Next Steps in Mars Polar Science:

In Situ Subsurface Exploration of the North Polar Layered Deposits

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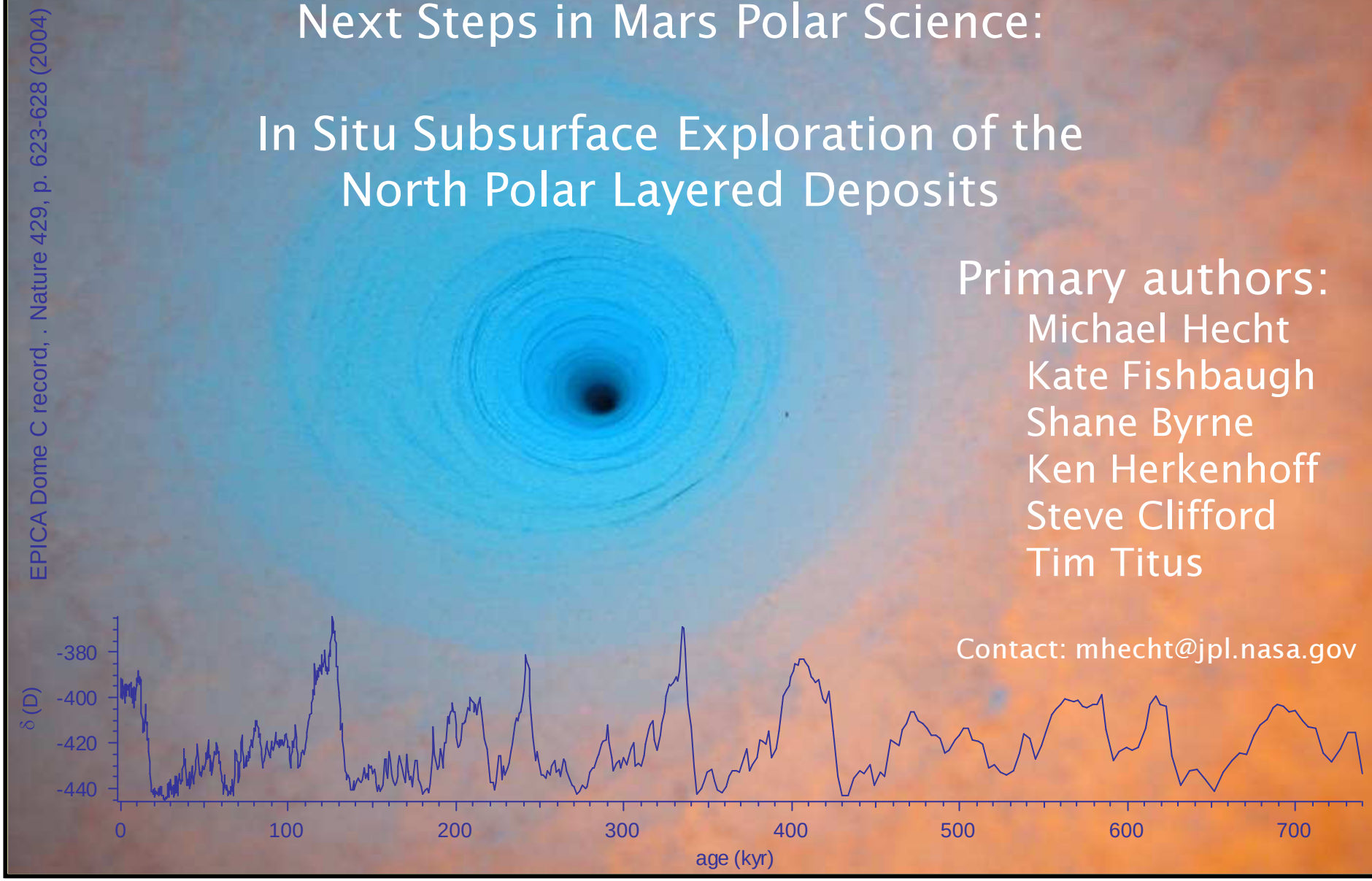

