# Triton Science Goals

## Major source: White papers submitted to Decadal Survey

*(Agnor et al., Hansen et al.)*

C. Hansen & W. McKinnon, July 2014

- ✧Interior
- ✧Surface Geology
- ✧Surface Composition and Atmosphere
- ✧Plumes
- ✧Interaction with Neptune's Magnetosphere

# Triton Interior

- **What is the nature and history of Triton's interior structure? Does Triton have a current magnetic dynamo? Does Triton have a subsurface liquid ocean?**
  - If Triton was captured early in the history of the Solar System, then tidal evolution to a circular orbit and differentiation may have been completed within several $10^8$ yrs, followed by billions of years of impact cratering. Yet the surface is lightly cratered.
  - New models of obliquity evolution suggest that modest tidal heating is ongoing. Can radiogenic *and* tidal heating today cause convection in a subsurface layer that erases craters and/or otherwise renews the surface? Is a metallic inner core dynamo possible?
  - Subsurface oceans may be a common feature of icy moons, and Triton's young surface age may be indicative that it too has a subsurface ocean.
  - If Triton possesses an internal ocean, is it 'perched' (perhaps like Ganymede) or in contact with the rock core (like Europa)?
  - If Triton collided with existing moons in orbit around Neptune during its capture, its composition could be a mix of planetocentric and heliocentric material. Is Triton still colliding with planetocentric debris?

**Color key: Origins, Habitability**

# Triton Surface Geology

- **What are the geologic processes responsible for Triton's unique surface features? What is the global cratering record on Triton? Has cryovolcanism (or cryodiapirism) played a major role in renewing the surface?**
  - Triton's surface age of <100 MY is derived from the paucity of craters on its surface. Triton's young surface with relatively few craters stands out among moons in the solar system and puts it in a class with Io, Europa, Titan and Enceladus – other moons with (various) active surface processes today.
  - What is the range of ages of Triton's surface units? We need a global data set to fill in Voyager's limited surface coverage and spatial resolution.
  - Many landforms are unique in our solar system (e.g., cantaloupe terrain) – how are they formed? What is the global distribution of geological terrains? What remains to be discovered?
  - How does the interaction of tidal dissipation, heat transfer, tectonics, cryovolcanism/diapirism, and surface-atmosphere interations drive resurfacing of Triton?

# Triton Surface Composition and Atmosphere

- **What does Triton's surface composition tell us about its origin? Is oceanic chemistry expressed on its surface? How are different composition ices partitioned across the surface? What is the nature of Triton's global circulation?**
  - The compositions of Triton's individual surface units are unknown because Voyager did not have an near-infrared spectrometer, and ground-based observations have limited spatial resolution.
  - Changes in atmospheric pressure since the Voyager flyby have been detected in stellar occultations observed from Earth. Seasonal volatile migration is predicted, as Triton's nitrogen atmosphere in vapor pressure equilibrium with surface ices responds to changes in insolation. How has seasonal volatile migration affected the south polar cap and atmosphere since Triton has gone from southern spring (Voyager) to summer?
  - How do volatile inventories compare between Triton and Pluto and other dwarf planets of the transneptunian region?

# Triton Plumes

- **What is the source of Triton's plumes? Are Triton's plumes a result of solar-driven activity? Or are they endogenic?**
  - What do the sites and timings of occurrence tell us about the energetics, relevant processes, and the nitrogen reservoir? Is there a true polar cap?
  - If solar-driven, similar activity may also be occurring on Mars, and Triton may prove to be a wellspring of information about this unearthly phenomenon.
  - If endogenic the plumes may be sampling a subsurface ocean; similar arguments apply to recent cryovolcanism. These would be important for understanding Triton's internal heat flow and tectonics, and would add Triton to the list of key astrobiological targets.

