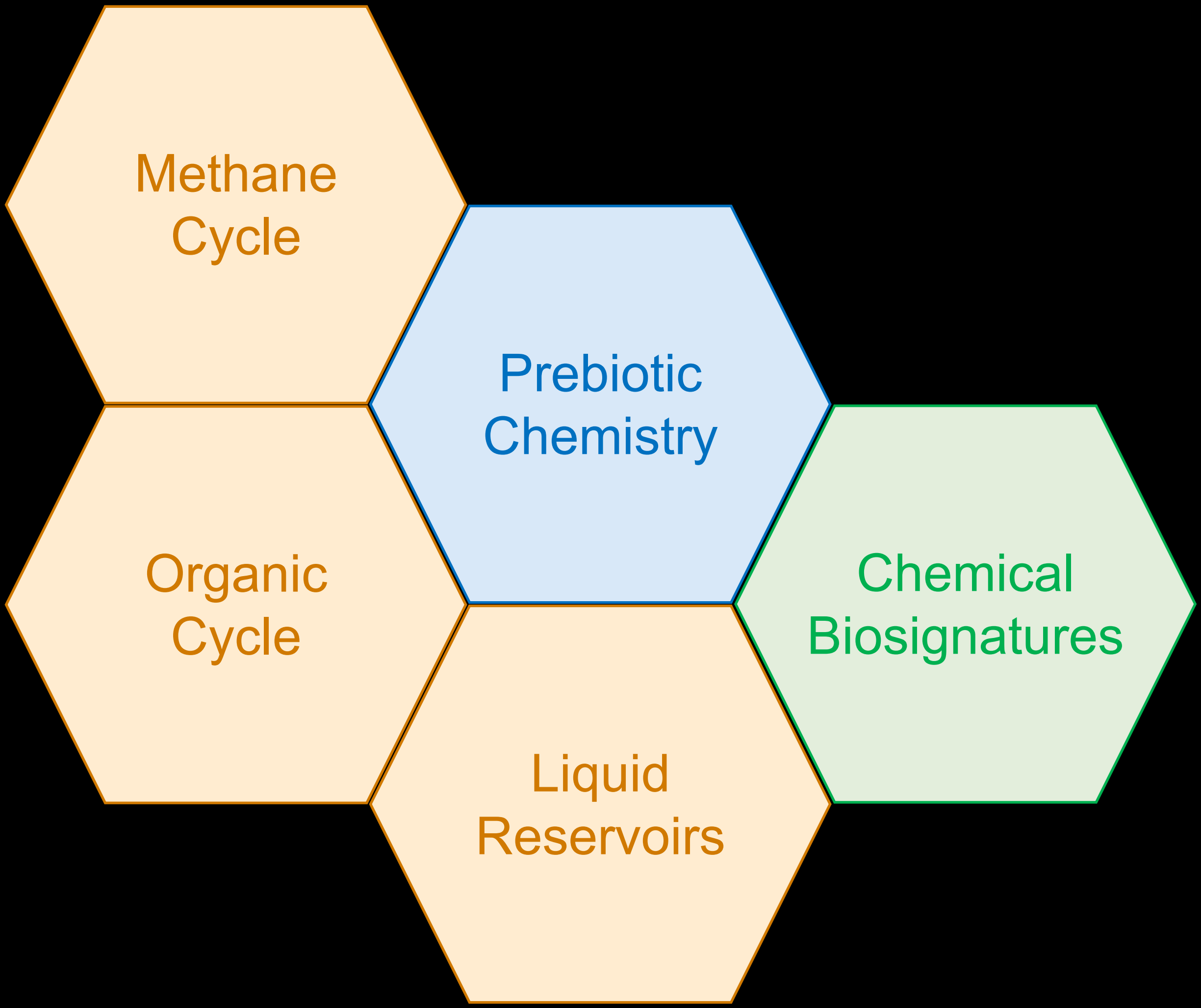
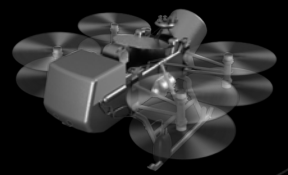
- Where and how has liquid water been in contact with organic material?
- Are there chemical signatures of past or extant water- or hydrocarbon-based life on Titan?



Science goals and payload focus on chemical inventory and opportunities for materials to interact



A. Determine the inventory of prebiotically relevant organic and inorganic molecules and reactions on Titan

B. Determine the role of Titan's tropical atmosphere and shallow subsurface reservoirs in the global CH_4 cycle

C. Determine the rates of processes modifying Titan's surface and rates of material transport

D. Constrain what physical processes mix surface organics with subsurface ocean and/or melted liquid water reservoirs

E. Perform broad-based search for signatures indicative of past or extant biological processes

- DraMS: Mass Spectrometer
- DrACO: Drill for Acquisition of Complex Organics
- DraGNS: Gamma-ray Neutron Spectrometer
- DraGMet: Geophysics & Meteorology Package
- DragonCam: Camera Suite

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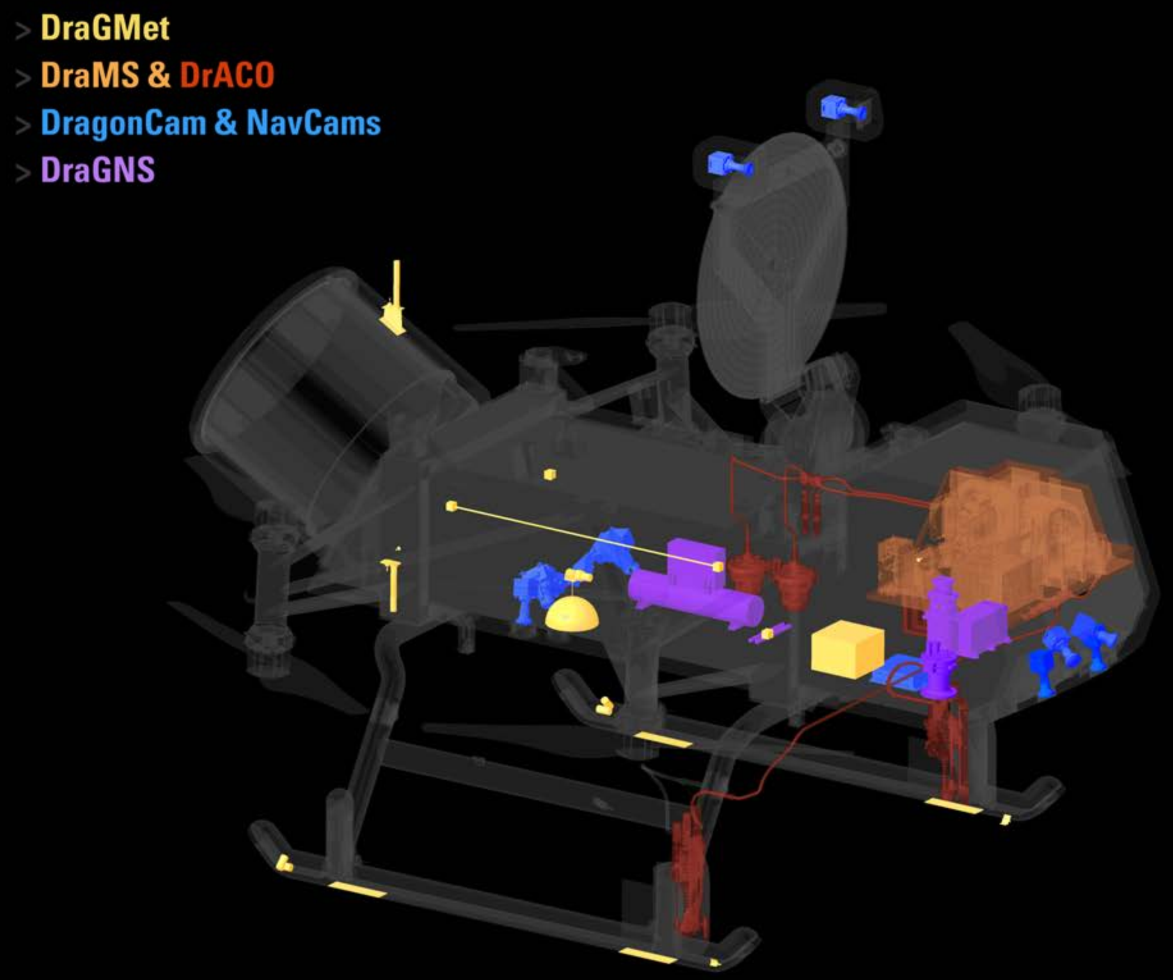

