In Situ Exploration of Titan's Prebiotic Organic Chemistry and Habitability

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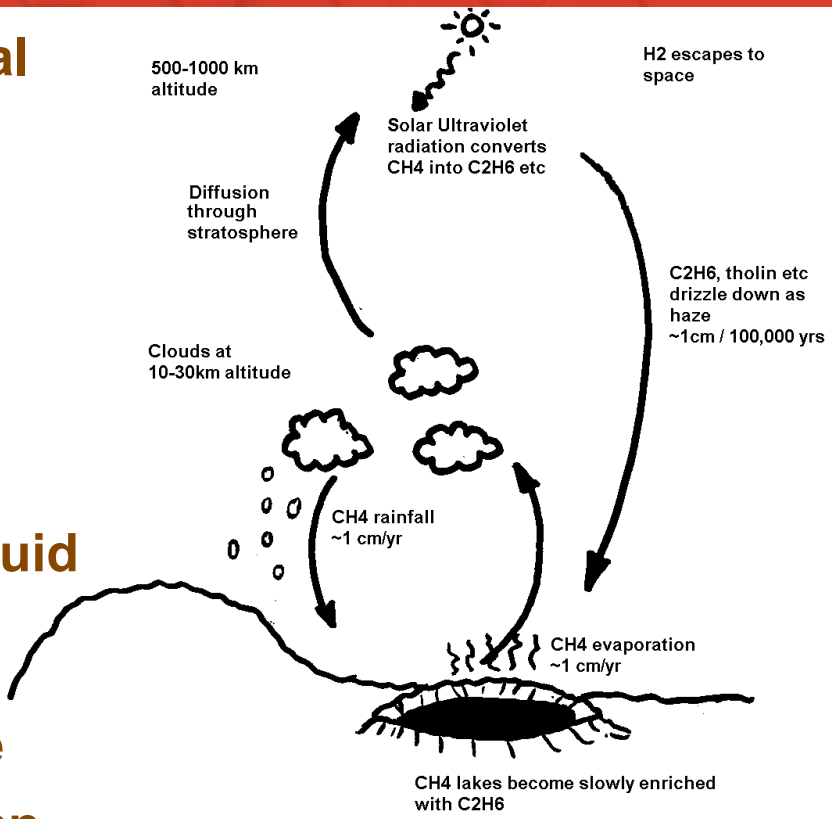
NASA Ocean Worlds Mission Themes
Titan Science Objectives

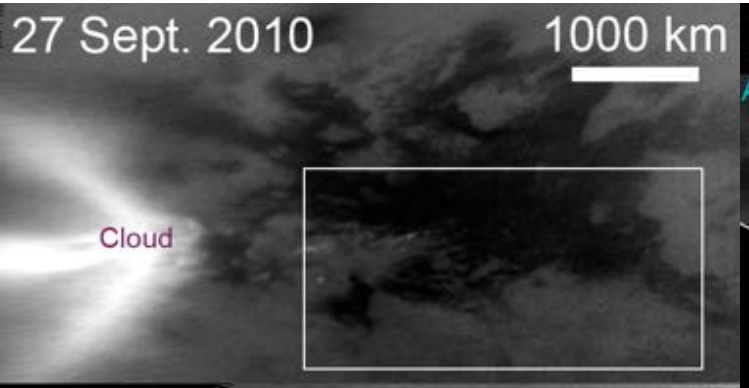
- **Understand the organic and methanogenic cycle on Titan, especially as it relates to prebiotic chemistry**

