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

Report to MEPAG at Virtual Meeting 4
February 25, 2019

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Credit: NASA/JPL/Arizona State University, R. Luk

Context

- MEPAG Preparation for Planetary Science Decadal Survey
  - Identify high-priority Mars science questions beyond* planning for Mars Sample Return
  - Prioritize mission concepts for further study
    - e.g., candidates for New Frontiers? Mars Polar Science and Network Science both discussed in last Decadal Survey
    - Potential inputs to NASA call for mission studies
  - Provide useful references 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 has yet to realize a landed mission (MPL lost, PHX not truly polar)

* Beyond *Mars Sample Return in scope, not necessarily in timing.*

ICE-SAG Charter: Guidelines

ICE-SAG is tasked with identifying:

- Compelling science objectives addressable within the decade 2023-2032, with traceability to MEPAG Science Goals (Life, Climate, Geoscience, Humans)
- 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 and 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

ICE-SAG Charter: Approach

ICE-SAG shall take into account the following:

- Recent discoveries relevant for studies of Martian volatiles and climate, such as those relating to the distribution of ice today and the processes that have produced that distribution in the late Amazonian period
- The updated MEPAG Goals Document, which reflects those discoveries
- The NEX-SAG report: Review science goals, measurement approaches, and proof-of-concept payloads and modify/focus as appropriate
- Inputs from recent conferences and workshops (see next slide)
- Expected contributions to volatile/climate science from missions (ODY, MEx, MRO, MSL, TGO, InSight, EMM Hope, etc.)