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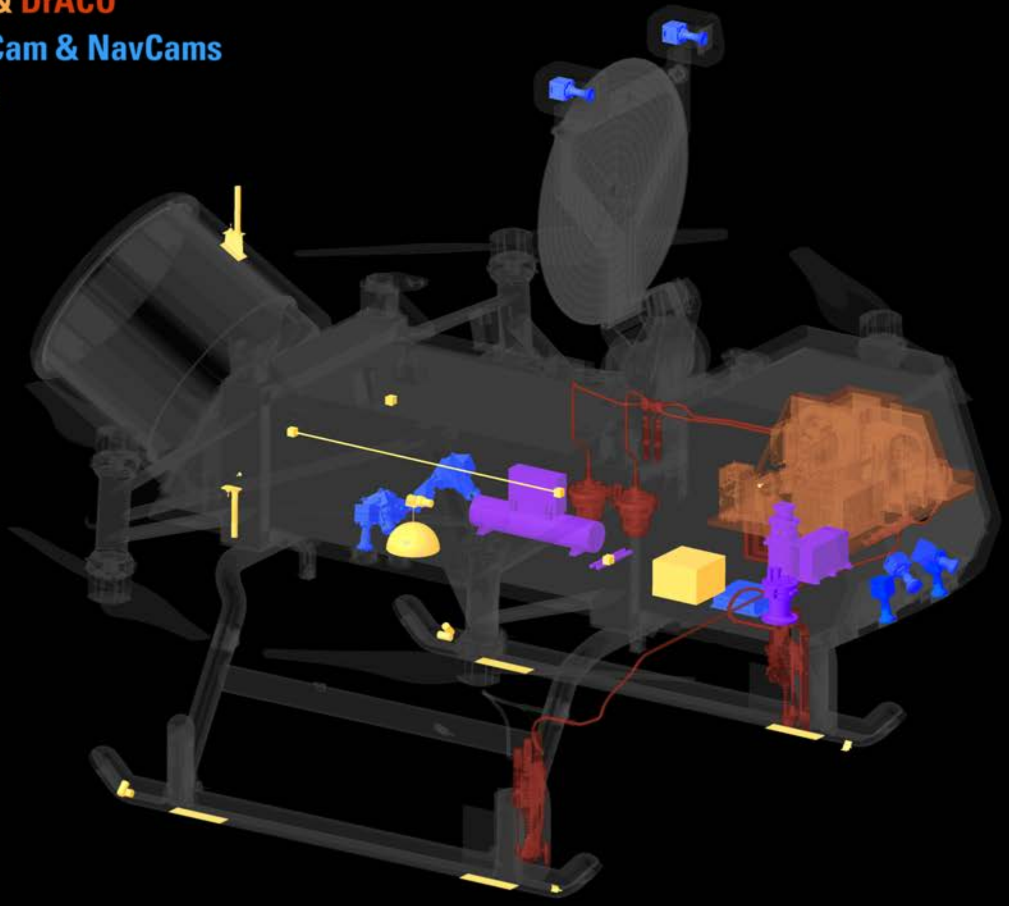
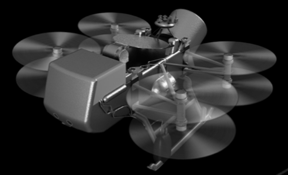
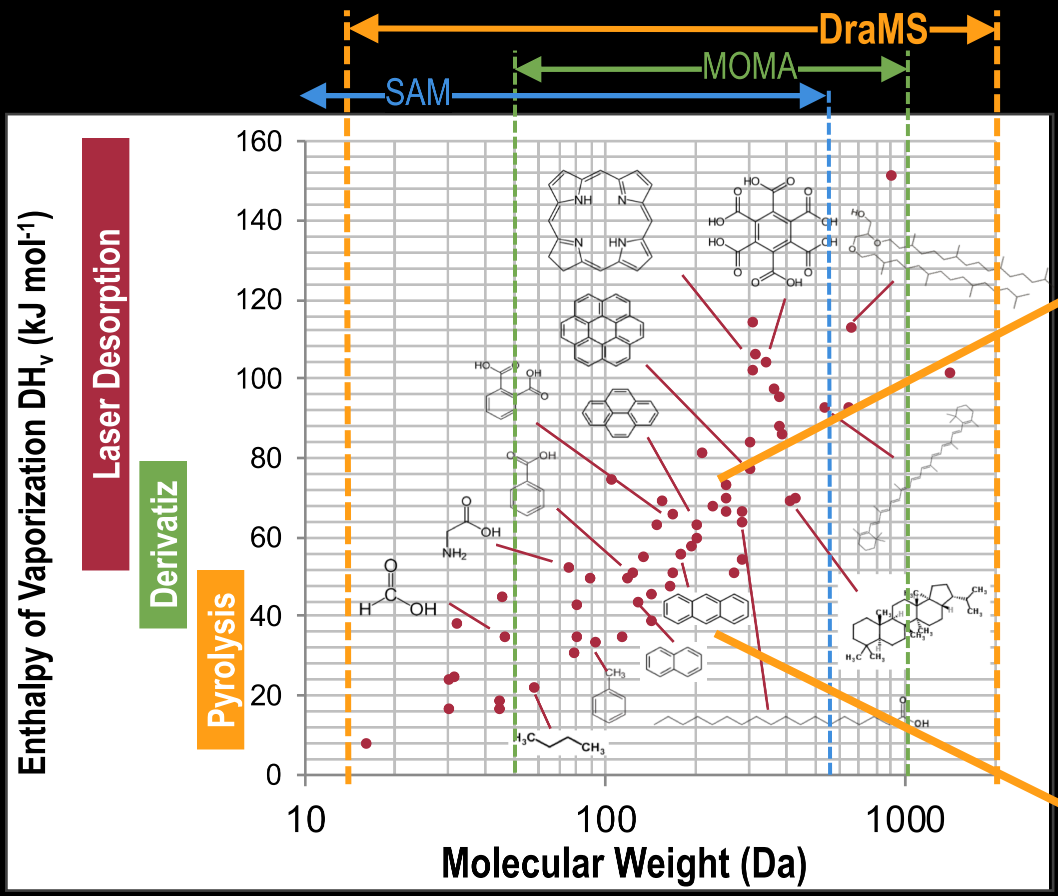
Science goals and payload focus on chemical inventory and opportunities for materials to interact

- DraGMet
- DraMS & DrACO
- DragonCam & NavCams
- DraGNS

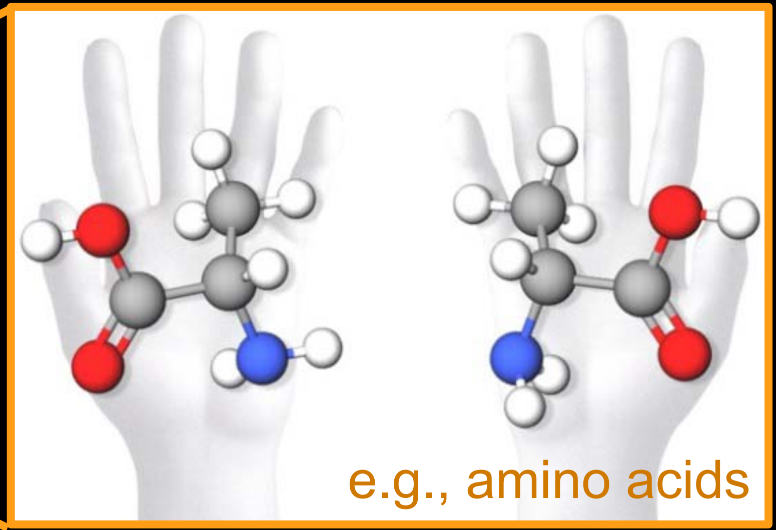


Comprehensive study of the chemical complexity and diversity of Titan's solid surface





- Analyze chemical components & processes that produce biologically relevant compounds
- Complementary sample analysis modes:
  - Laser Desorption MS: Broad survey and structural analysis
  - Gas Chromatography MS: Definitive molecular detection, chirality

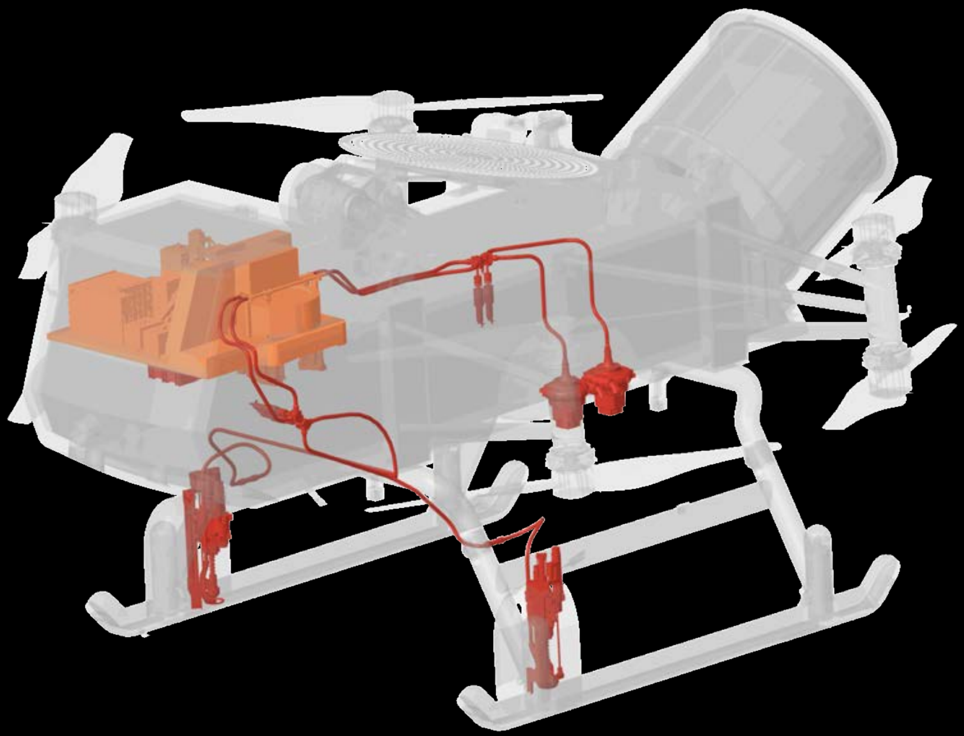


(Trainer et al., 2017)

(Hand et al., 2017, Europa Lander SDT Report)

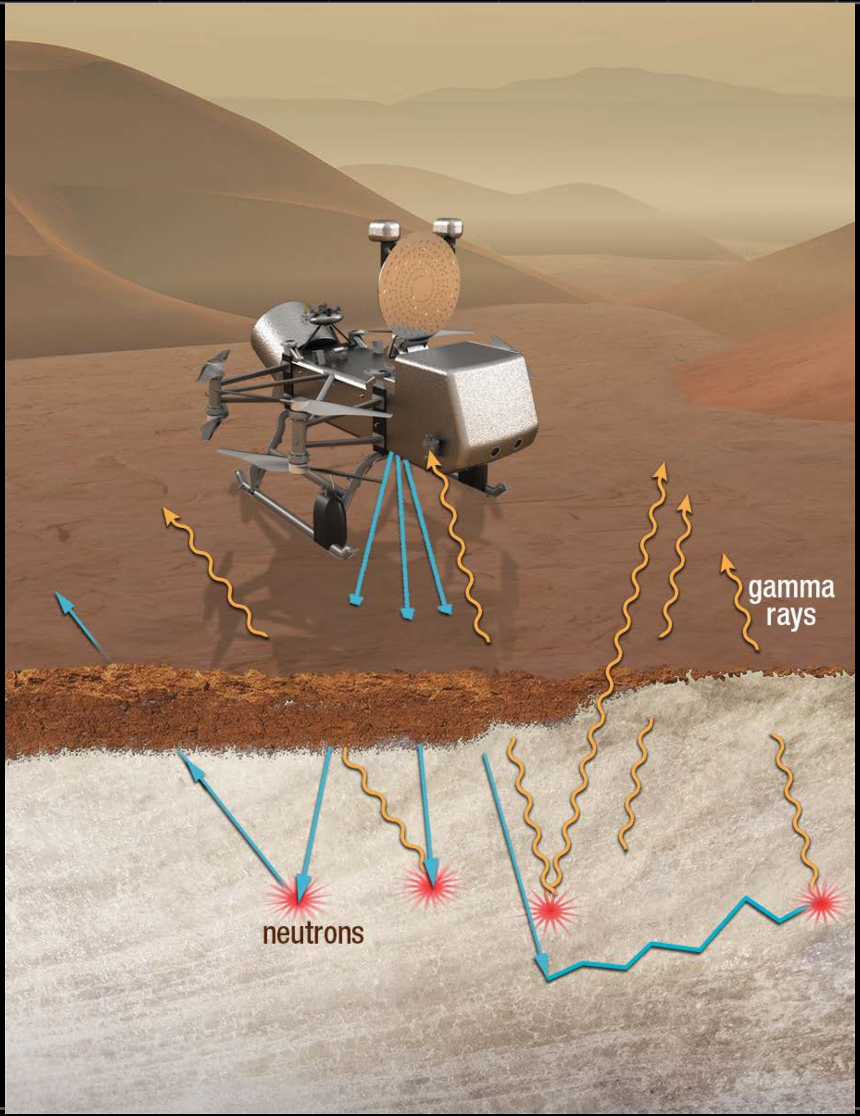
Comprehensive study of the chemical complexity and diversity of Titan's solid surface