Key issues in Mars Polar Science*

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1. What is the mechanism of climate change on Mars? How has it shaped the planet, and how does it relate to climate change on Earth?
   - **Investigation:** Determine what seasonal and interannual variability, geologic history, and record of climatic change is expressed in the stratigraphy of Planum Boreum and Planum Australe
2. How do the PLD evolve, and how are they affected by planetary-scale cycles of water, dust, and CO_2?
   - **Investigation:** Determine the mass & energy budgets of the PLD, residual caps, and seasonal caps, and what controls these budgets on seasonal and longer timescales.
   - **Investigation:** Determine the physical characteristics of the polar layered deposits and residual caps.
3. What is the global history of ice on Mars? Where is it sequestered outside the polar regions, and what disequilibrium processes allow it to persist there?
   - **Investigation:** By comparing polar and non-polar ice, determine the relationship between the PLD and residual cap record and processes elsewhere on Mars.

**Synthesized from Mars Polar Science Conference 2006, reviews by Fishbaugh (2008), Clifford (2005), Titus (2008), Byrne (2009)*

Spatial structure of NPLD stratigraphy

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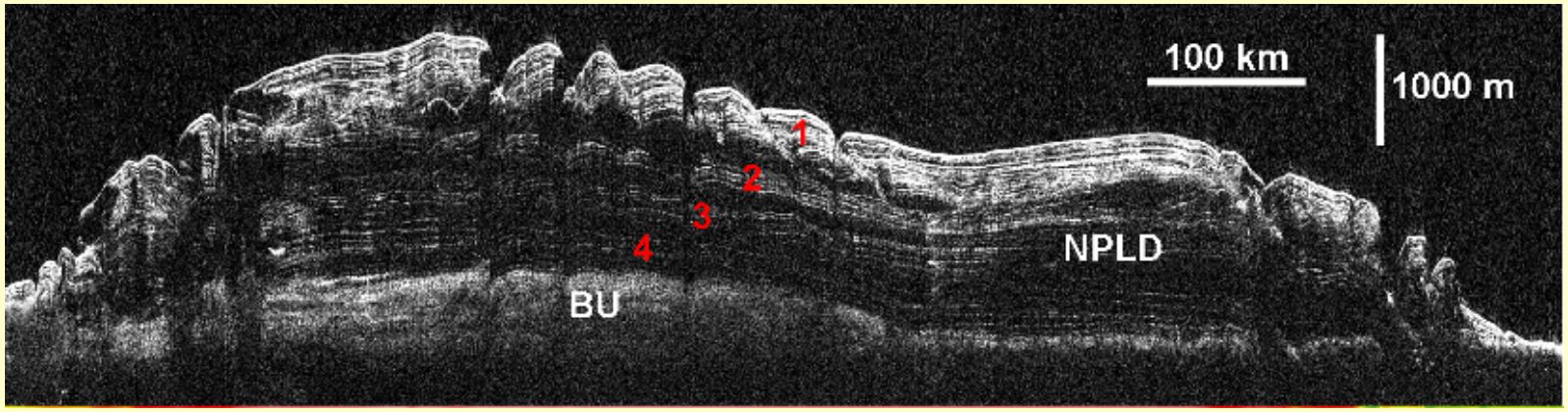
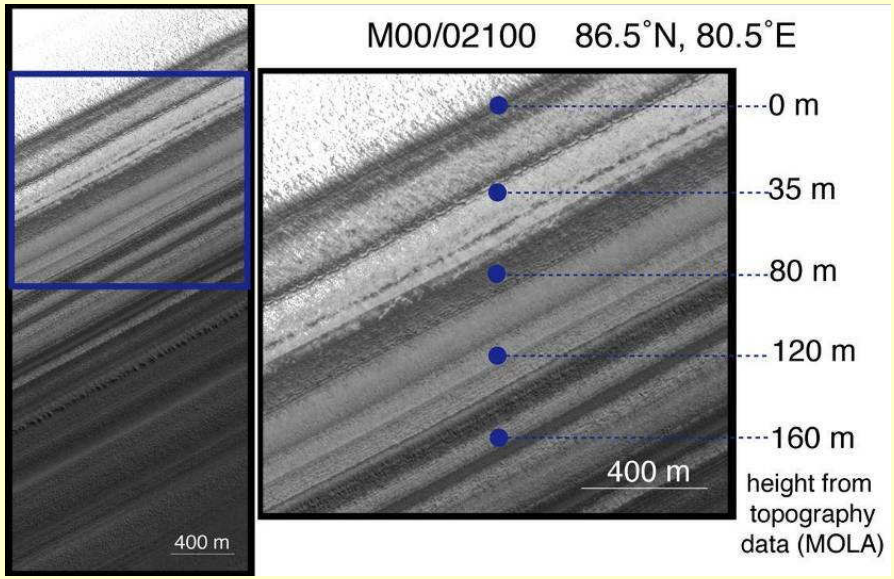