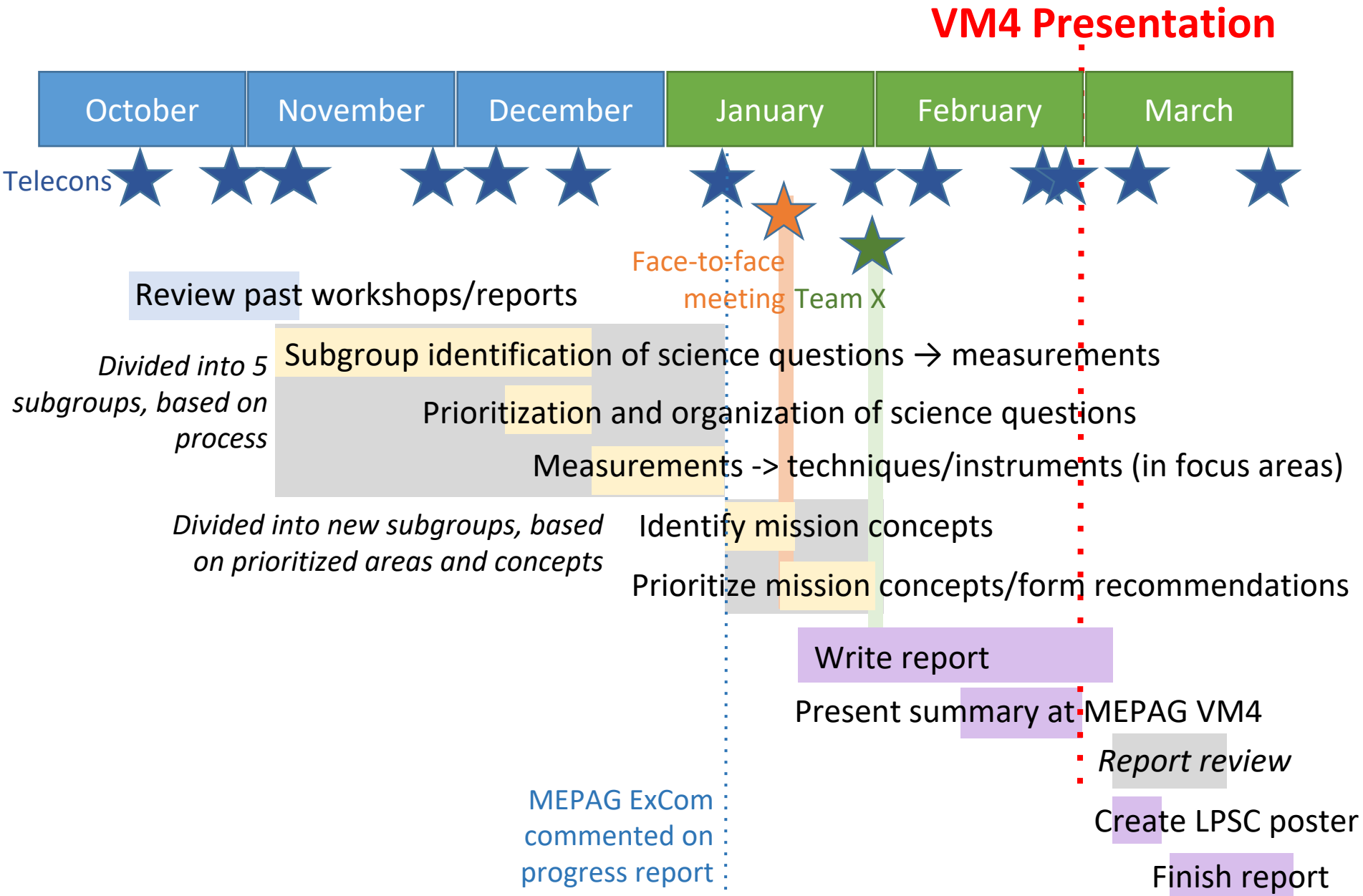
22 ICE-SAG Members

Than Putzig	**PSI**	**subsurface, thermal properties, resources**
Serina Diniega	**JPL**	**surface activity, geomorphology**
Shane Byrne	U Arizona	cap/plds
Wendy Calvin	U Nevada-Reno	cap/plds
Colin Dundas	USGS	subsurface ice, surface activity, geomorphology
Lori Fenton	SETI	aeolian, climate
Paul Hayne	U Colorado-Boulder	atmosphere
David Hollibaugh Baker	NASA-Goddard	subsurface ice
Jack Holt	U Arizona	subsurface ice
Christine Hvidberg	U Copenhagen	cap/pld, ice drilling
Melinda Kahre	NASA-Ames	climate modeling
Michael Mischna	JPL	climate modeling
Gareth Morgan	PSI	volcanism, periglacial, radar, field
Dorothy Oehler	PSI	astrobiology, resources
Anya Portyankina	U Colorado-Boulder	surface ice, CO_2 ice lab
Deanne Rogers	Stonybrook U	surface mineralogy
Hanna Sizemore	PSI	subsurface ice, volatile transfer in regolith lab
Isaac Smith	PSI and York U	pld, subsurface ice, climate
Alejandro Soto	SwRI	climate
Leslie Tamppari	JPL	atmosphere
Timothy Titus	USGS	climate, surface activity
Chris Webster	JPL	Martian isotopic records