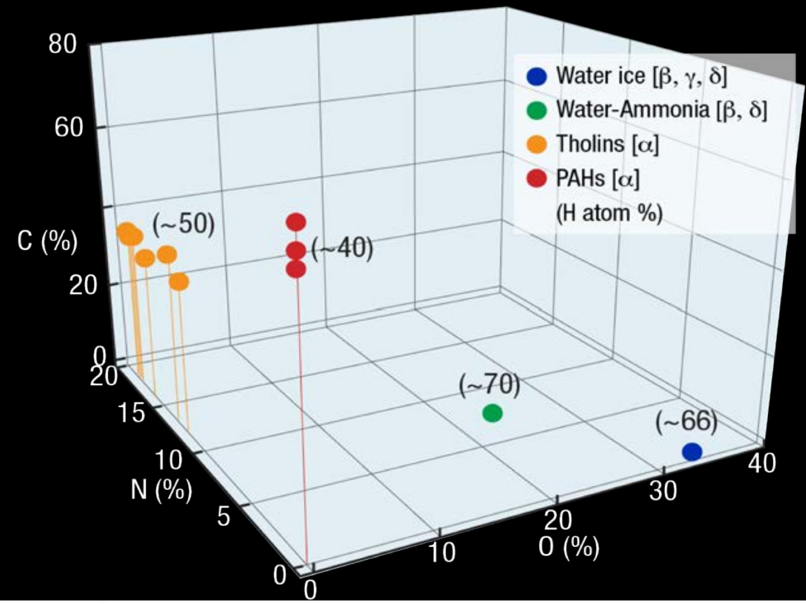
- DrACO uses redundant rotary-percussive drills and blowers to pneumatically transfer surface material to DraMS for detailed chemical analyses

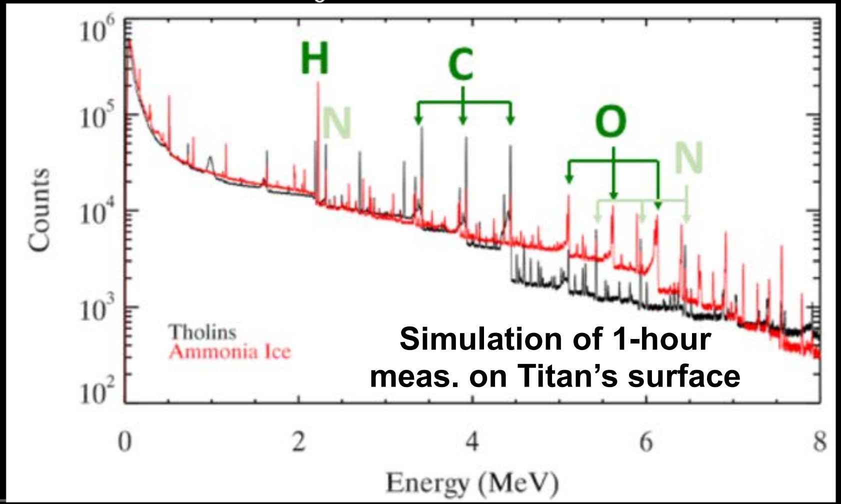


Classification of surface materials at every site

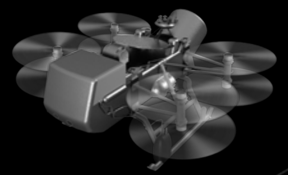
- Measure bulk elemental surface composition
  - Classify surface material
  - Detect minor inorganic elements
  - Reveal near-surface stratigraphy





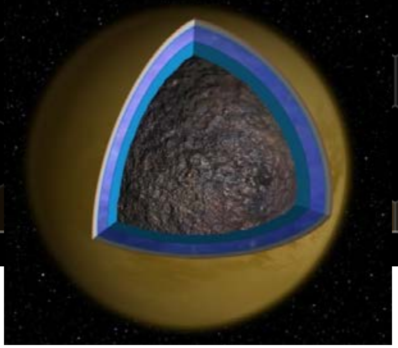


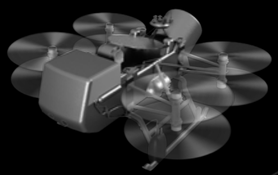
Meteorological and seismological monitoring of an ocean world



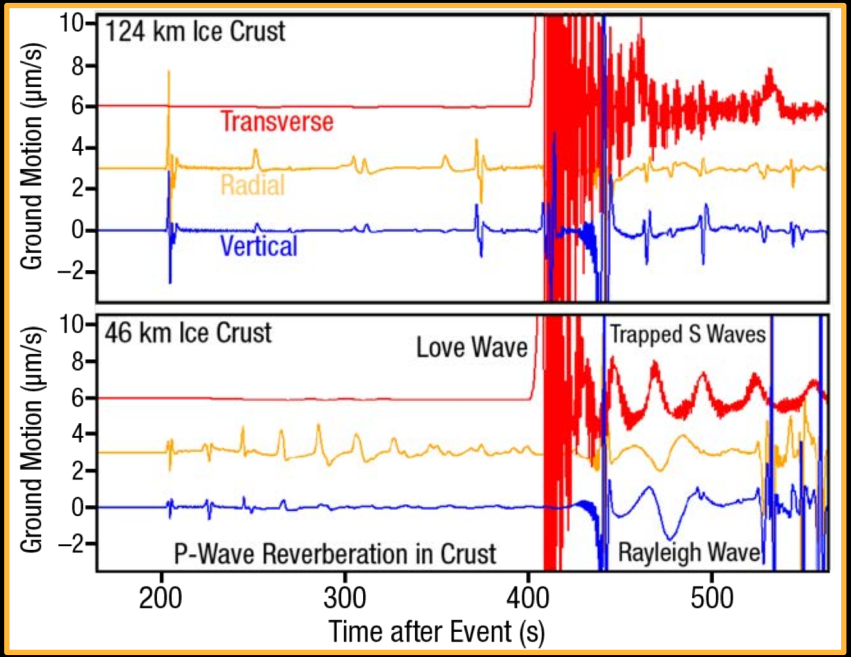
- Monitor atmospheric conditions, identify CH_4 reservoirs, and determine transport rates
  - T, P, CH_4, wind speed & direction
  - Diurnal and spatial variations; atmospheric profiles
- Constrain regolith properties (e.g., porosity)
  - Thermal diffusivity, dielectric constant
- Constrain processes that mix organics with past surface liquid water or subsurface ocean
  - E-Field (Schumann resonance), seismic activity

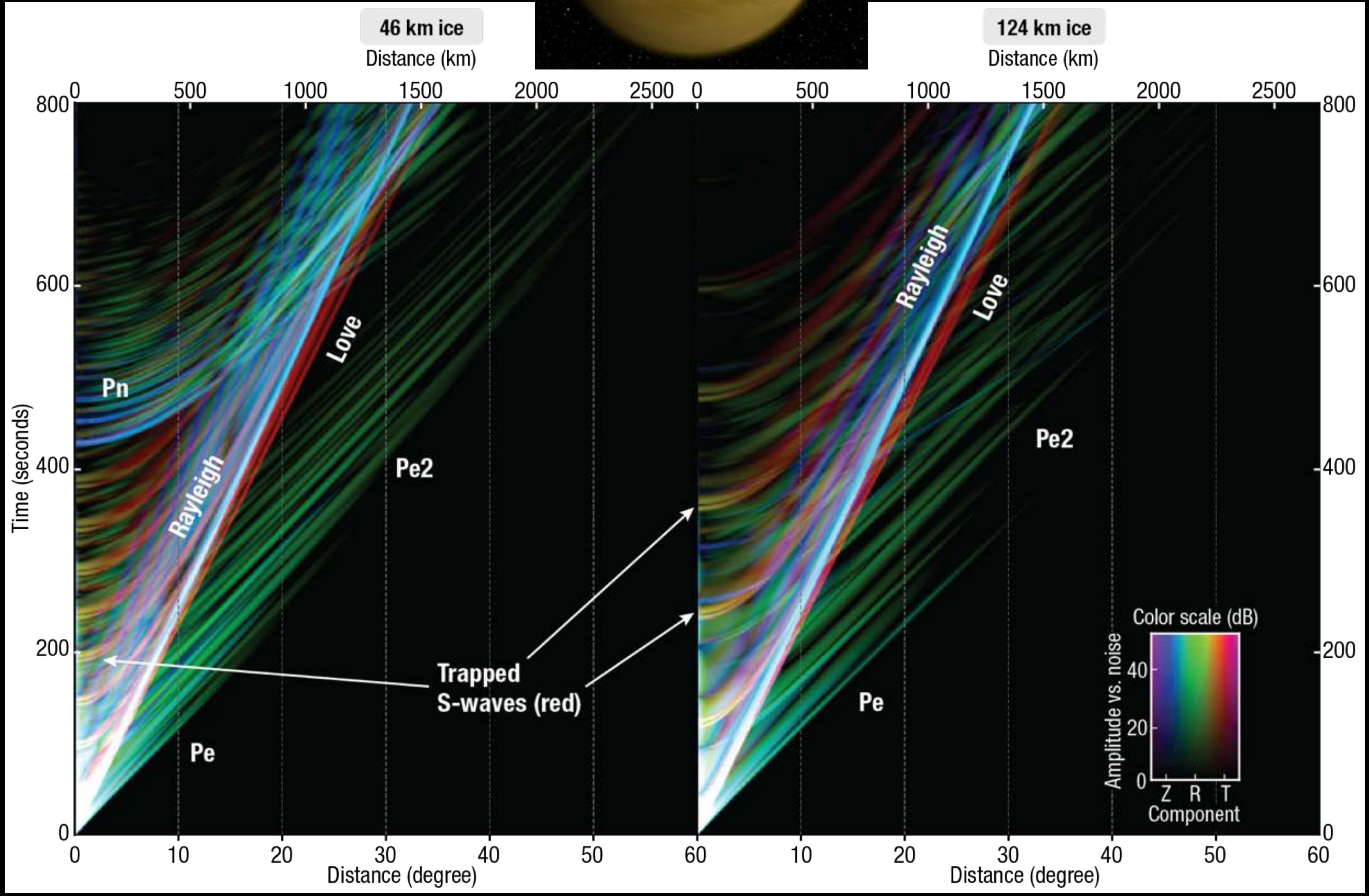
Seismological monitoring of an ocean world