SHARAD profile (courtesy NASA/JPL/Caltech) of the major stratigraphy of the NPLD, indicating the lateral conformity (Phillips 2008).



A typical exposed section of NPLD topography indicating elevations (from MOLA). A study of 150 m of this column can be expected to transect diverse strata. A 50 m descent, while valuable, transects only a few strata and is not necessarily representative.

Orbital forcing and climate

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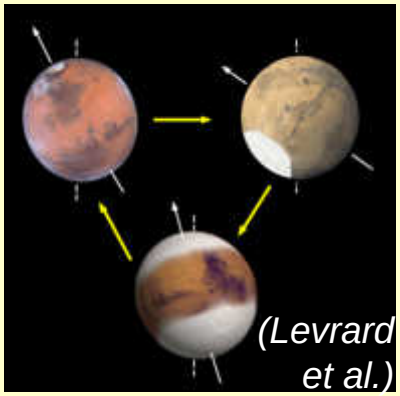
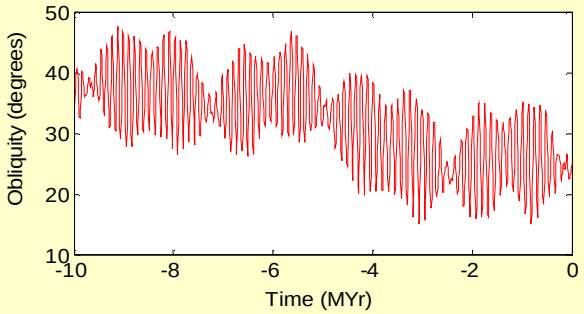
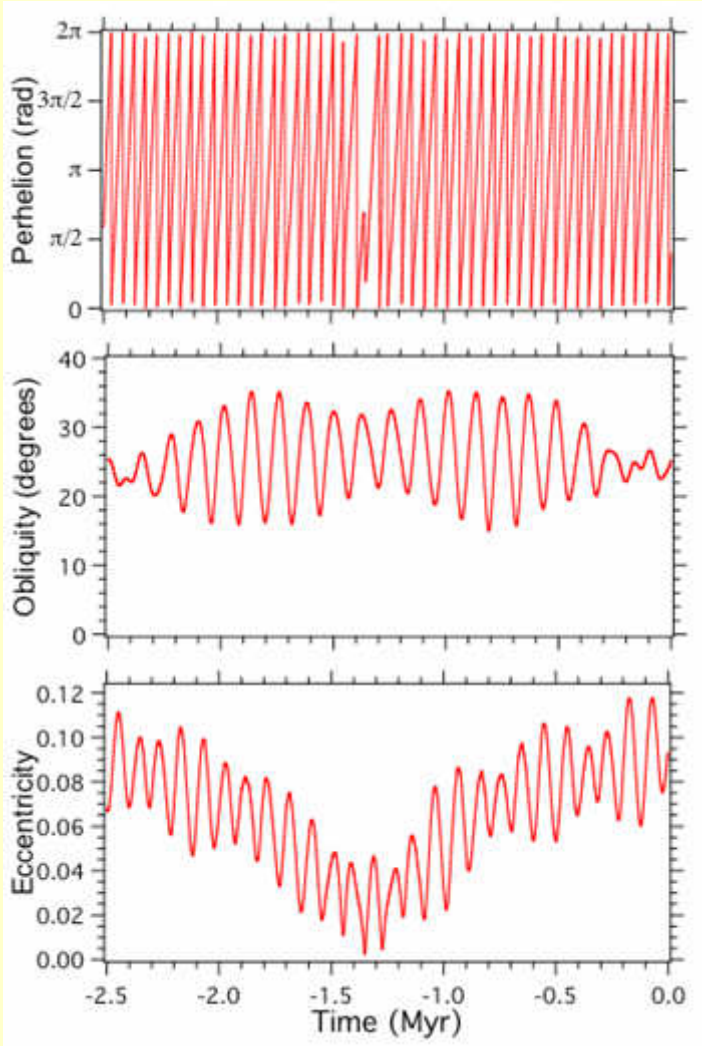