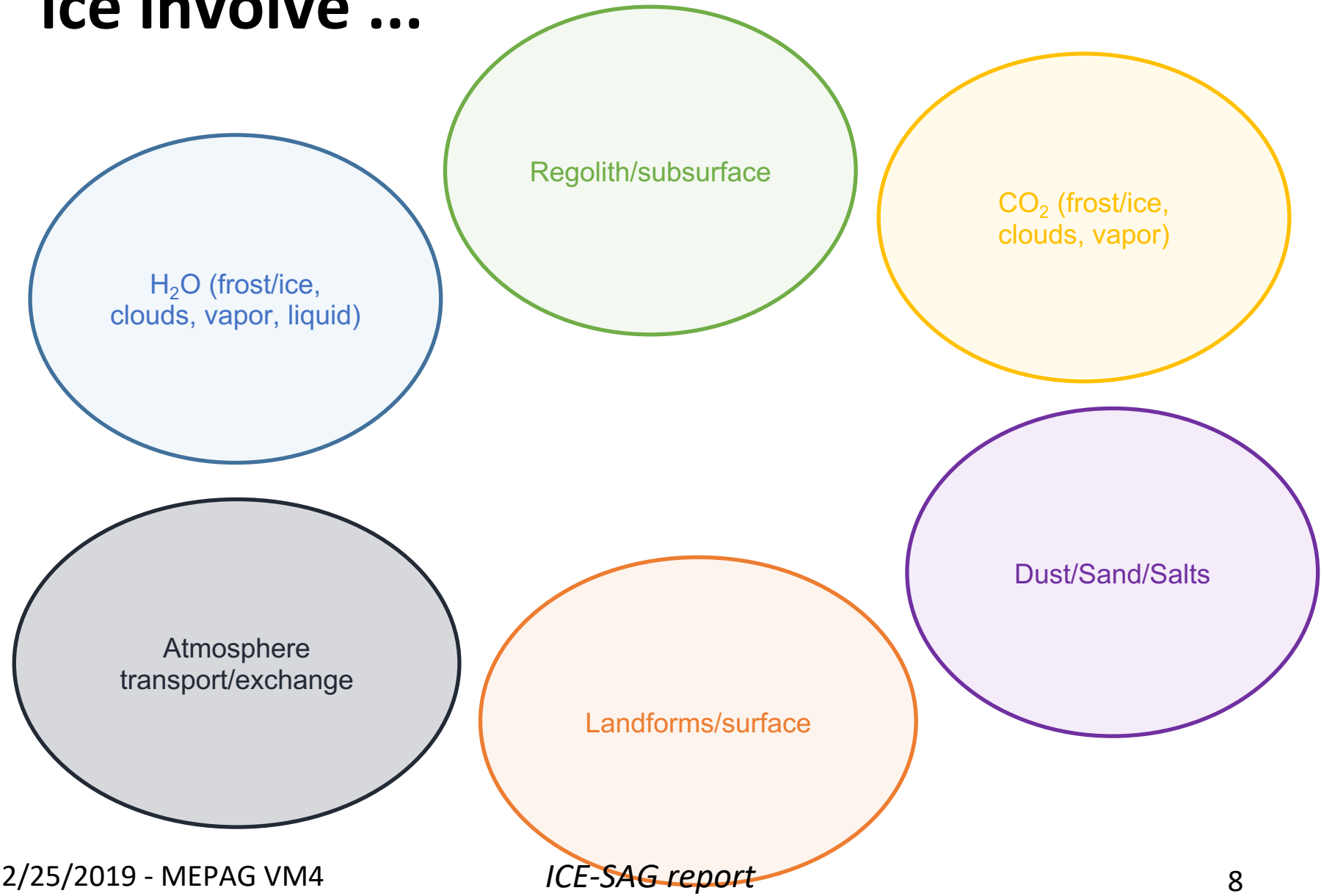
Study & Workshop Reports, Past/Planned Subject Matter Expert Presentations

NAME	INSTITUTION	TOPIC
Rich Zurek & Bruce Campbell	JPL & Smithsonian	NEX-SAG report
Portyankina/Dundas/Mischna/Oehler*		Late Mars workshop
Isaac Smith	PSI and York U	Mars Polar Science conference Amazonian Climate workshop
Vlada Stamenkovic	JPL	KISS MarsX Subsurface workshop
Hayne, Byrne, Smith*		KISS North Polar Science workshop
Kris Zacny	Honeybee Robotics	Subsurface access concepts
Tyler Jones	UC Colorado	Terrestrial isotopic records in ice
Franck Montmessin	LATMOS, IPSL	Martian isotopic records in atmosphere/ice
Jen Eigenbrode	NASA Ames	Astrobiology investigations in ice
Lisa Pratt & Andy Spry	NASA PP Office	Planetary Protections concerns
Don Banfield & Chris Eckert	Cornell U & MIT	Wind-generated power concept
Don Banfield	Cornell U	InSight meteorological measurements
Mike Hecht	MIT	Heated drill concept
Ryan Stephan	NASA PESTO	Planned NASA technology development

