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


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- 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
**Cassini** VIMS map showing spectral diversity of Titan's surface with 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
  - 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

- 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