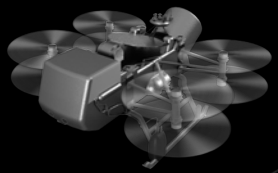


- Detection and characterization of seismic activity
- Variation with orbital phase





Characterization of landforms and surface processes in multiple geologic settings



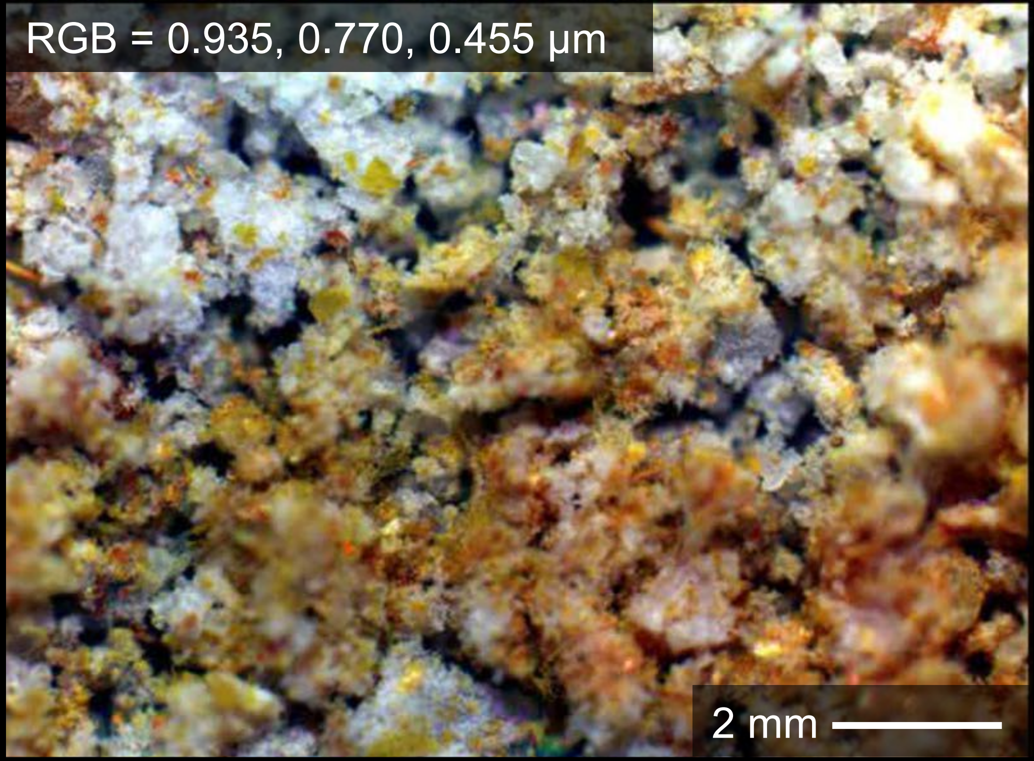
Panorama

Forward

Downward

Microscopic

LED illuminated mixture of water ice (white) and two tholin flavors (orange + yellow)



(MacKenzie, Nunez, et al. 2019)

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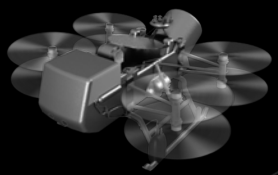