*Presentation by ICE-SAG members


VM4 Presentation
October
November
December
January
February
March
Telecons
Face-to-face meeting
Team X
Review past workshops/reports
Divided into 5 subgroups, based on process
Subgroup identification of science questions → measurements
Prioritization and organization of science questions
Measurements -> techniques/instruments (in focus areas)
Divided into new subgroups, based on prioritized areas and concepts
Identify mission concepts
Prioritize mission concepts/form recommendations
Write report
Present summary at MEPAG VM4
Report review
Create LPSC poster
Finish report
MEPAG ExCom commented on progress report

Questions relating to Martian climate and ice involve …



Top questions that came up … (Slide 1 of 2)

Overarching

- How is the current state of the surface and subsurface ices (including ices in the permanent caps) connected to the observable past records?

1) Ice layer (e.g., in PLD) formation processes

- How many layers are present in the PLD? What are their thicknesses and compositions, i.e., can we inventory the record?
- What is the vertical structure of icy materials: depth to ice, ice content/layering, and properties of embedded lithic material?
- Do internal layers in CO_2 deposits represent sublimation lags of water ice or are they deposits formed during CO_2-accumulation hiatuses? What climatic inferences can we draw from their presence?
- What processes make a layer?

2) Vertical structure within perennial ice deposits

- What are the distribution and material properties of internal layers within the CO_2 deposits?
- How much interaction does mid-latitude ice have with the atmosphere, and by what mechanisms?
- How does subsurface ice affect landform development?

Colors correspond to our different subgroups: Climate record in polar perennial ice, Mars' thermal and energy budget, Subsurface ice and methane, Surface activity, role of volatiles, surface-atmos exchange, Atmospheric state and cycles

Top questions that came up … (Slide 2 of 2)

3) Global distribution of perennial subsurface ice

- What is the current distribution and state of sub-surface H_2O and CO_2 ices?
- What is the spatial distribution of ice planet-wide?

4) Evidence of/record left by liquid water on Mars (within "recent" climate)