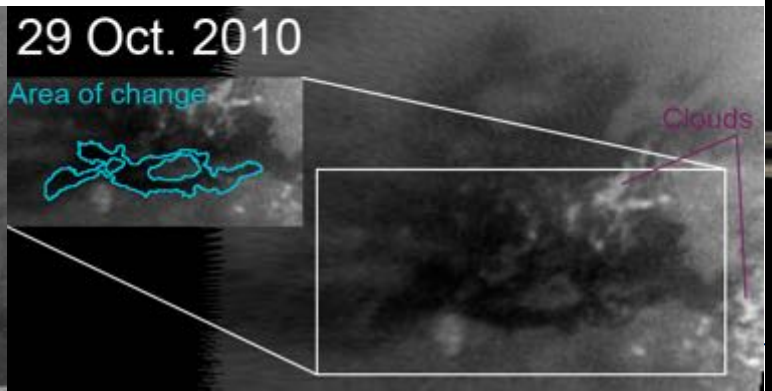
- **Investigate the subsurface ocean and/or liquid reservoirs, particularly their evolution and possible interaction with the surface**

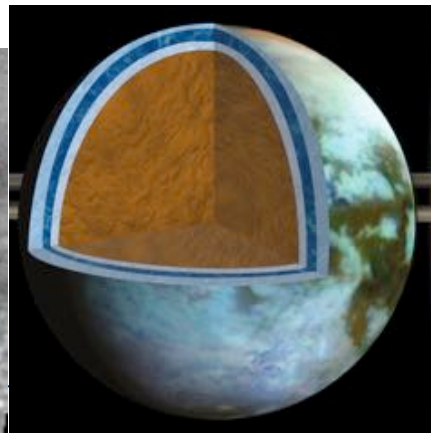
Titan is a high-priority target for prebiotic chemistry and habitability

- Accessibility of complex organic material on the surface
- Earth-like system with methane cycle instead of water cycle
- Unique natural laboratory to investigate prebiotic chemistry and to search for biosignatures of hydrocarbon-based life
- Potential for organics to interact with liquid water near or at the surface → furthers prebiotic chemistry potential as well as search for signatures of water-based life
- Potential for exchange with interior ocean