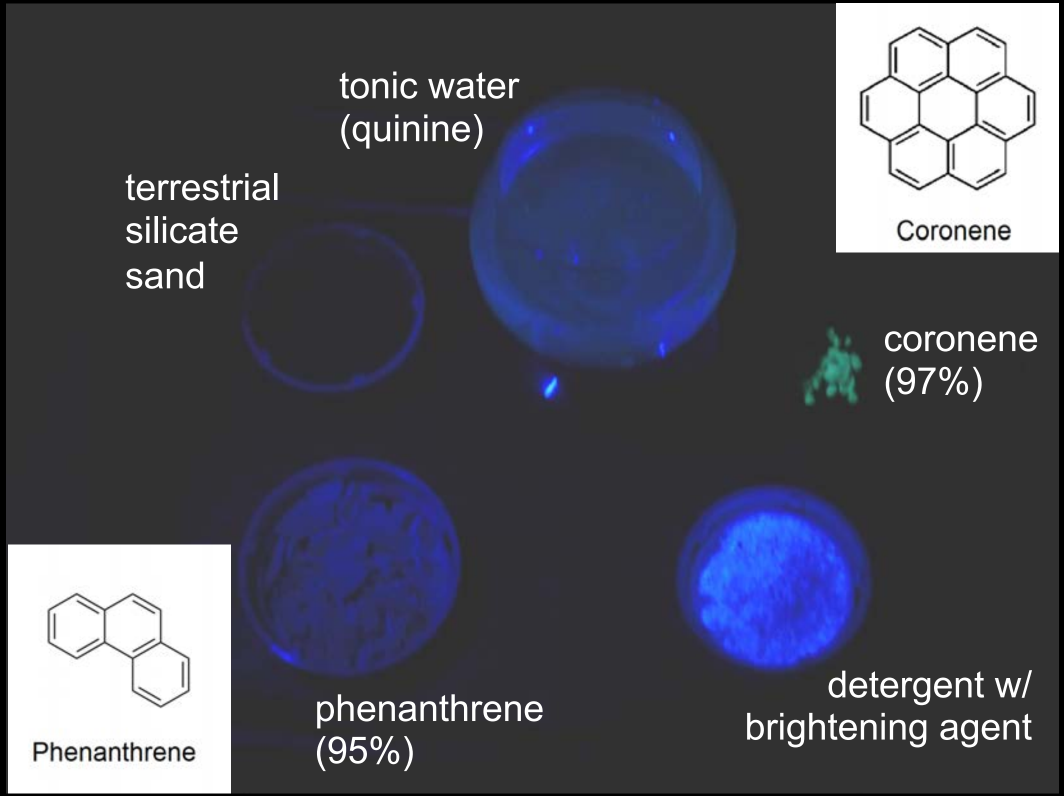
Panorama

Forward

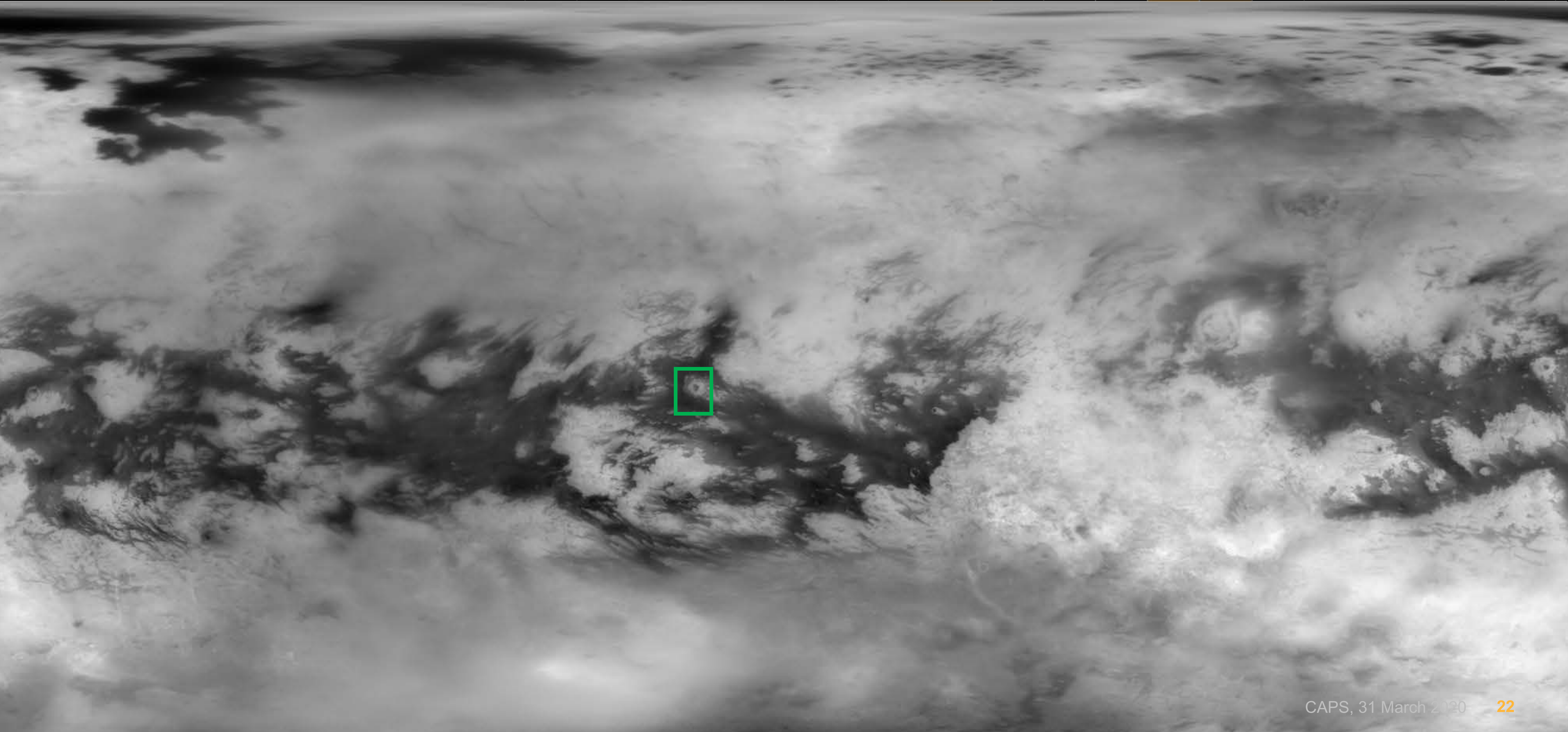
Downward

Microscopic

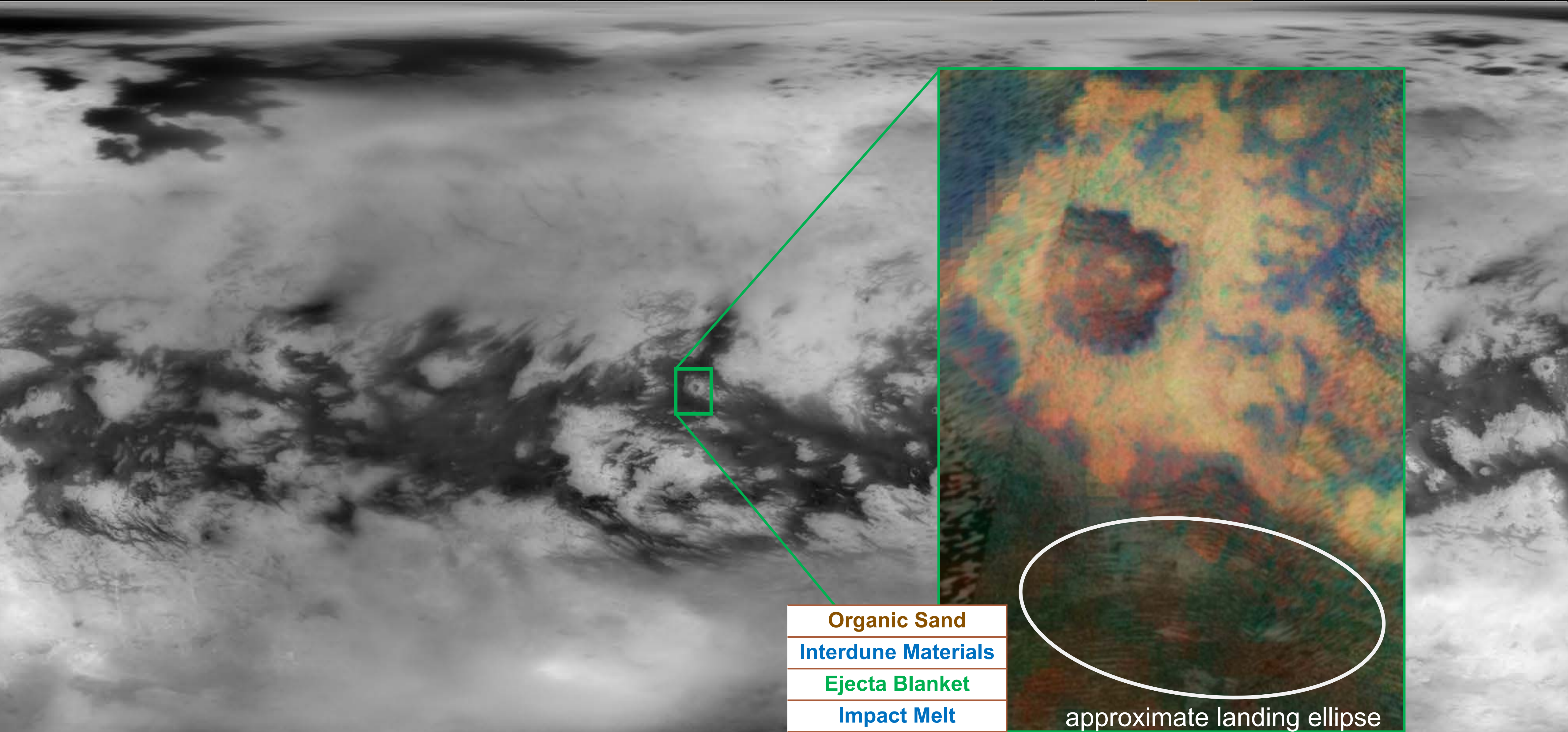
Aromatic organics, especially PAHs, exhibit fluorescence when stimulated by near-UV light



Initial landing site provides access to multiple geologic settings



Organic sediments and materials with a water-ice component: dunes, interdunes, impact crater deposits



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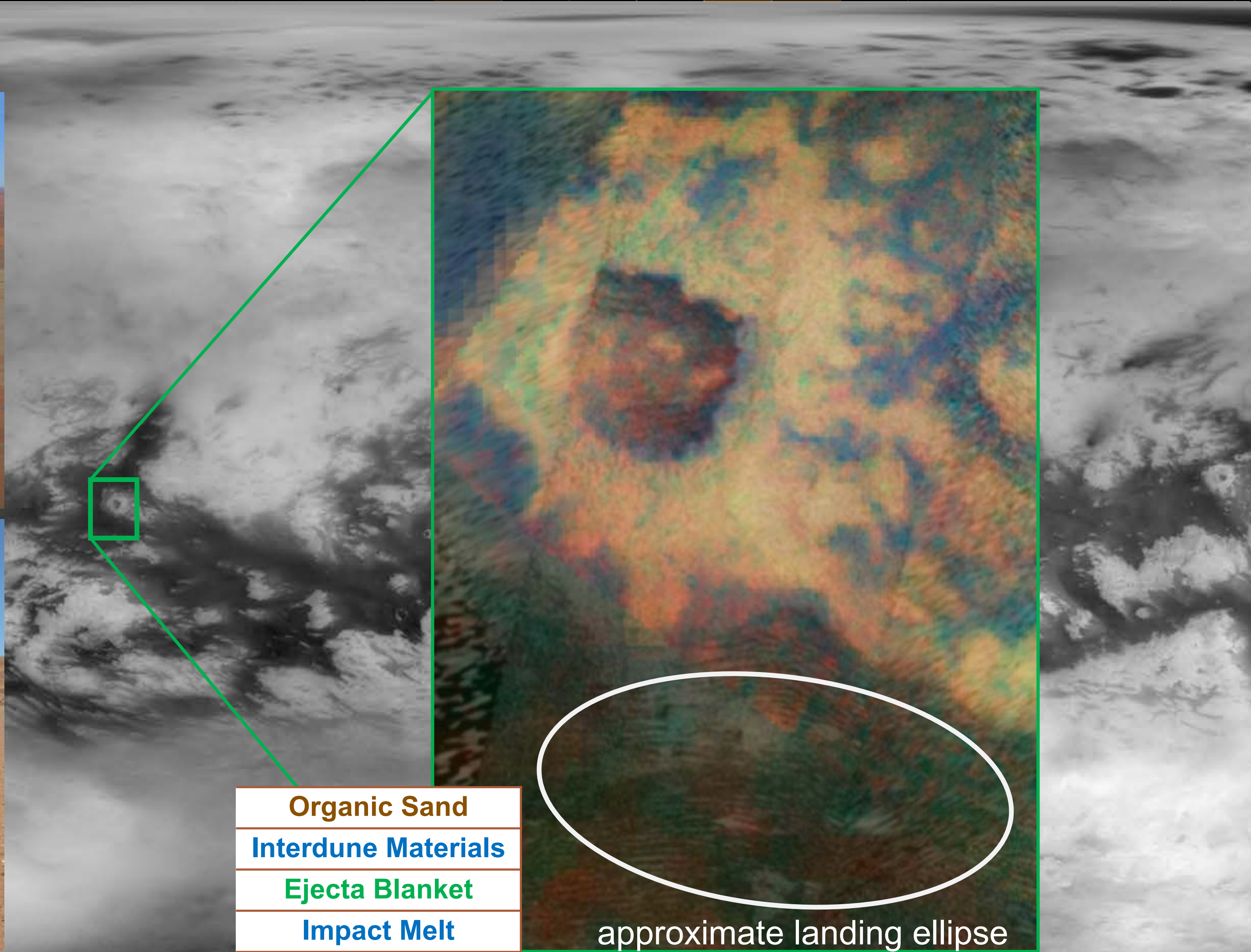
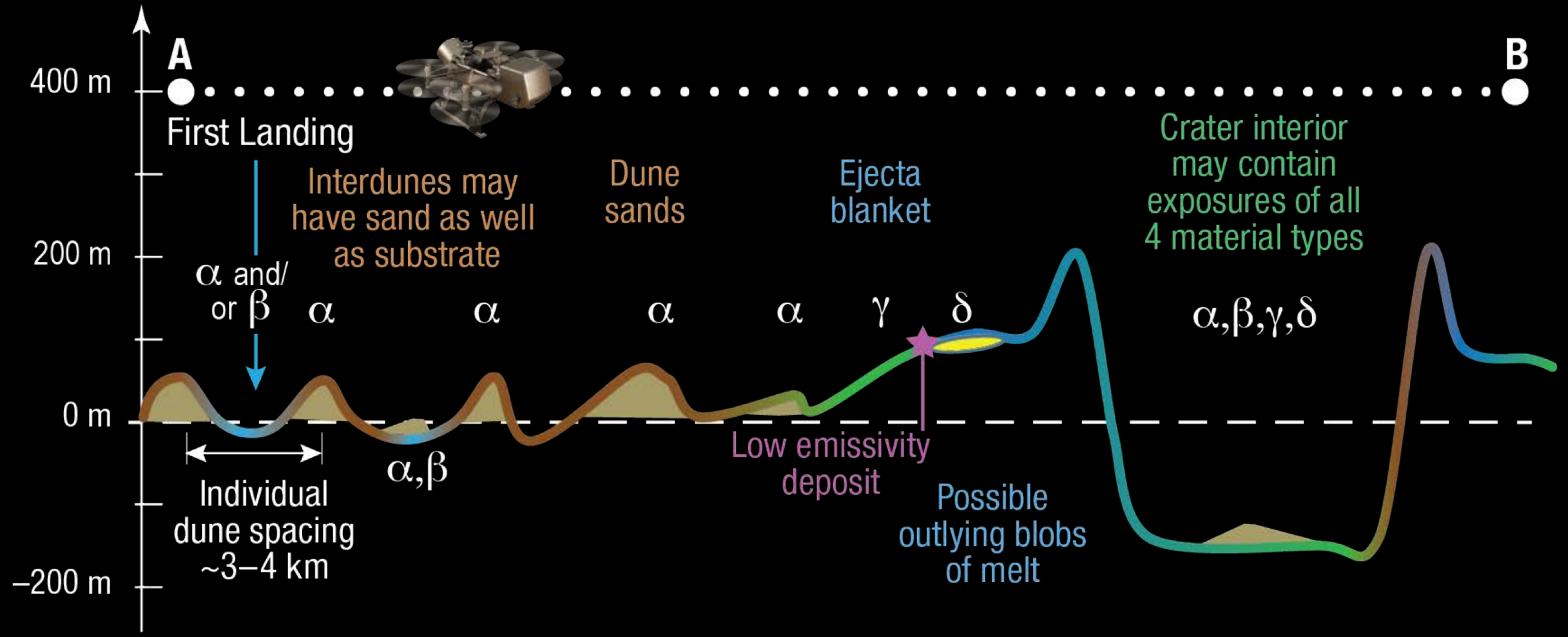