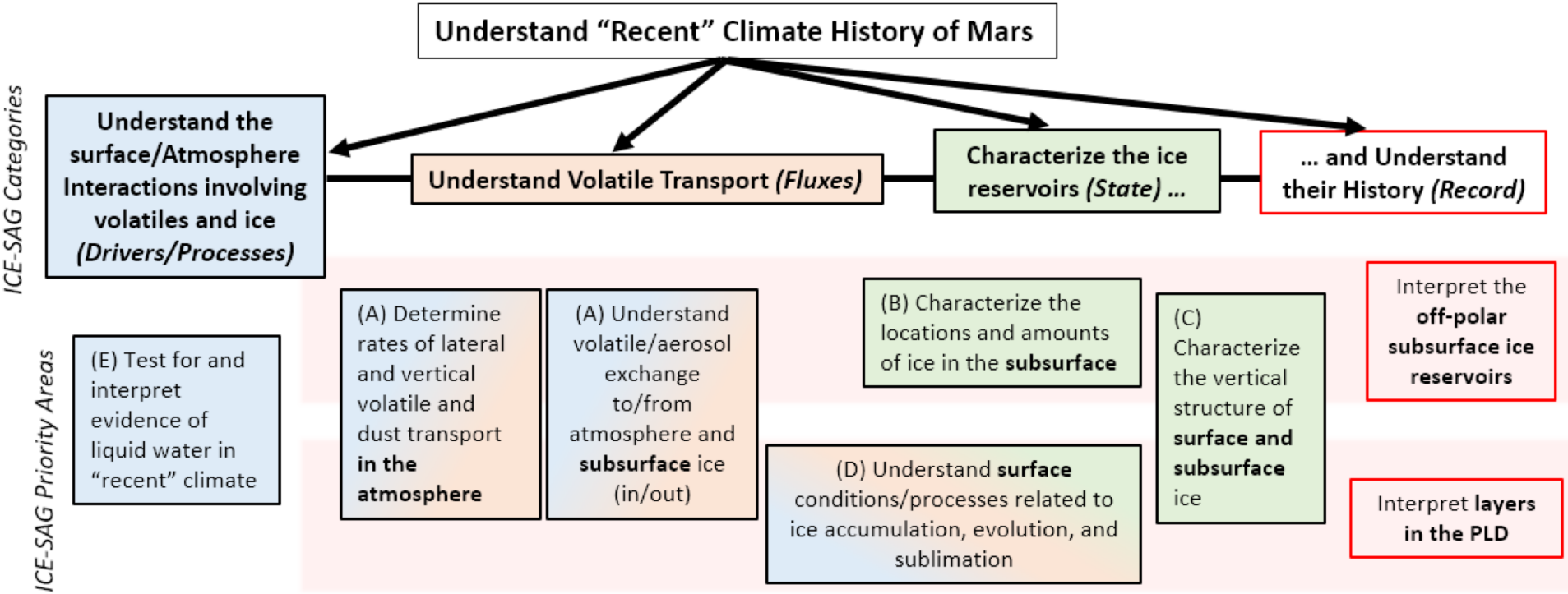
- Do any aspects of landforms or ice stratigraphy indicate melting in the recent past?
- Are liquid H_2O-bearing phases occurring at or near the surface, or in recent past?

5) Transport of volatiles and dust to/from the poles

- What are rates of deposition and removal of ice and dust on the NPRC and SPLD in the current climate? What is the geographic variability of such?
- What is the present day H_2O and CO_2 mass fluxes from/to the polar caps?
- Is mass currently being lost or gained from PLDs?
- What is the current annual net (global-scale) transport of volatiles, including H_2O and CO_2, and dust from/to polar and non-polar ice reservoirs?
- What factors control the current mass balance of the surface H_2O and CO_2 ices?
- What controls the vertical movement (i.e., surface/atmosphere exchange, deposition, abrasion, sublimation, and mixing) of volatiles and dust from the boundary layer to the top of the atmosphere in both polar and non-polar regions with ice deposits?
- How do diurnal, seasonal, and multi-annual atmospheric cycles affect and/or control the distribution of ice in the atmosphere and on the surface?

Colors correspond to our different subgroups: Climate record in polar perennial ice, Mars' thermal and energy budget, Subsurface ice and methane, Surface activity, role of volatiles, surface-atmos exchange, Atmospheric state and cycles

Compelling Science Objectives



- We started by listing important ice and "recent" climate science questions (and associated measurements), spanning all areas.
  - The Categories helped us to organize these questions.
- We then identified the highest-priority areas feasible to address in the next decade:
  - Topics that consistently came up in discussions became our Priority Areas.
  - Our mission concepts relate to these areas.

