Dragonfly Planetary Protection Categorization Independent Review

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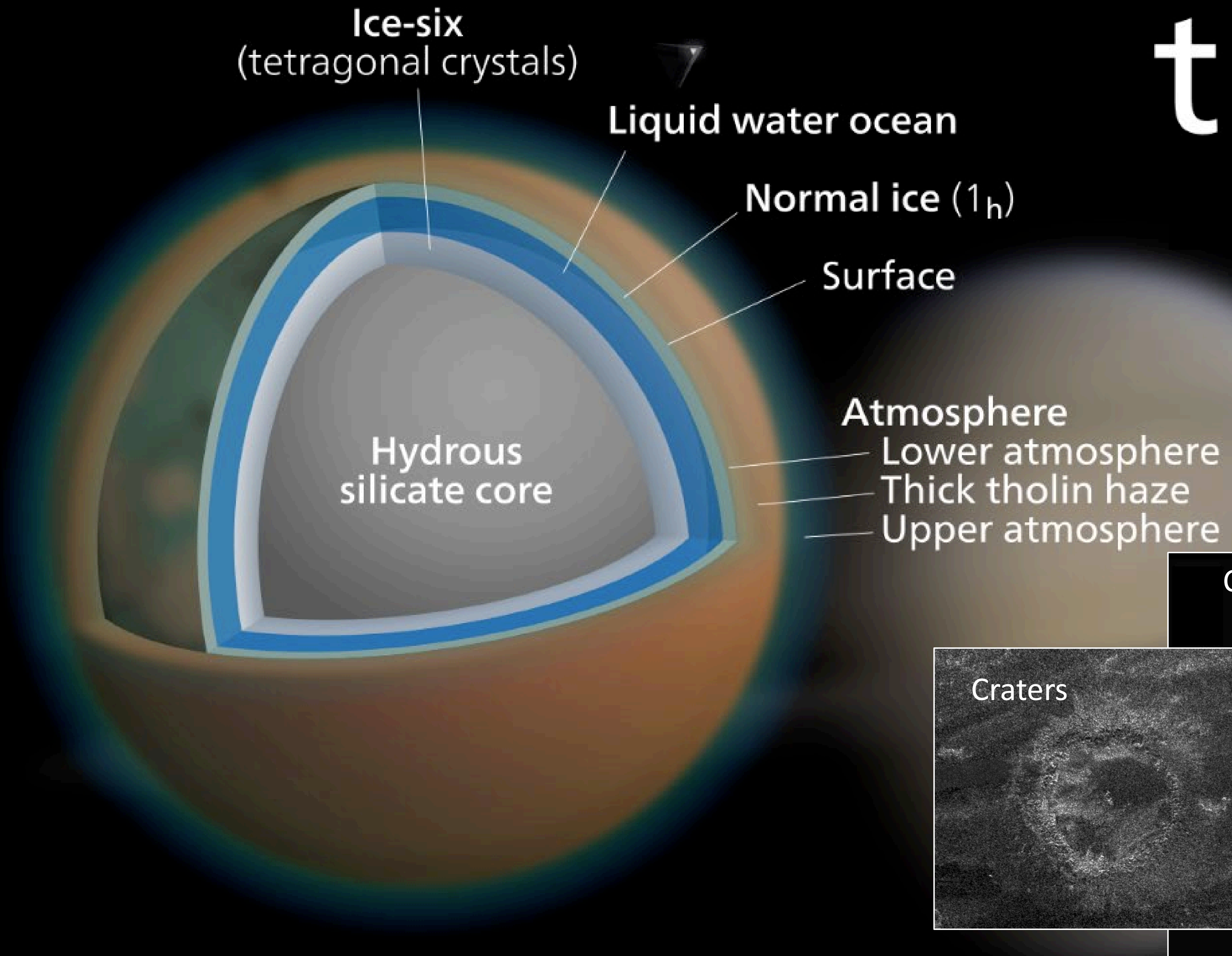
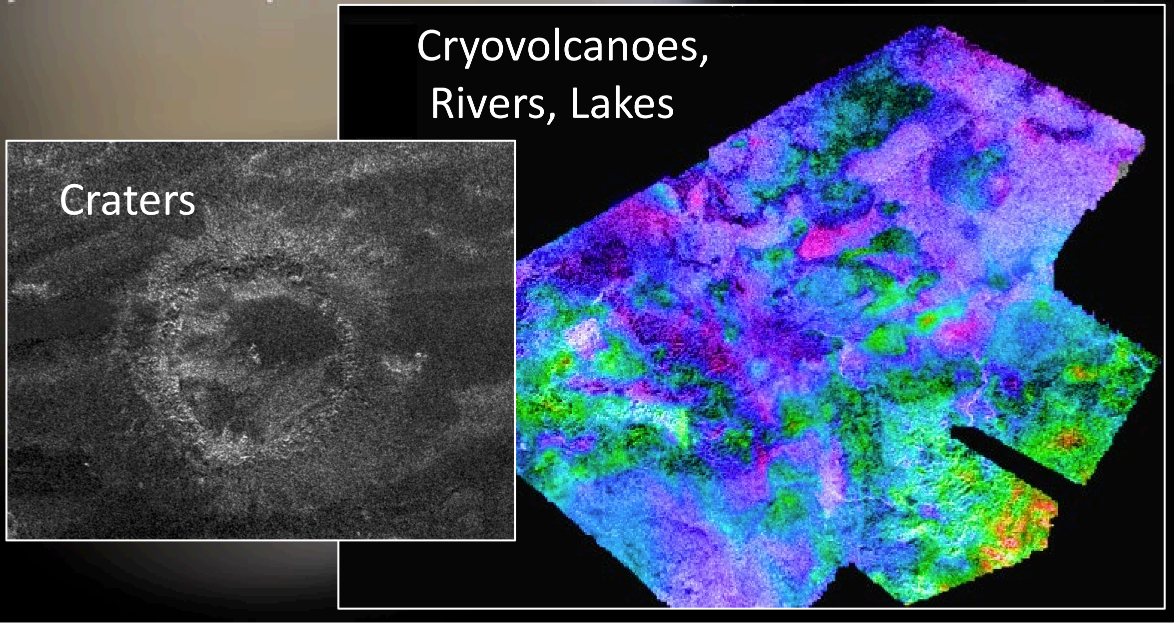
COSPAR Planetary Protection Panel