Dragonfly exploration strategy

- Over 2.5 years of exploration
  - ~60 Tsols of science operations
  - Traverse distance up to ~180 km
  - Exploration of ≥24 unique sites



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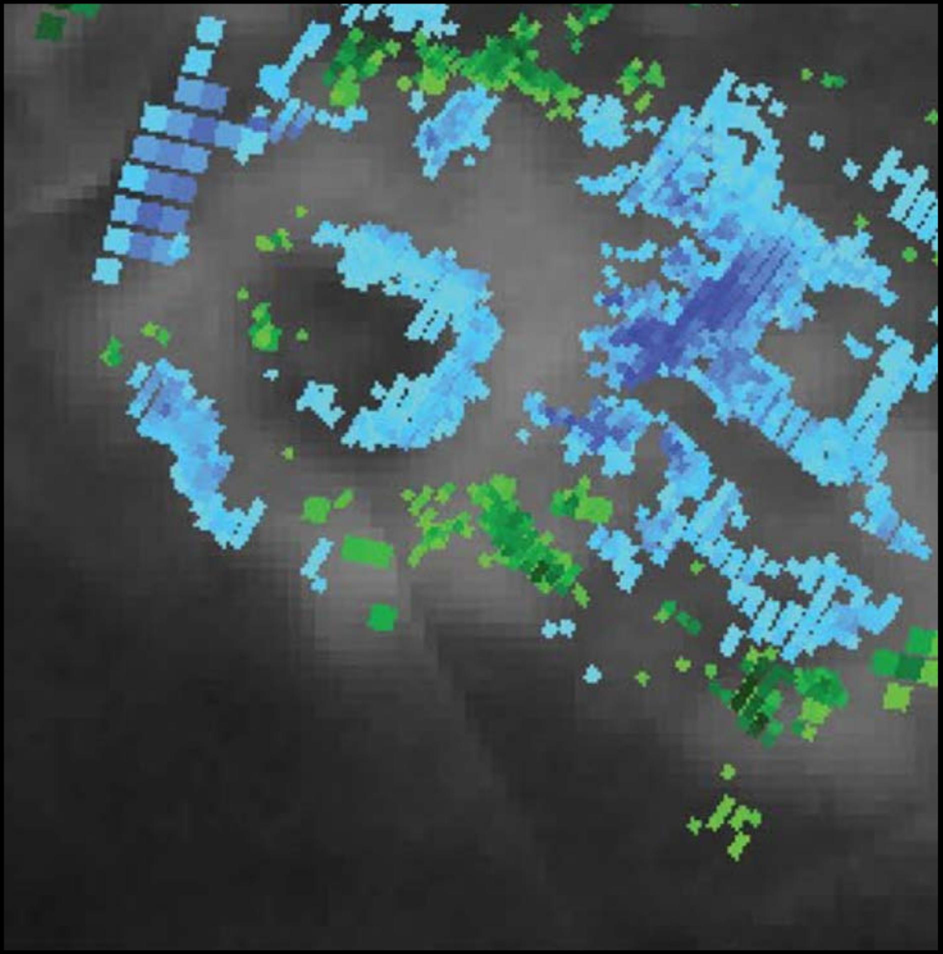

(Griffith et al., 2019)

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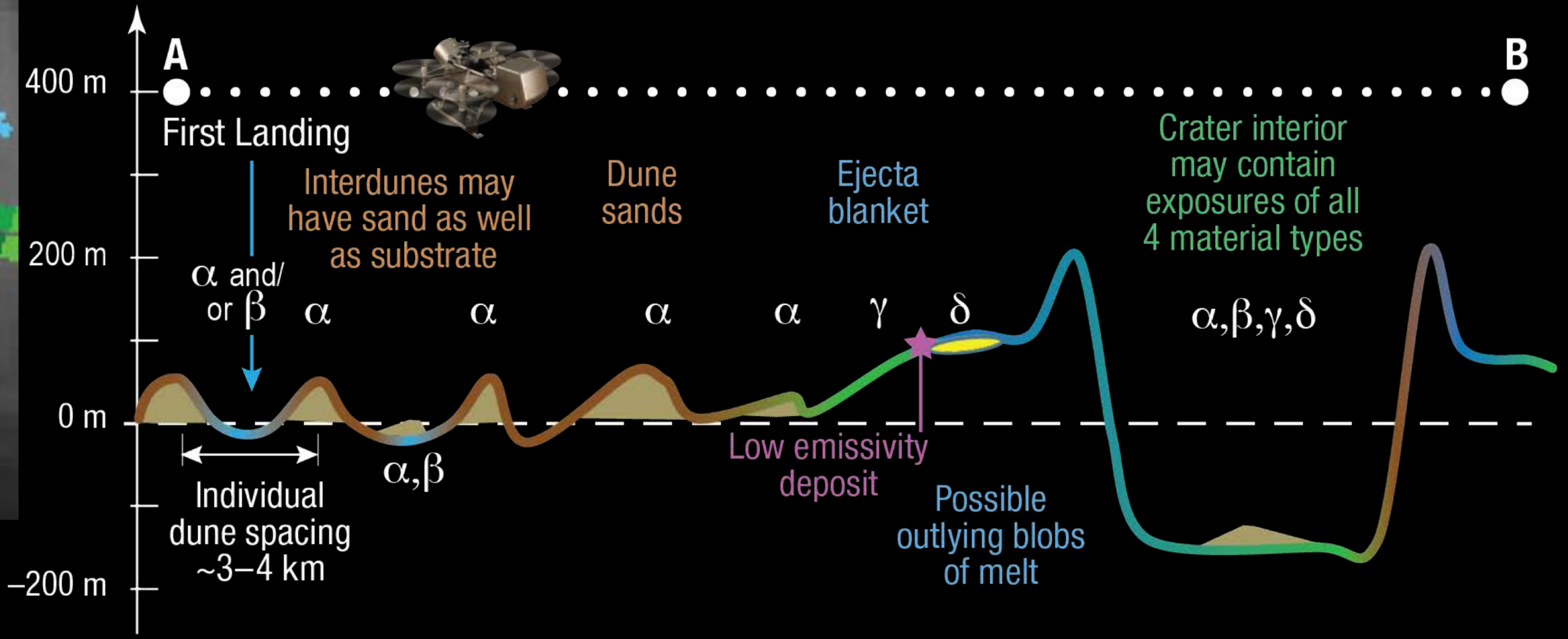
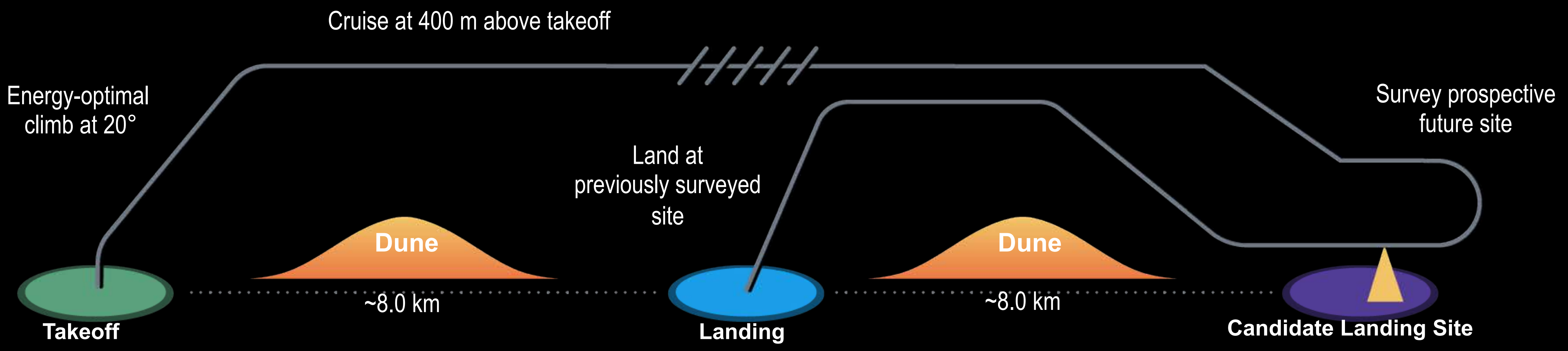
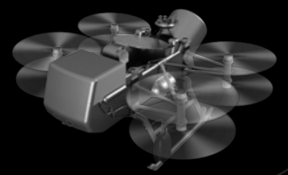


Dragonfly exploration strategy

- “Leapfrog” exploration strategy to scout future landing sites
- 16-day Titan sols → relaxed operations schedule
  - Most of time is spent on the surface making science measurements

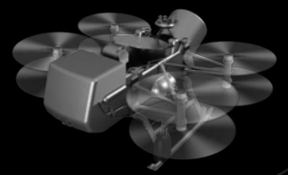


Multidisciplinary science measurements at multiple landing sites



- Prebiotic chemistry
  - Analyze chemical components and processes at work that produce biologically relevant compounds
- Habitable environments
  - Measure atmospheric conditions, identify methane reservoirs, and determine transport rates
  - Constrain processes that mix organics with past surface liquid water reservoirs or subsurface ocean
- Search for biosignatures
  - Search for chemical evidence of water- or hydrocarbon-based life

Dragonfly science closely tied to Planetary Science Decadal Survey cross-cutting science themes



Planetary habitats (Priority Questions 4–6):

