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

Report to MEPAG
Virtual Meeting 5, 2019 June 6

SAG Co-chairs:
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SAG members:
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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 [--> ROSES NRA]
  - Provide 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 (MPL lost, PHX not truly polar)

* *Beyond planning for Mars Sample Return 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 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 & 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 was asked to 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
- Expected contributions to volatile/climate science from missions (ODY, MEx, MRO, MSL, TGO, InSight, EMM Hope, etc.)

Updates since VM4 Presentation

- Sent draft report to reviewers on March 16
- Presented poster at LPSC (Ab. 2035)
- Received comments from 17 reviewers through April 11
  - These were extensive and very helpful!
- Updated report based on community questions/comments and reviewer critiques
- Submitted Pre-print version to MEPAG ExCom May 21
  - Publically released Pre-print on May 28

Why Mars Climate & Ice Science is Compelling

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

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

The investigations described and prioritized by ICE-SAG aim to yield dramatic improvements in our understanding of the present and recent climate Mars, which are key inputs for:

- understanding **environmental and process constraints** for investigations of Martian geologic history and habitability,
- developing ways to use **buried water ices as in situ resources** for future 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.

ICE-SAG Report Aim & Scope

Based on our chartered tasks, we focused on:

- science questions that have been prompted or refined by recent new discoveries,
- science questions that require the acquisition of new data,
- mission concepts that could achieve compelling Mars climate and ice science within NASA's New Frontiers cost-class (<$850M), and
- prioritizing the science questions and measurements, then focusing only on those mission concepts that addressed high-priority science questions and measurements.

ICE-SAG Priority Science Areas

The ICE-SAG scope was very broad and we defined MANY relevant science questions worthy of investigation … but these 5 areas kept rising in discussions about where the biggest advancements could be made:

A. Transport of volatiles and dust into and out of ice reservoirs

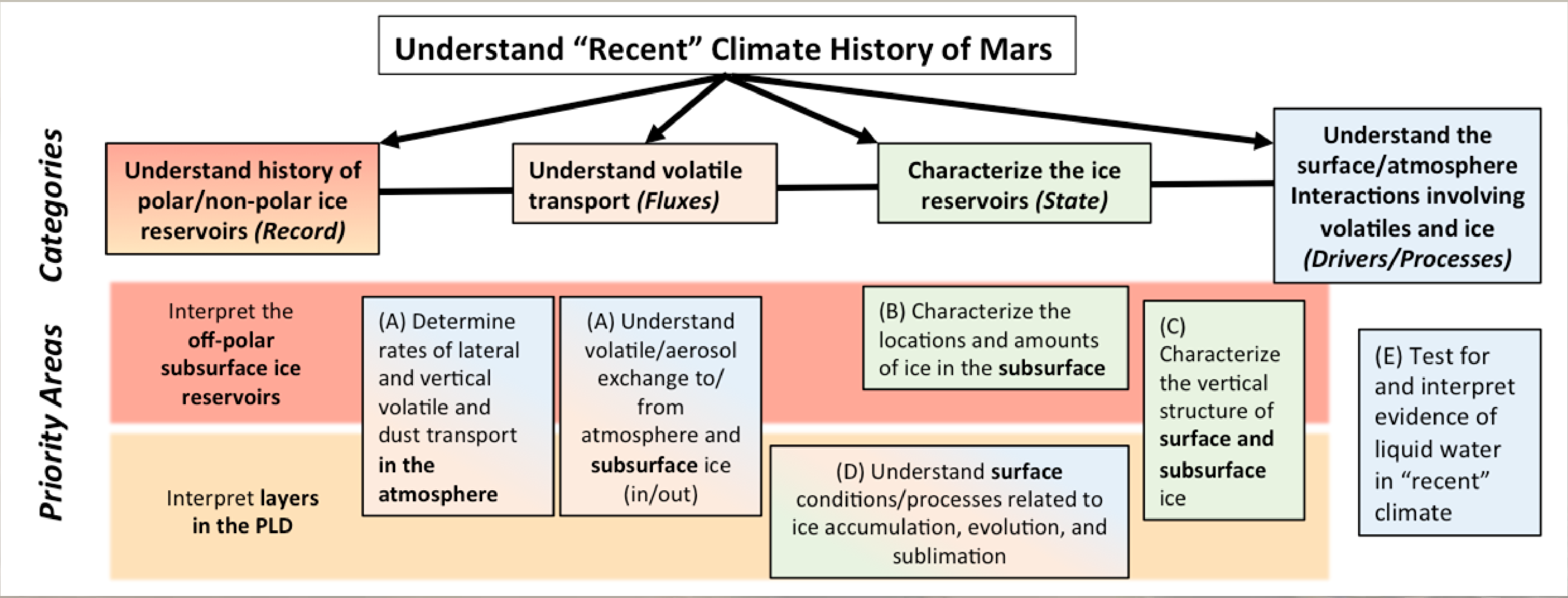
B. Global distribution and volume of subsurface ice