- Geological evidence suggests dramatic changes in martian climate over 10^4-10^7 years.
- The major cause of these changes is *believed to be* orbital variations (Milanković cycles)
- Milanković cycles have not yet been shown to correlate with stratigraphy



Orbital variations over 2.5 Myr (Laskar et al. 2004)

Suggested approach

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- Ongoing orbital program is bearing fruit and will continue to do so
- On Earth, we learn about past climates from physical and chemical properties of polar ice cores. Mars PLD likely harbors an analogous record. → ***In situ* investigation of PLD is needed.**
- Energy and mass balance investigations call for long-lived surface platform on PLD
- Opportunistic investigations from *in situ* platform
  - Extract a chronological record of biomarkers from the PLD.
  - Monitor planet-wide seismic activity and measure the geothermal constant from a polar subsurface platform

Approach to Chemical and Physical properties of strata

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- Exposed stratigraphy has been modified by current conditions, so subsurface access is needed.
- Two approaches have been suggested:
  - Deep thermal drilling from a stationary platform
  - Shallow drilling at numerous sites from a rover traverse
- RPS probably required for drilling, certainly for meteorology monitoring*
- Deep drill is Scout or New Frontiers class mission
- From MSL experience Rover w/ RPS is likely flagship

* Full spacecraft sterilization may be required for RPS near ice

Two popular drilling methods

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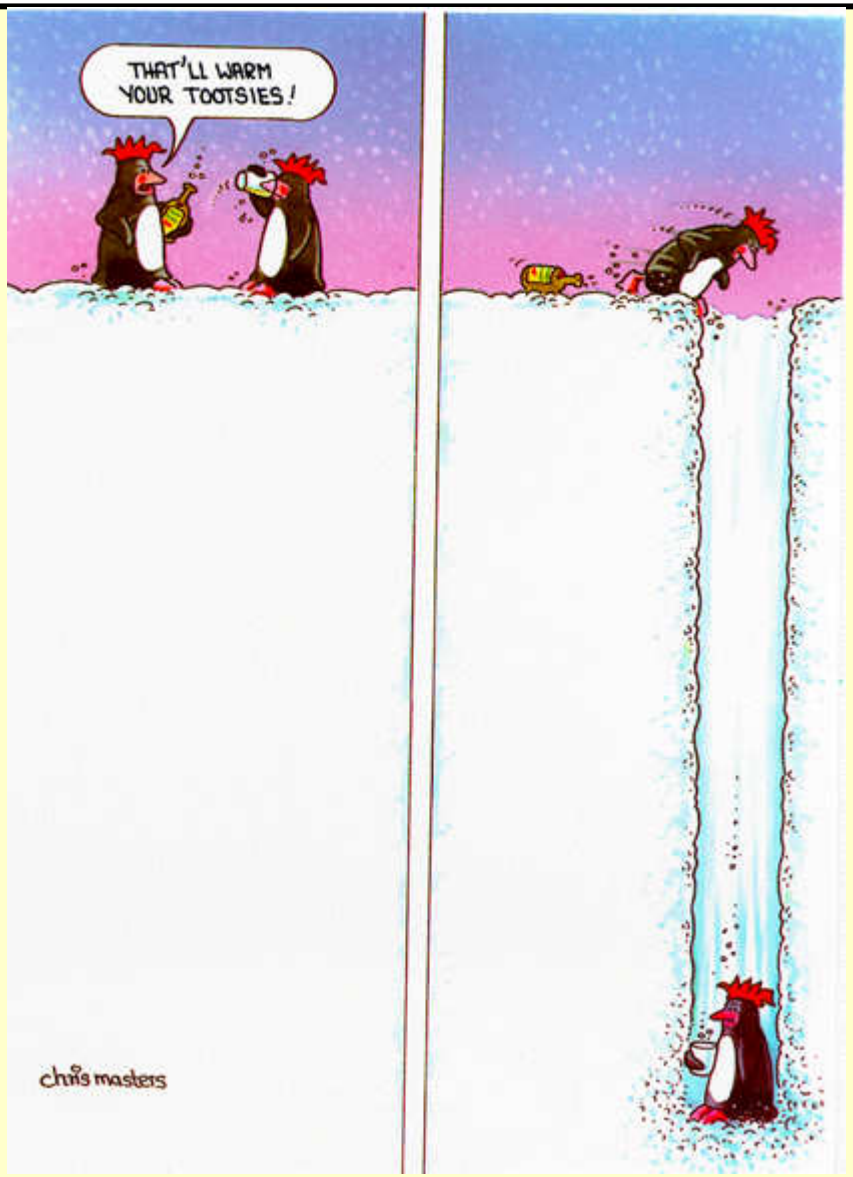