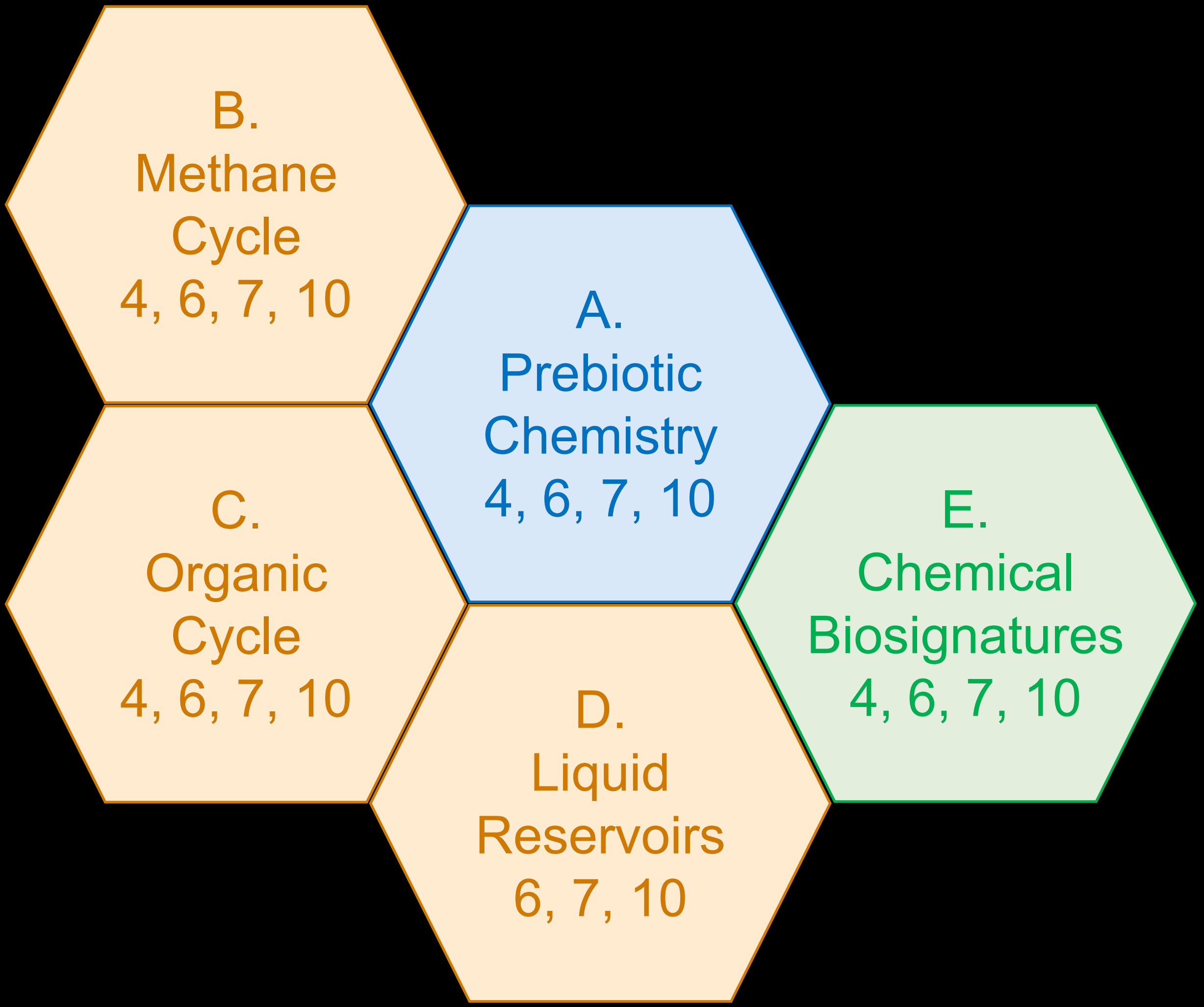
- identify sources of organics and ongoing organic synthesis
- document environments with necessary conditions, materials, and energy to sustain life
- search for chemical signatures of past or extant water- and/or hydrocarbon-based life

Workings of solar systems (PQ 7–10):

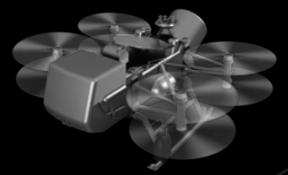
- study atmosphere-surface-subsurface interactions and exchange processes and atmospheric processes

Building new worlds (PQ 1–3):

- investigate initial conditions, including processes analogous to those that supported prebiotic chemistry on early Earth



Titan exploration strategies



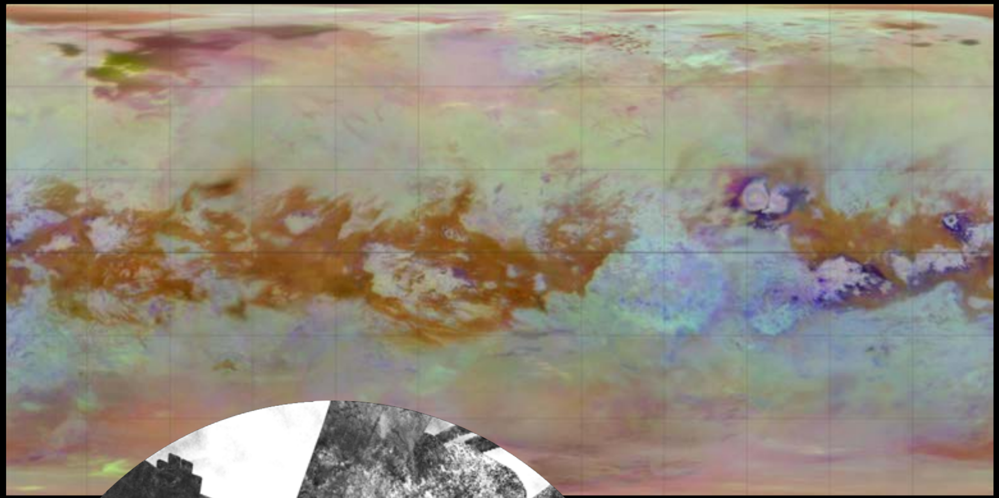
- Helicopter (Lorenz 2000)
- Airship (helium or hydrogen; Levine & Wright 2005; Hall et al. 2006)
- Montgolfière hot-air balloon (Reh et al. 2007)
- Airplane (Levine & Wright 2005; Barnes et al. 2012)
- Sea lander (TiME proposal to NASA Discovery Program, Stofan et al. 2013)
- NASA Titan Explorer Flagship study (Leary et al. 2007)
  - Lander + Montgolfière-type balloon
  - Two landers
- NASA-ESA Titan Saturn System Mission (TSSM; Lunine, Lebreton et al. 2008)
  - Montgolfière + lander

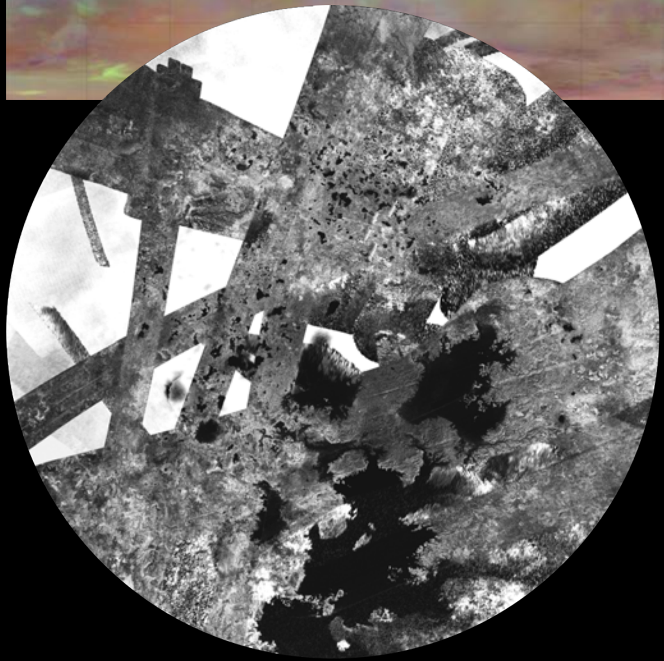
With both landed and aerial capability, Dragonfly accomplishes science objectives of multiple concepts using current technologies.

Titan exploration strategies

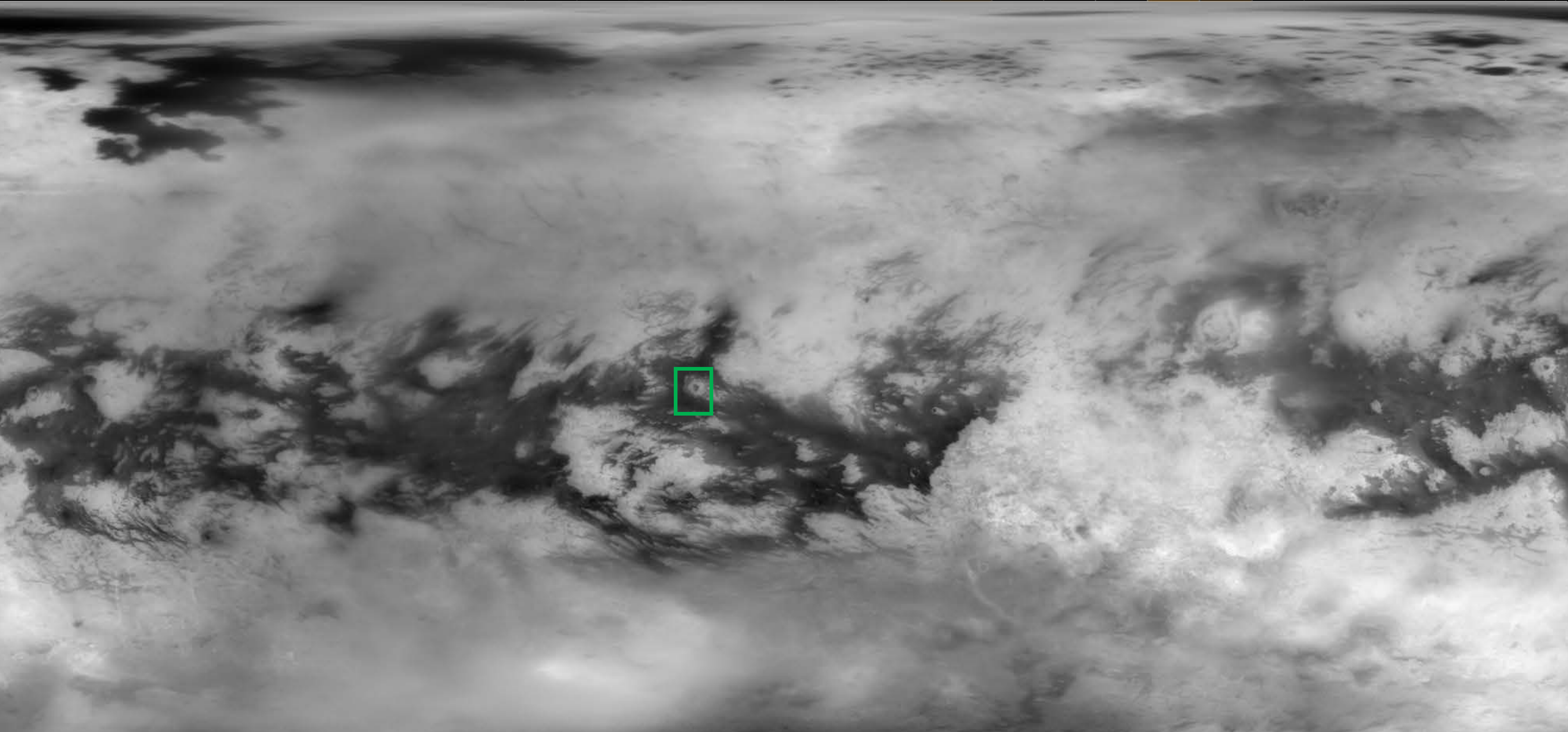
Mission Concept Studies for 2013-2022 Decadal Survey

