Ice and Climate Evolution Science Analysis Group (ICE-SAG)

Report to
Planetary Science & Astrobiology Decadal Survey, Mars Panel
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- Final Report available on the MEPAG Reports Page: https://mepag.jpl.nasa.gov/reports.cfm?expand=topical
- DS white paper summary: here

Image credit: NASA/JPL/Arizona State University, R. Luk

Context

- MEPAG Preparation for Planetary Science Decadal Survey
  - Identify high-priority science questions beyond* Mars Sample Return
  - Prioritize mission concepts for further study
    - Identify candidates for New Frontiers. Mars Polar Science and Network Science are both discussed in latest Decadal Survey.
    - Provide inputs to NASA Planetary Mission Concepts Studies
  - Provide a useful reference for community white papers

- Polar Science, Modern Mars, & Recent Climate are prominent
  - Polar Science community self-organization (meetings, reports, revision of 2018 MEPAG Goals, etc.)
  - MEPAG 36 Forum and Discussion (e.g., Jeff Johnson's presentation, Potential SAG topics – slides 15-17)
  - Decades of polar science have yet to realize a landed mission (Mars Polar Lander was lost, and Phoenix was not truly polar)

** Beyond MSR in scope, not necessarily in timing.*

ICE-SAG Charter: Guidelines

ICE-SAG was tasked with identifying:

- Compelling science objectives addressable within the decade 2023-2032, with traceability to the four MEPAG Science Goals concerning Life, Climate, Geoscience, and Preparation for Human Exploration
- Measurements required to address these objectives
  - Proof-of-concept techniques needed to make these measurements
  - Technology investments needed to develop the required techniques
- Mission approaches—orbiters, landers, drillers, rovers, networks—that address the science objectives and make the required measurements
  - Linkages between mission concepts & measurements/science objectives
  - Timing: which are needed before others, which are needed concurrently
  - Major technical challenges (e.g., operations in the polar night)
  - Classes: Small spacecraft, Discovery, New Frontiers, Flagship

Prioritize the New Frontiers and Flagship class missions for potential costing and technical evaluation (CATE) by NASA

Why Mars Climate & Ice Science is Compelling

Processes related to frost and atmosphere are the dominant forces shaping the surface during the Amazonian period. **Current ice deposits are the best record we have of "recent"* Mars climate conditions**, which have varied over both short and long (millions-of-years) timescales. At present, Mars science has identified:

- a variety of ice deposits and hypotheses for how they are shaped by the climate, but **we cannot yet read the history that they record**;
- a dynamic evolution of the surface by processes (some not yet understood), but **we cannot yet extrapolate their effects back in time with confidence.**

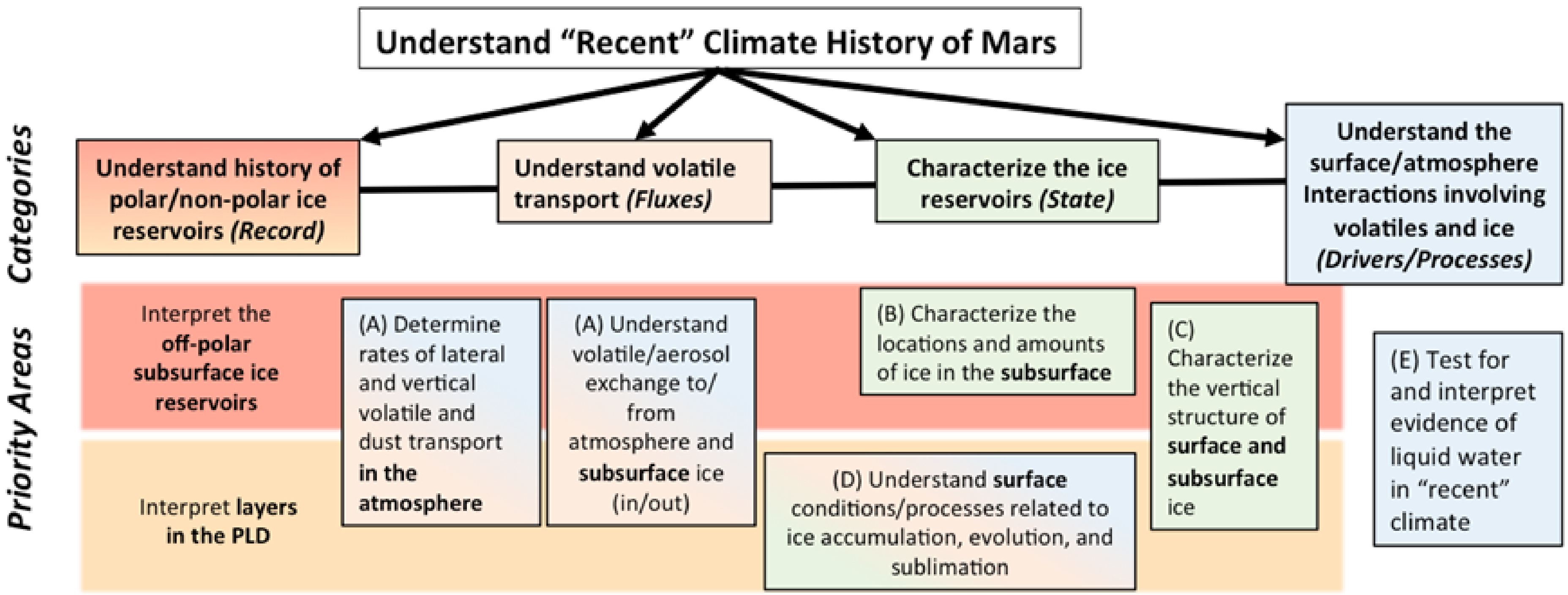
ICE-SAG mission concepts aim to yield dramatic improvements in our understanding of Mars' present and recent climate, which are key inputs for:

- understanding **environmental and process constraints** for investigations of Martian geologic history and habitability;
- developing use of **buried water ices as in situ resources** for human missions.

Additionally, the Martian climate system serves as a natural laboratory for a **broader understanding of planetary climate systems**, and as a second body for comparison with Earth systems, processes, and records over a range of scales.

** "Recent" is Amazonian climate periods potentially recorded in polar and non-polar icy layers.*

Compelling Science Objectives



The Priority Science Areas A-E trace into all four MEPAG Goals

- Predominantly they trace into Goals II (Climate) and III (Geology)
    - some tracing directly to objectives, sub-objectives, or investigations
- There are also connections to Goals I (Life) and IV (Preparation for Human Exploration), where they would constrain past or present habitability and enable identification of potential water sources

Mission Concepts

ICE-SAG discussed mission concepts addressing key questions over a broad range of mission sizes:

- We presented **five concepts in New Frontiers class** (<~$850M), with options to expand or contract into other classes
- Additional concepts likely fit within Discovery (<~$500M) or smaller mission classes
- Cost and technology development estimates for these concepts are rough, largely based on analogy with existing or heritage instruments and missions
- A few concepts were examined in slightly greater detail, via support from the Mars Program Office and JPL's Team X

Ordering of the mission concepts and the choice to explore some in greater detail do not represent a prioritization of the concepts.

We emphasize that the concepts explored demonstrate feasible ways to acquire needed measurements, but they are not necessarily the only ways to do so.

Mission Concepts

New Frontiers Cost-class Mission concepts:

NF1: A polar lander to investigate the upper 1 m or more of northern layered structure, incl. drill or geophysical sounder

NF2: A polar lander to make in situ observations of the seasonal frost layer, incl. met. station -- operations through polar night

NF3: An orbiter and small lander(s) to carry out meteorological monitoring from surface to 80 km over diurnal & annual cycles

NF4: A mid-latitude lander to investigate the vertical structure of buried water ice, including a drill and geophysical sounder

NF5: An orbiter to map the structure and activity of near-surface ices with InSAR and sounder, and spectral & thermal imagers

