SCIENCE GOALS FOR THE STUDY OF *TITAN*

Goal 1: Explore surface and interior processes

Explore the processes active on the surface and in the interior of Titan and how these processes are related to Titan's history and composition, and relate them to similar processes on Earth and other solar and extrasolar planets.

Goal 2: Investigate change in the atmosphere and surface

Investigate how and where change occurs on Titan today as a result of orbital and internal variations, as a means to help us understand similar processes and activities on Earth and other planets.

Goal 3: Determine habitability

Investigate the surface and subsurface oceanic compositional and environmental conditions of Titan and determine if they have been amenable to the rise or life, or its molecular precursors.

SCIENCE OBJECTIVES FOR *TITAN*

1. (Addresses Goal 1): What processes are active on Titan's surface and in the lithosphere and how have these processes, and the surface of Titan, changed over time?

Surface features that are the end result of extensive modification from both physical (transport / erosion) and chemical (deposition / dissolution) processes have been observed on Titan. These features include channels, lakes, evaporite deposits, dunes, mountain belts, and potential cryo-volcanoes. The evolutionary history of these features, and their current state and activity, is not fully known. It does appear many processes are currently operating and the surface is generally young, as evidenced by the presence of only a handful of named impact craters. The primary mode of resurfacing, whether by erosion, cryo-volcanism or overturn, tectonism, or deposition from atmosphere-derived organics, is not yet determined. In addition, it is not known whether the primary mode of resurfacing has changed over time. For methane and ethane fluids to be the primary agents of surface erosion, an interplay between the surface, interior and atmosphere must occur. Exchange of volatiles from the interior to the atmosphere may transpire via a number of processes, for example, disruption of clathrates, which contain methane, ethane and other noble gases in near-surface and interior ices, though how frequently and where this occurs is not known.

2. (Addresses Goal 2): How and when do changes in Titan's atmosphere occur, and how are these expressed at the surface?

Seasonal changes are thought to occur in Titan's atmosphere, based on studies of the orbital parameters, surface morphologies and upper atmospheric chemistry. Titan's orbit requires it to undergo shorter, more severe southern and longer, more mild northern summers, which has likely led to the presence of vast lakes and seas in the northern hemisphere. Solar cycles have an effect on the methanological cycle in the upper atmosphere, which affects the overall atmospheric dynamics and deposition of materials on the surface. This also affects atmospheric flow and can be observed as changes in clouds and precipitation. Long-term changes likely cause rising/falling lake levels, modifications to dune fields and wind streaks and regional climate change. The dynamics of Titan's atmosphere can be compared with those of Earth, Venus and Mars and mutually inform their evolution.

3. (Addresses Goals 1 and 2): What was the thermal evolutionary history of Titan, and how was/is thermal activity expressed at the surface?

Based on moment of inertia measurements, Titan appears to have a low degree of differentiation. Given the size and tidal energy present, as well as the young surface, more internal differentiation would be expected. New studies show there could be more differentiation if the silicate mantle were in a state of hydration. Studies of the mode and amount of release of internal heat would inform the amount of internal differentiation as well as the amount of energy available for lithospheric tectonism and volcanism. In addition, understanding the release of volatiles from the interior, such as ammonia and methane, which aids differentiation and volcanism, is important. Studies of tectonism and volcanism on Titan also helps us understand the communication between the liquid water ocean at 50 km depth below the ice lithosphere and the organic-rich surface, which has astrobiological implications.

4. (Addresses Goals 1, 2 and 3): What processes occur in Titan's atmosphere and on the surface that lead to the formation of organic molecules, and could these materials undergo prebiotic and biotic processes?

Photodissociation of methane high up in Titan's atmosphere leads to the formation of long-chain organic (C-H based) molecules. Some compositions have been determined, such as ethane, hydrogen cyanide, propane, butane and acetylene, and many other low-mass hydrocarbons and nitriles. The details of the ion neutral chemistry, the effects of lower atmosphere radical chemistry, the effects of coagulation or condensation processes and how abundant they are, and the degree of the incorporation of nitrogen have yet to be determined. In addition, reactive oxygen species delivered to Titan from Enceladus have the potential to be incorporated into the photochemical manifold to create oxygenated materials such as amino acids. The organic molecules in Titan's lakes, on the beaches and in the rivers have the potential for prebiotic and biotic processes. Yet where these processes could occur, through what chemical pathways, and at what rates is not yet known.

5. How can Titan inform us about extrasolar planets?

An extrasolar planet similar to Titan in size and effective temperature would orbit a typical M-dwarf star at around 1 AU, where tidal locking, coronal mass ejections, flares, and inefficiency in volatile delivery during formation are not of concern. Around the smallest M-dwarfs, this distance would shrink to 0.2 AU, but even were we to disregard these, the number of remaining M dwarfs vastly outnumbers G dwarfs like the Sun, leading to a high probability of finding Titan-like bodies in the galaxy. Because the 1 AU environment around M dwarfs is benign, in the same sense as is that of our Sun, planets at that distance from an M-dwarf should have stable methane hydrologic cycles for which our own Titan is a good guide.