- Titan Saturn System Mission: orbiter, balloon, lander
  - Explore and understand processes common to Earth that occur on another body, including the nature of Titan's climate and weather and their time evolution, its geologic processes, the origin of its unique atmosphere, and analogies between its methane cycle and Earth's water cycle.
  - Examine Titan's organic inventory, a path to prebiotic molecules. This includes understanding the nature of atmospheric, surface, and subsurface organic chemistry, and the extent to which that chemistry might mimic the steps that led to life on Earth.
- Titan Lake Probe: floating and/or submersible at Kraken Mare
  - Understand the formation and evolution of Titan and its atmosphere through measurement of the composition of the target lake, with particular emphasis on the isotopic composition of dissolved minor species and on dissolved noble gases.
  - Study the lake-atmosphere interaction in order to determine the role of Titan's lakes in the methane cycle.
  - Study the target lake as a laboratory for both prebiotic organic chemistry in water (or ammonia-enriched water) solutions and non-water solvents.
  - Determine if Titan has an interior ocean by measuring tidal changes in the level of the lake over the course of Titan's 16-day orbit.





Dragonfly's exploration of Titan



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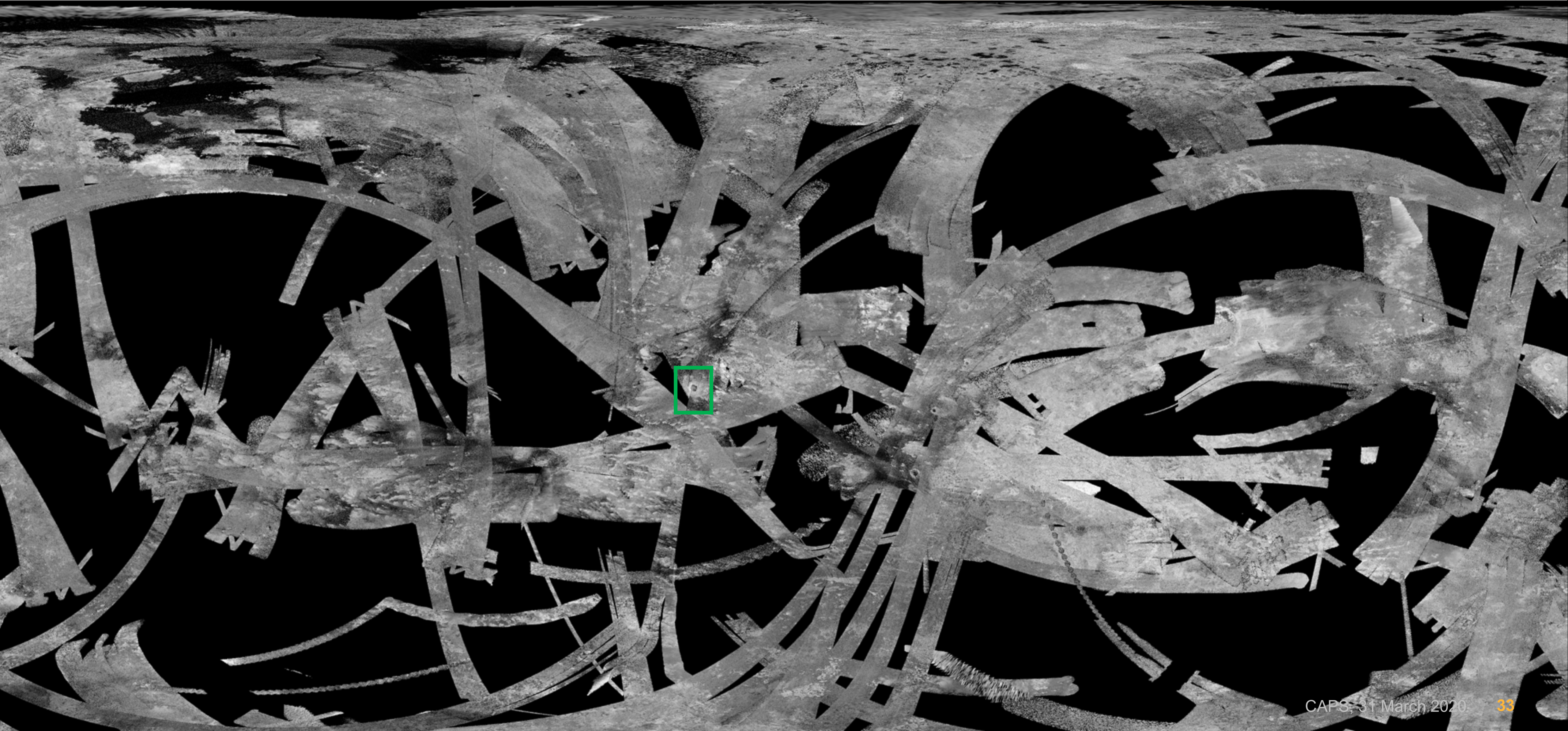
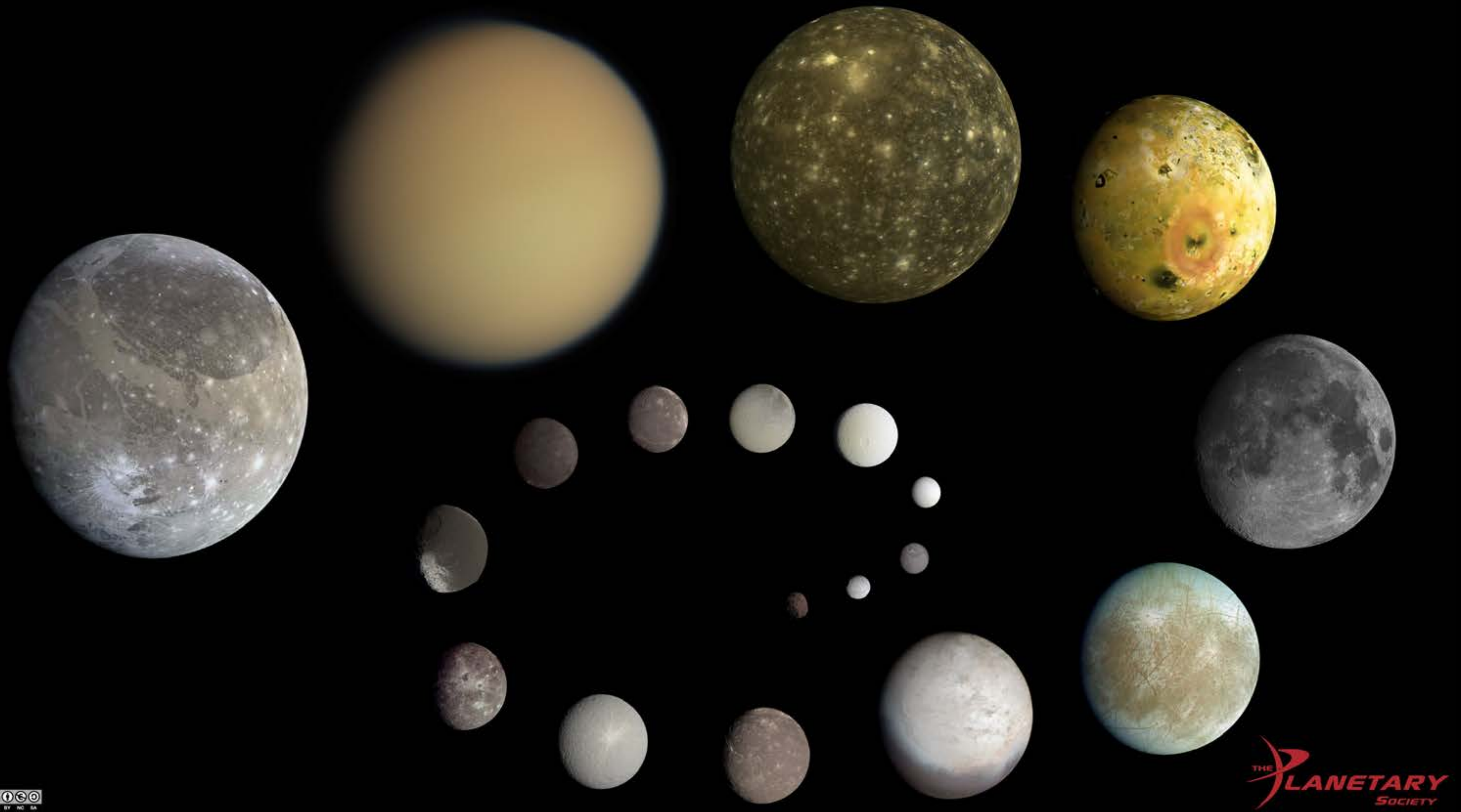


Titan's unique environment




Exploration and discovery on an ocean world to determine how far chemistry has progressed in environments providing key ingredients for life

DRAGONFLY

http://dragonfly.jhuapl.edu