titan


Ice-six
(tetragonal crystals)
Liquid water ocean
Normal ice (1h)
Surface
Atmosphere
Lower atmosphere
Thick tholin haze
Upper atmosphere
Hydrous
silicate core


Cryovolcanoes,
Rivers, Lakes
Craters

Summary of the Report

Charge from NASA PPO: "To evaluate and identify the science assumptions and associated risks in the *Dragonfly Planetary Protection Categorization Proposal* by ensuring that the project has adequately addressed and has leveraged the current, scientific consensus for Titan planetary science and astrobiology inputs…"

• The emphasis here being on if new scientific results would change Titan's PP Cat II designated for *Dragonfly* since determining an appropriate planetary protection categorization involves a required mission risk assessment that is specific to a mission's location and purpose.

Conclusion: After a careful and extensive review of the current scientific literature about Titan's atmospheric and geological processes (from 2012 to present), this independent review provides several findings that should be addressed in any Titan surface mission to provide a comprehensive planetary protection plan. The review panel believes that there is nothing uncovered in its scientific review that would change the assertion that the *Dragonfly* mission remains at a Planetary Protection Category II determination.

Atmospherically Driven Transport of Material Across Titan’s Surface

The report considered the probability of whether bioburden material from *Dragonfly* could be transported by atmospherically driven processes to a cryovolcanic vent or a crater, where material could then make its way to more habitable environments in Titan’s deeper subsurface.

FINDING 1: Additional studies and models that seek to understand the efficiency of transport of material (organics deposited through the atmosphere) on Titan’s surface, to cryovolcanoes or craters, and then possibly through Titan’s shallow crust into its deeper interior, would be of high value to understanding the potential habitability of Titan’s subsurface ocean.

Transport of Bioburden by Groundwater Flow

Titan likely has a “groundwater” system in which fluids like methane and ethane circulate through subsurface pore space like water does in Earth’s aquifers. Evidence for this interpretation includes similar elevations of fluid surfaces within closely clustered lakes in Titan’s north polar region, and the detection of elevated levels of methane vapor immediately following the touchdown of the Huygens probe, which may have been the product of pore fluid evaporating due to the probe’s warm hull 2016.