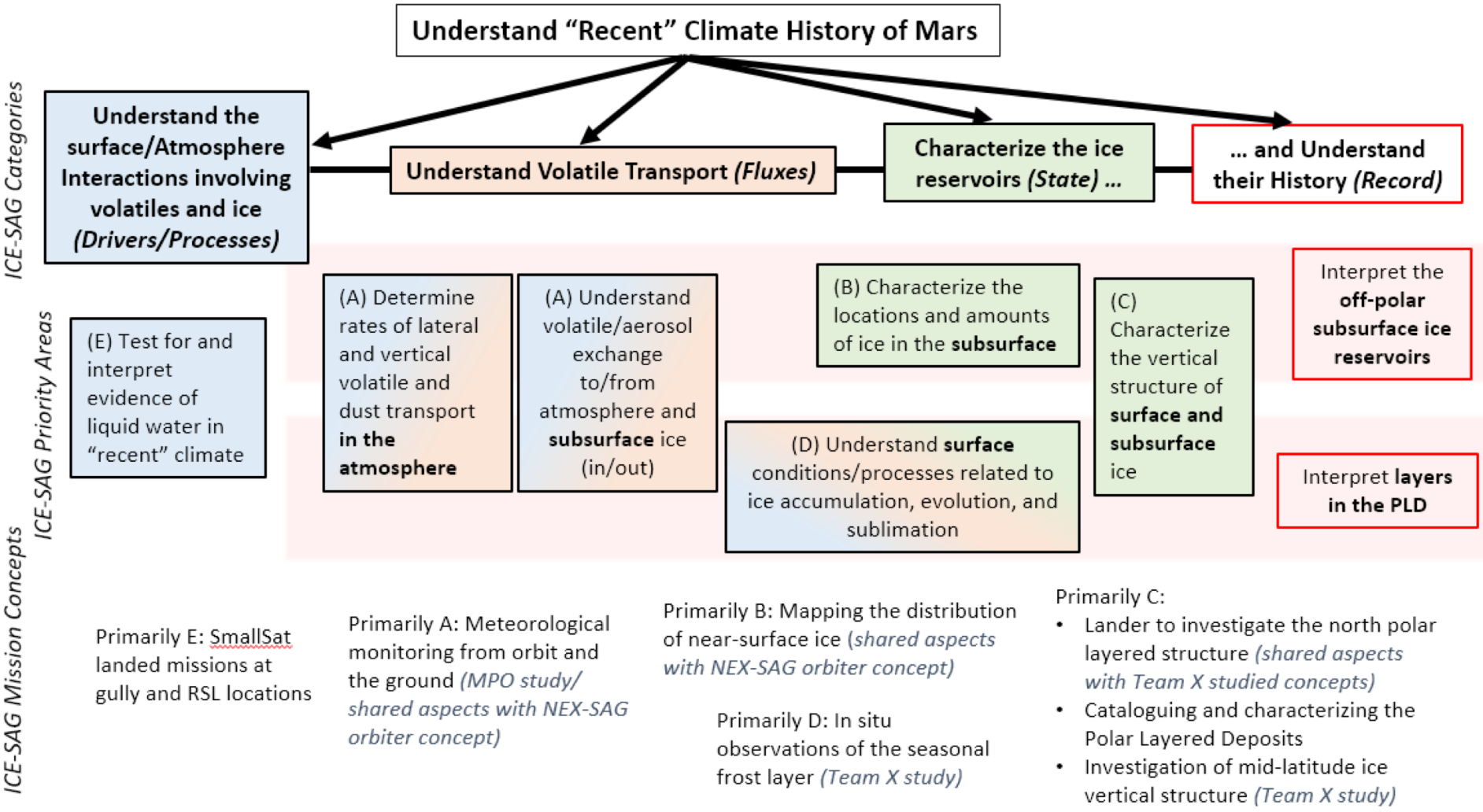
Mission Concepts

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

- We present six 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 and are 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.

Mission Concepts



Mission Concepts

New Frontiers Class:

1. Investigate polar layered structure and formation
   - Lander with atmos. + material properties instruments; drill or geophys. sounding
2. Assess deposition & sublimation of seasonal polar frost layer
   - Lander instrumented for monitoring atmos. + surface conditions through polar night
3. Measure key atmospheric parameters from surface to 80 km
   - Orbiter + lander(s) for meteorological monitoring over annual, diurnal cycles
4. Catalog and characterize the north polar layered deposits
   - Rover mission to traverse and sample layered deposits in a trough
5. Investigate mid-latitude ice vertical structure & exchange
   - Lander w/ atmos. + material prop. instruments; drill and geophys. sounding
6. Map global near-surface ice, stratigraphy, changes
   - Orbiter with InSAR, radar sounder, spectral and thermal imagers