# Triton's interaction with Neptune's magnetosphere

- **How does the highly conducting Triton ionosphere interact with the corotating magnetosphere of Neptune? How is Triton's extremely strong ionosphere generated and maintained, and are magnetospheric interactions key?**
  - How is the relatively dense neutral torus of Triton formed, and what is its relationship to loss processes from Triton's atmosphere?
  - Voyager radio science observations revealed a significant ionosphere with a well-defined peak at ~350 km altitude; however, the distance and the geometry of the Triton closest approach precluded in situ observations of either the ionosphere or its interaction with Neptune's magnetosphere.

# Enceladus Science Goals

## Major source: White papers submitted to Decadal Survey

*(e.g., Hurford et al.)*

W.B. McKinnon, July 2014

- ✧Interior
- ✧Ocean Composition
- ✧Plumes
- ✧Tidal Energy
- ✧Habitability

# Enceladus Interior

- **What is nature of Enceladus' interior? That is, what is the size and shape of its rocky core, the thickness of its icy crust as a function of location, and most importantly, what is the thickness and extent of any subsurface ocean or sea?**
  - Gravity models are consistent with at least a regional sea at the south pole and a large, low density (~2500 kg/m$^3$) core.
  - Is the sea global? Whatever its extent, any subsurface sea or ocean should be more directly confirmed.
  - How uniform is the ice shell thickness? What are the various contributions from thickness and density (salinity, clathrates, porosity) variations?
  - If Enceladus' core is low density, is it porous, and is there internal hydrological circulation.
  - Is Enceladus an original regular satellite, or was it born from a massive mega-ring during a later epoch?

**Color key: Origins, Habitability**

# Enceladus Ocean Composition

- **What is the composition of the ocean, sea, or liquid reservoir that apparently feeds the plumes erupting from the South Polar Terrain? How does this composition relate or map to in situ mass spectrometer and dust or other measurements of plume vapor and solid particles?**
  - Are ammonia, methanol, choride, or bicarbonate salts, or some other materials, depressing the melting point and enabling a liquid water layer or changing rheological properties within Enceladus?
  - What are the global characteristics of the ocean, in terms of temperature, oxidation state, pH, and Eh?
  - What does ocean chemistry imply for Enceladus' origin and evolution?

# Enceladus Plumes

- **How do the mechanics of Enceladus' erupting plumes actually work**? **What are the roles and importance of tidal and endogenic stresses (that is, those due to convection, diapirism, freeze/thaw of the sea/ocean)?**
  - How does the liquid water reservoir communicate with the surface?
  - What are the physical and chemical conditions in the plumes? What are the plume characteristics, particle masses, size and velocity distributions?
  - How long-lived are the plumes? Does plume production vary in time? Are plumes cyclic, episodic? Do source regions migrate along the tiger stripes?
  - Were other regions on Enceladus cryovolcanically active in the past (or even active today at a low level)?
  - How does plume fallout affect Enceladus' surface? How do the plumes feed the E ring? What are the escape and resurfacing rates?

# Enceladus Tidal Energy

- **Where is the tidal energy that powers Enceladus' activity actually deposited? What is the balance between anelastic dissipation in the solid ice shell, frictional dissipation on faults in the icy lithosphere, and oceanic dissipation? Moreover, how has this varied in the geological past and across different terrains? Under what circumstances could there be or have been substantial tidal dissipation in the rocky core?**
  - What is Enceladus' heat flow and how is that heat flow distributed? How is that heat flow stored (if it is) and transported?
  - How long can a liquid ocean exist on Enceladus?
  - How large are the tidal stresses, and how much tidal deformation occurs?
  - What is the nature of the tectonic features on Enceladus? Why do tectonic expression and patterns vary across the surface?
  - To what extent are the active tectonics on Enceladus a model for geologically recent tectonics on Europa and older tectonized terrains on Ganymede and other icy satellites?

# Enceladus Habitability

- **Is Enceladus habitable? What do the answers to the earlier questions imply for conditions in the geological past that may have been conducive to the origin and evolution of life.**
  - We know there is 'CHON,' but is there 'CHONPS' and are other elements bioavailable?
  - What energy sources are available for life?
  - What lessons from Enceladus apply to Europa, and visa versa?
  - Is there extant life on Enceladus?