FINDING 2: For the reasons discussed in the report, it is not clear that transport of material to the subsurface by groundwater flow is ‘impossible’, and this topic, as well as the assigned probability, deserves more scrutiny.

FINDING 3: Studies that seek to understand the flow of methane through Titan’s shallow crust, and possibly into its deeper interior, would also be of high value to understanding the potential habitability of Titan’s subsurface ocean.

Transport of Bioburden by Rivers and by Wind

While aeolian processes are clearly important on Titan, hydrologic processes are as well, with the relative importance varying spatially and temporally across the globe.

FINDING 4: The transport of material by rivers should be assessed for completeness.

The *Dragonfly PP Proposal* estimates the probability that wind-blown bioburden could reach a liquid conduit that extends down to Titan's liquid interior. Given the recommendation to consider bioburden transport by rivers, the report should first evaluate the probability of bioburden transport to a cryovolcanic conduit by either aeolian or riverine processes, and then subsequently evaluate the probability of bioburden transport through a cryovolcanic conduit to the subsurface.

FINDING 5: Transport of biological material by wind at a background transport rate, and in a smaller range of transport directions, should be assessed independently.

Estimated Thickness of Titan's Rigid Ice Shell

Nimmo & Bills (2010) estimated the ice shell (over the global ocean layer) thickness of ~100 km. The ice shell thickness influences the timescales for any transport process to convey bioburden to potentially habitable regions in Titan's interior and therefore the probability of contamination via such transport processes. The ice shell thickness also determines whether some transport mechanisms could plausibly operate at all. The thickness of the rigid, conductive outer ice layer is therefore of great interest.

FINDING 6: Considering that the community's understanding of Titan's interior structure and dynamics continues to evolve, a wider range of possible ice shell thicknesses should be considered.

Impact-driven Transfer of Material through Titan's Ice Crust

Given what is known on Earth regarding microbes living in hypersaline liquid water micro pockets between ice grains in deep ice sheets, the warm convective ductile ice layer on Titan is a potentially a habitable environment. The ductile ice layers lie beneath the colder brittle ice zone which is nearly in contact with the surface. Titan's convective ice layer is speculated to begin from 7 to 40 km below the surface.

FINDING 7: Future calculations should include formal modeling of the frequency and evolution of intermediate impacts that could breach the brittle ice layer and immediately deliver material into the potentially habitable warm ice layer. In this case, the transient crater would immediately breach the 7 km to 40 km brittle layer. For complete consideration of processes with longer timescale (>1000 years) processes, the parameter space of varying depths of the two layers, as well as thermal gradients, would need to be considered.

Contamination of Titan for future investigations due to the concentration of material via surface transport processes

Planetary protection concerns not only whether terrestrial microbes from Dragonfly hardware, or any other Titan mission, could contaminate habitable regions on Titan (i.e., its subsurface), but also whether such microbes could contaminate Titan in a way that compromises future scientific investigations. Microbes from a lander/rover mission could collect on the surface, increasing their volumetric concentration and potentially generating a false-positive biosignature by follow-up missions to Titan.

FINDING 8: A Titan mission's categorization proposal should evaluate the possibility that bioburden borne by the mission could be spatially concentrated by surficial processes into locations of potential future scientific exploration on Titan.

Microbial bioburden at launch and landing and implications for risk of contamination

An estimate of a likely bioburden at launch for both scenarios in which the mission is categorized as Category IV (with required hardware sterilization) and Category II (no sterilization), combined with modeling of microbial survivability during transit would be a reasonable estimate of the viable bioburden the spacecraft might ultimately carry to the surface of Titan.

FINDING 9: A Titan mission should consider an estimate of the viable bioburden remaining on the spacecraft upon landing.

Relationship to the Ganymede Planetary Protection Plan

The probability that terrestrial microbes from a rover/lander mission hardware or spacecraft from the point of view of planetary protection could be transferred to the subsurface ocean has been considered for Ganymede in the framework of the JUICE mission. Ganymede is a satellite like Titan, with an undersurface liquid water ocean trapped between two ice layers, where the first one is located at about 80 km under the surface.

FINDING 10: Considerations previously applied to Ganymede could be applied to Titan, since Titan has an interior water ocean, but it is, perhaps, isolated beneath a ~100-km thick ice crust.