A 7 cm diameter thermal drill descends into the Greenland ice cap returning meltwater for analysis through an aerogel-insulated tether. In the final frame, the drill is 47 m below the surface (images from JPL).

Down-hole climate markers

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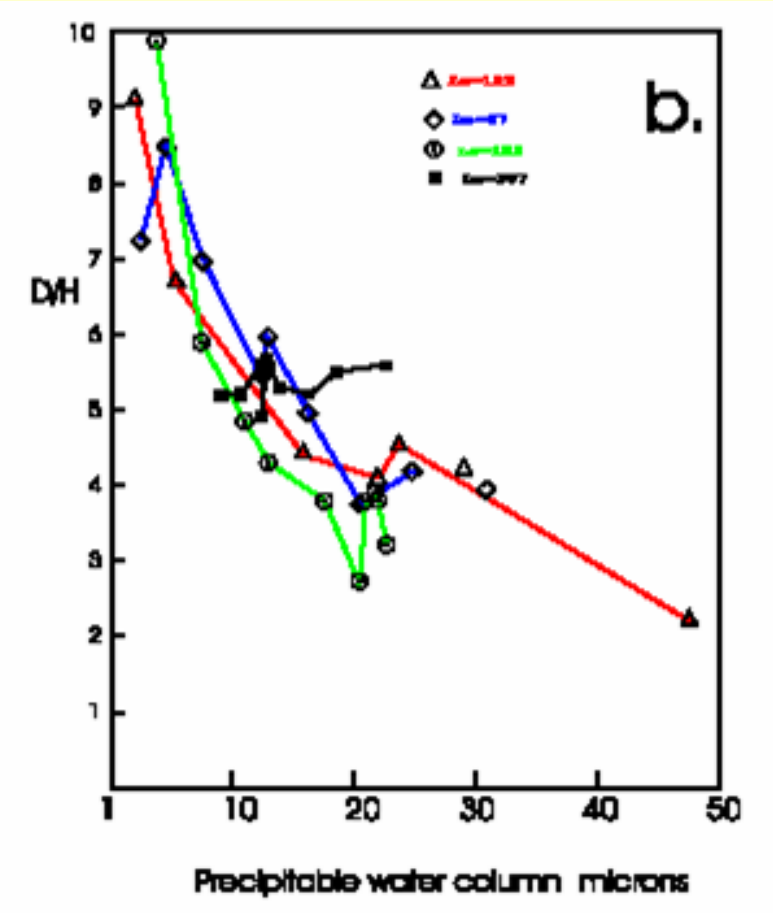
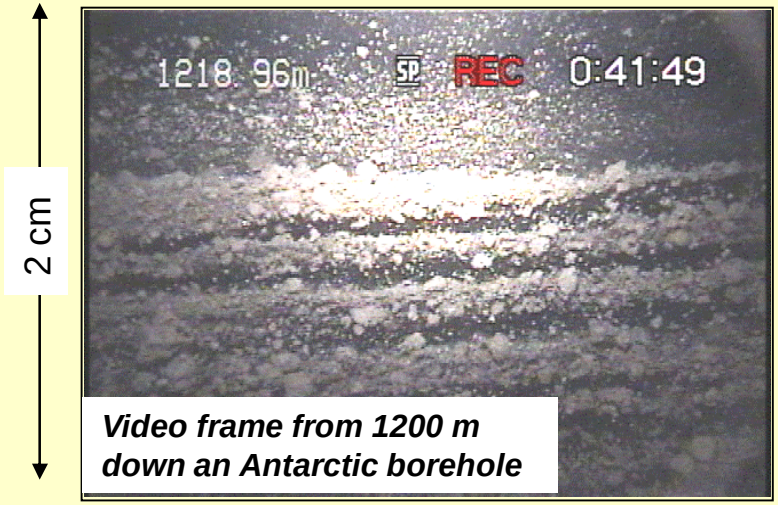
- Isotopic climate markers (D/H, $^{18}O/^{16}O$)
- Fine scale (annual?) stratigraphy
- Chemical (evaporitic, photochemical, or volcanic) markers