Pre-Decisional Information – For Planning and Discussion Purposes Only

Mission Concepts

Flagship Class:

- Add-ons to New Frontiers list

Smaller Mission Classes:

- Descopes of New Frontiers list
- SmallSat Landed Missions for Gully and RSL Locations

Table of Contents (Current DRAFT)

1 Purpose and structure of ICE-SAG

2 Current state of knowledge

2.1 "Recent" Climate Record: Ice Reservoirs

2.1.1 Residual Caps and Polar Layered Deposits (PLD)

2.1.2 Sub-PLD ice deposits

2.1.3 Off-polar subsurface ice deposits

2.2 Volatile Exchange with other Reservoirs and their relation to the Climate Record

2.2.1 Atmospheric volatile history

2.2.2 H_2O exchange with the regolith and liquid water activity

2.2.3 Methane

2.3 Atmosphere State and Dynamics

2.3.1 Atmospheric circulation

2.3.2 Present key atmosphere constituents

2.4 Surface Environment and Processes

2.4.1 Boundary layer meteorology

2.4.2 Seasonal frost

2.4.3 Surface activity

3 Compelling Ice and Climate Science Questions

3.1 The Types of Questions We Explored

3.2 High-priority Areas

3.2.1 (A) Transport of volatiles and dust into and out of ice reservoirs

3.2.2 (B) Global distribution and volume of subsurface ice

3.2.3 (C) Vertical structure within ice reservoirs

3.2.4 (D) Formation conditions and processes for ice reservoir layers

3.2.5 (E) Evidence of potential liquid water

3.3 Relationship of High-priority Areas to Astrobiology

3.4 Relationship of High-priority Areas to Human Exploration Interests

3.5 Tracing to MEPAG Goals

4 Needed Measurements and Some Ways to Acquire Them

5 Sample Mission Concepts to Address Key Ice and Climate Science Questions

5.1 Investigate the north polar layered structure

5.2 In situ observations of the seasonal frost layer

5.3 Meteorological monitoring from orbit and the ground

5.4 Cataloguing and characterizing the Polar Layered Deposits

5.5 Investigation of mid-latitude ice vertical structure

5.6 Mapping the distribution of near-surface ice

5.7 SmallSat landed missions at gully and RSL locations

6 Key challenges and constraints on Ice and Climate focused Mars missions

6.1 Surviving the polar night in polar regions

6.2 Surviving polar night in mid-latitudes

6.3 Contamination concerns

6.4 Access to poles during specific times of year

6.5 Drilling technologies

6.6 Access to surface with small spacecraft

7 Key areas of enabling or enhancing laboratory/modeling studies

7.1 CO_2 frost evolution

7.2 Water transfer through and into regolith, water interaction with regolith

7.3 Material properties of mixtures (of regolith, dust, volatiles, etc.)

7.4 Radiative balance, including clouds/dust

7.5 Field analog work to support investigation of Martian ice layers

8 Conclusions

Draft Draft Draft Draft

Key points we will make in the report

- We identified high-priority Mars ice and climate science questions
  - **Because of recent science discoveries and technology development, many of these questions are well defined and addressing them is timely**
  - **Connection to astrobiology and human exploration interests**
- These questions can be addressed through mission concepts that are feasible over the next decade
  - **Compelling concepts exist in all mission classes and types**
  - **Some key ideas would be best/only approached through missions larger than Discovery class**
  - **Such missions would fill existing key observation gaps (such as global/surface winds and what happens in polar night)**
- Specific technology development and laboratory/modeling studies could strategically enable more efficient acquisition of key science

Want to find out more?
LPSC Abs. 2035 - Putzig et al.
Tuesday night Poster 679

And the final report will be published on the MEPAG Reports page … check there in early April.