Mission Concepts

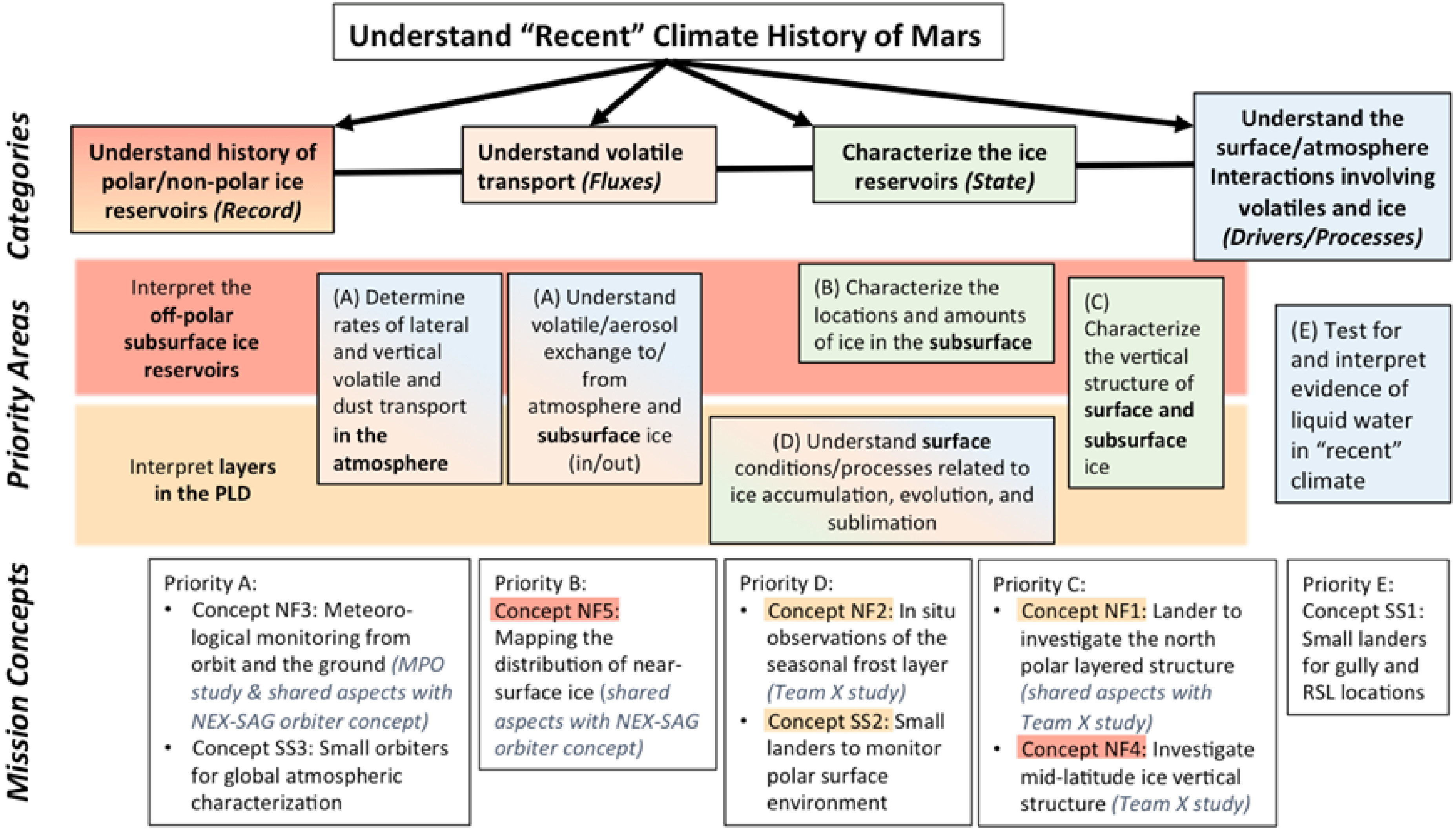
Flagship Cost-class mission concepts:

- Add-ons to New Frontiers list

Discovery Cost-class and smaller mission concepts:

- Descopes of New Frontiers list
- Small Spacecraft Landed mission concepts for Gully and RSL Locations (SS1 in report) and polar surface environment monitoring (SS2 in report)
- Small Spacecraft Orbiter mission concept for atmospheric characterization and monitoring, such as through radio occultations (SS3 in report)

Mission Concepts



Pre-decisional information, for planning and discussion only

NF2: A polar lander, ice-forming processes

- In situ measurements in polar region, for a full Mars year
- Monitor transport of volatiles, processes that happens within the atmosphere and surface through the polar night (including deposition, ice evolution, sublimation)
- *What atmospheric or climate cycle is represented by the smallest physical layer of the PLD? What processes can be recorded in a single PLD layer and what are the signals of these records? What atmospheric processes (mechanisms) control the deposition and removal of water ice on the PLD?*

- Meteorology station with temperature, pressure, and humidity sensors, including atmospheric LiDAR, looking up for clouds and winds monitoring
- Visible camera to watch the sky and landscape
- Bolometer to estimate the surface radiance
- Tunable laser spectrometer to look at atmosphere oxygen isotopes in H_2O and CO_2
- Microscope (VIS, NIR) to look closely at surface, measure ice/dust grain sizes and evaluate composition
- Thermogravimeter or quartz-crystal microbalance to determine frost/dust surface accumulation rates and what is accumulating/changing