Video frame from 1200 m down an Antarctic borehole

D/H in martian atmosphere varies spatially and temporally (M. Mumma), and correlates with precipitable water column (D. Fisher)

Goals of PLD subsurface investigation

- Explore several layers of the stratigraphy visible from orbit.
- Analyze D/H and $^{18}O/^{16}O$ (depth resolution of ~1 cm is feasible)
- Visually measure dust concentration and ice structure (depth resolution of <1 mm is feasible)
- Measure soluble chemical species (depth resolution of ~1 cm is feasible)
- Monitor seasonal polar weather
- Opportunistic:
  - Trace organics (amines, etc.)
  - Geophysics probe (embed seismometer, heat flow sensors)

What to follow?

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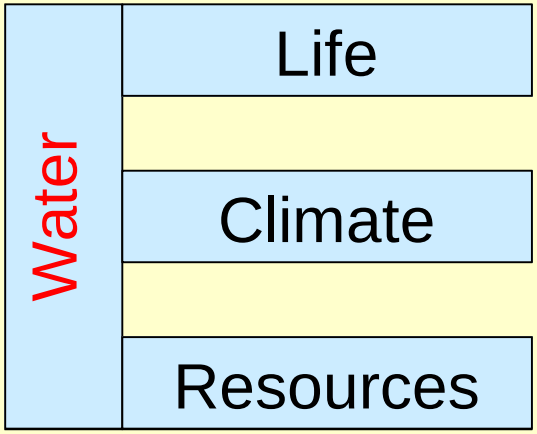
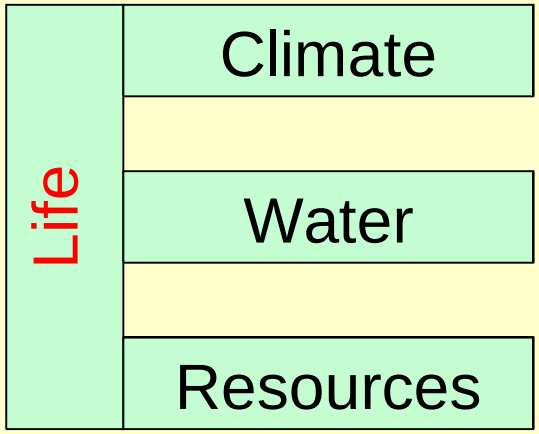
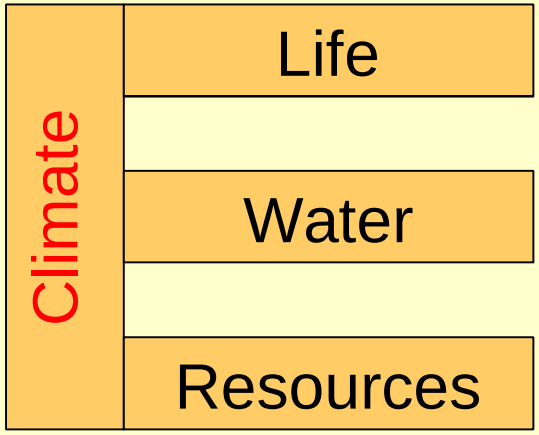


The Mantra



Earth?



Mars?

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