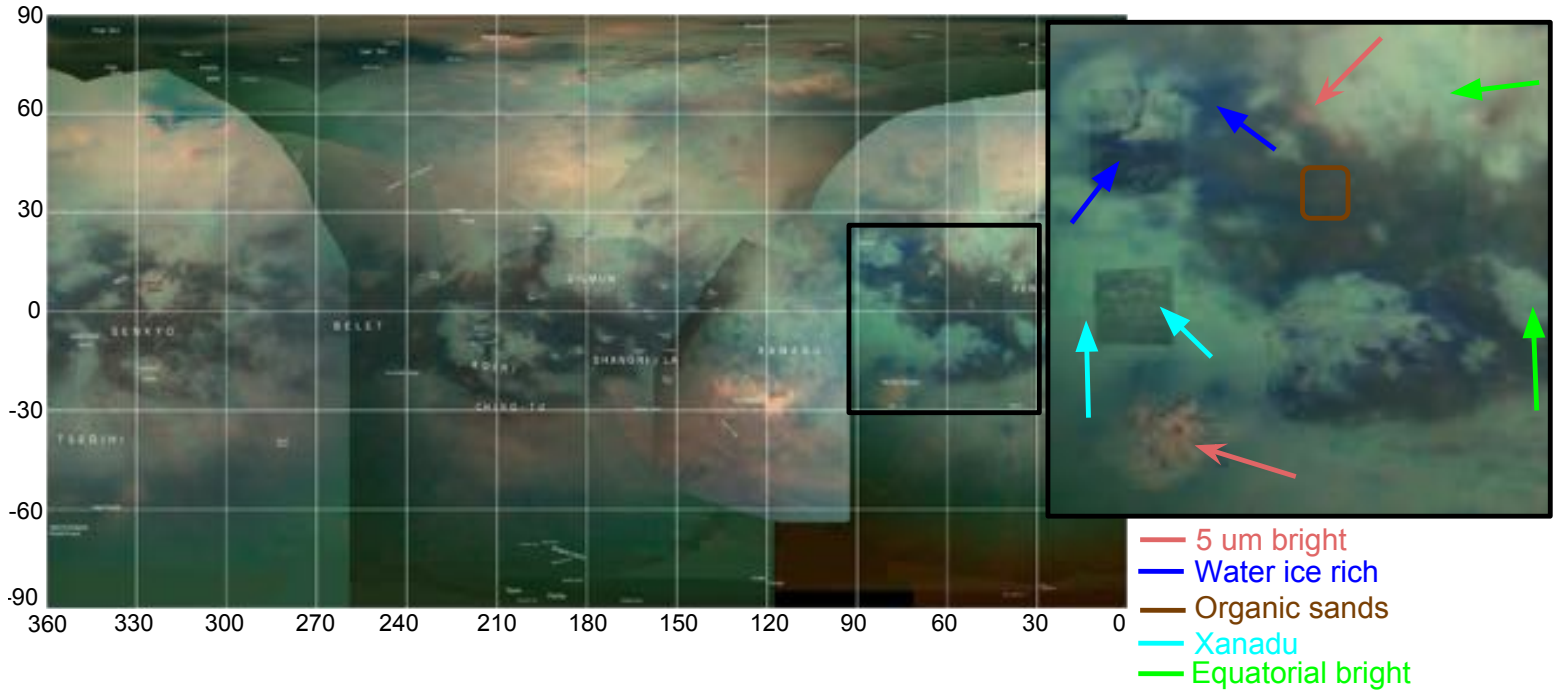








Diversity of surface materials → scientific priority to sample diverse locations



- *Cassini* VIMS map showing spectral diversity of Titan's surface w/ higher-resolution inset from T114 (Nov 2015)
  - Red = 5 µm, green = 2 µm, blue = 1.3 µm
  - Dark blue = higher water-ice content
  - Dark brown = organic sands (Barnes *et al.* 2007; Soderblom *et al.* 2007)
  - Orange = 5-µm bright unit with characteristics consistent with evaporitic material (MacKenzie *et al.* 2014)

Mobility is key to accessing material in different settings

- Compositions of solid materials on Titan's surface still essentially unknown
- Measuring the composition of materials in different geologic settings → how far has prebiotic chemistry progressed in environments that provide known key ingredients for life

- Multiple landers are an inefficient strategy, requiring multiple copies of instrumentation and sample acquisition equipment
- More efficient approach is to convey a single instrument suite to multiple locations
- Heavier-than-air mobility highly efficient @ Titan (Lorenz 2000; Langelaan *et al.* 2017)
  - Titan's atmosphere 4x denser than Earth's → reduces the wing/rotor area required to generate a given amount of lift → all forms of aviation are easier (lighter-than air as well as heavier-than-air)
  - Titan's gravity 1/7th Earth's → reduces the required magnitude of lift → powerful factor in favor of heavier-than-air vehicle

Strategies considered for in situ Titan exploration in previous mission concepts

- Helicopter (Lorenz 2000)
- Titan airship (helium or hydrogen; Levine & Wright 2005; *Hall et al.* 2006)
- Montgolfière hot-air balloon (Reh *et al.* 2007)
- Airplane (Levine and Wright 2005; Barnes *et al.* 2012)
- Lander (TiME, Stofan *et al.* 2013)

Flagship mission studies:

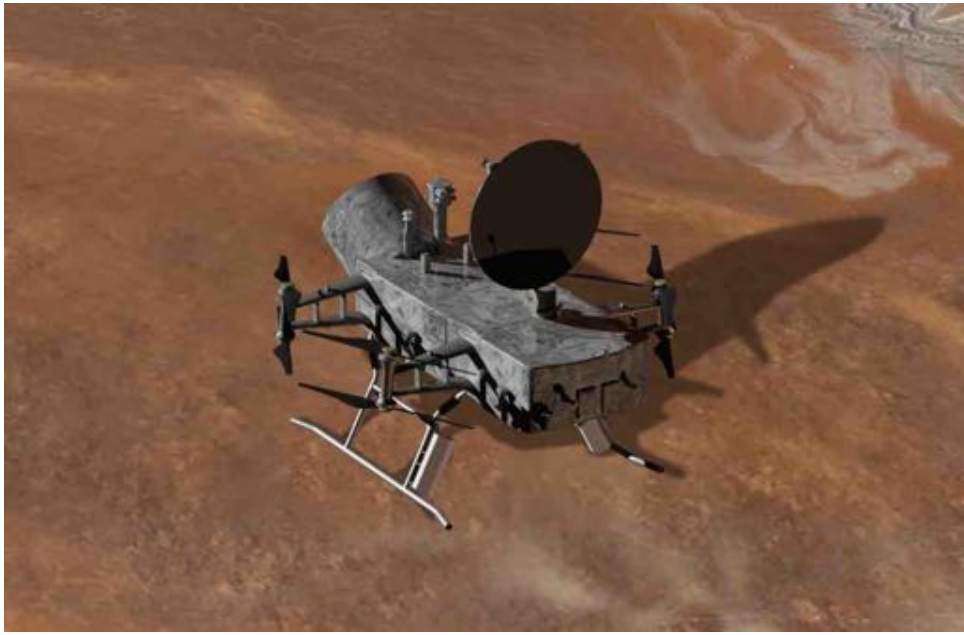
- NASA Titan Explorer Flagship Mission (Leary *et al.* 2007):
  - Lander + Montgolfière-type balloon
  - Two landers
- NASA-ESA Titan Saturn System Mission (TSSM; Lunine, Lebreton *et al.* 2008):
  - Montgolfière + lander

Dragonfly Rotorcraft Lander

- **Challenge is to get a capable mission suite to high-priority sites**
- **Most efficient approach is to convey a single instrument suite to multiple locations on a *lander* with *aerial mobility***
  - **Modern control electronics make a multi-rotor vehicle (Langelaan et al. 2017) mechanically simpler than a helicopter, *cf.* proliferation of terrestrial quadcopter drones**
  - **Improved flight control authority and surface sampling capability**
  - **Redundant and failure tolerant**
  - **Straightforward to test system on Earth**
  - **Efficient to package in entry vehicle**
- **Atmosphere provides means to access different geologic settings *10s–100s km apart***

Surface measurements

- Sample surface material into a mass spectrometer to identify chemical components available and processes at work to produce biologically relevant compounds.
- Measure bulk elemental surface composition with neutron-activated gamma-ray spectrometer.
- Monitor atmosphere and surface conditions with meteorology sensors and remote sensing instruments, including diurnal and spatial variations
- Characterize geologic features with remote sensing instruments; also provide context for samples and scouting for scientific targets
- Perform seismic studies to detect subsurface activity and structure.



In-flight measurements & conops

- Atmospheric profiles, including diurnal and spatial variations
- Aerial imagery for scouting landing sites and surface geology

- Concept of operations similar to rovers:
  - Science activities while landed and some in flight
  - Use aerial scouting observations to identify sites of highest scientific potential for characterizing prebiotic chemistry, Titan's environment, and its habitability to inform prioritization of activities
- More relaxed pace with 16-day Titan-sols

Additional science opportunities

- Participating Scientist Program
  - Prockter *et al.* 2016, DPS
  - Rathbun *et al.* 2017, Planetary Science Vision 2050 Workshop, Poster 8079: The Planetary Science Workforce: Goals through 2050
- E/PO
- Earth-based Titan weather campaign
- Extended mission
  - Follow up on discoveries
  - Access more distant targets

Dragonfly

A rotorcraft lander to investigate prebiotic organic chemistry and habitability using Titan's unique organic laboratory to understand how far chemistry can progress in environments that provide known key ingredients for life

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LaRC
ARC
JPL
GRC

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Applied Physics Laboratory

University of Idaho

DRAGONFLY

Malin Space Science Systems

PennState College of Engineering

Honeybee Robotics