C. Vertical structure within ice reservoirs

D. Formation conditions and processes for ice reservoir layers

E. Potential evidence of liquid water

Compelling Science Objectives



The Priority Science Areas traced into all four MEPAG Goals

- of course mostly into Goals II (Climate) and III (Geology)
  - with some tracing very directly to objectives, sub-objectives, or investigations
- there's also connections to Goals I (Life) and IV (Preparation for Human Exploration), with regards to constraining past or present habitability and finding potential water sources

ICE-SAG Top Questions (21 total)

A. Transport of volatiles and dust into and out of ice reservoirs

Q1: How does the atmosphere control the exchange of ice and dust between ice reservoirs, within global-scale horizontal and vertical transport?

Q4: What is the current annual net (global-scale) mass flux transport of volatiles, including H_2O and CO_2, and dust from/to polar and non-polar ice reservoirs?

Q6: What are rates of deposition and removal of ice and dust on the residual caps in the current climate?

B. Global distribution and volume of subsurface ice

Q8: Where does subsurface water ice presently exist, and at what depth?

Q9: What is the volume and purity of water ice present in the non-polar ice reservoirs?

C. Vertical structure within ice reservoirs

Q16: What are the physical, chemical, and isotopic nature of constituents that may be present in the layered ice on Mars, that reflect a climate record?

D. Formation conditions and processes for ice reservoir layers

Q19: What processes, including sublimation and deposition of ice and other materials, make and modify a layer?

E. Potential evidence of liquid water

(Q20: Which surface features may be formed or modified by the flow of relatively large amounts of liquid water?)

ICE-SAG Top Measurements (22 total)

A. Transport of volatiles and dust into and out of ice reservoirs

M1: Wind velocities, global-scale and including within boundary layer

M2: Water mixing ratio, dust concentration, temperature, and pressure, at a global-scale and including within boundary layer

B. Global distribution and volume of subsurface ice

M6: High-resolution, regional-to-global mapping of near-surface structure

C. Vertical structure within ice reservoirs

M12: Characterization of layered material (physical, chemical, isotopic, density, etc.), as a function of depth and correlated with specific layers, at centimeter-resolution and precision, in the polar deposits

D. Formation conditions and processes for ice reservoir layers

M16: Meteorological conditions (i.e, surface temperature, pressure, absolute humidity, winds, etc.) above an icy layer, through a full Mars year

E. Potential evidence of liquid water

(M20: High frequency and high resolution monitoring (from ground) of present-day activity and the local environment)

Mission Concepts

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

- We present **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 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

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 geophys. 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 annual, diurnal cycles

NF4: A mid-latitude lander to investigate vertical structure of buried water ice, incl. a drill and geophys. sounder

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

Mission Concepts

Flagship Cost-class mission concepts:

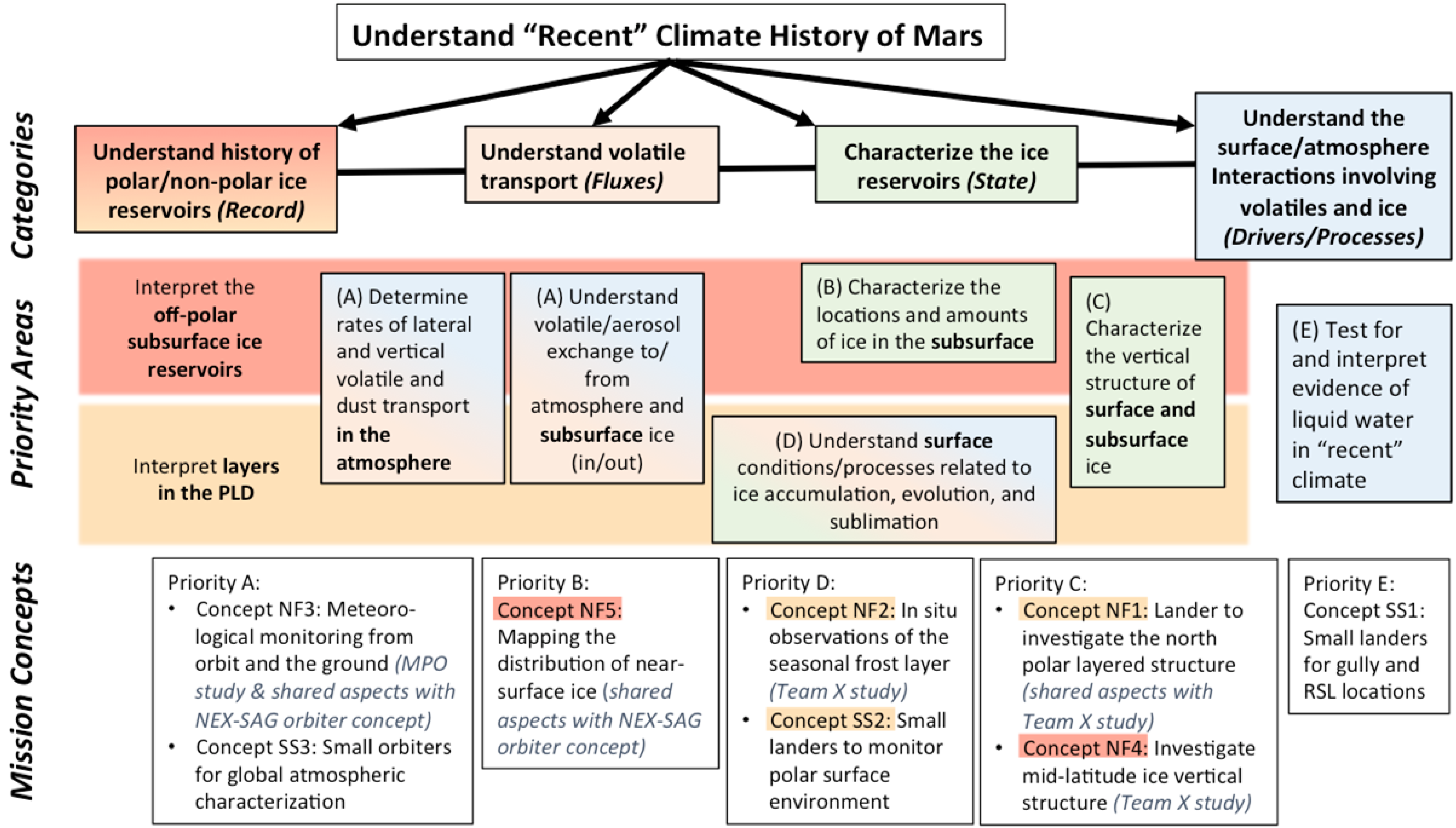
- Add-ons to New Frontiers list

Smaller Mission Classes mission concepts:

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

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

Mission Concepts



Tracing Concepts to High Priority Questions

QUESTIONS	NF1	NF2	NF3	NF4	NF5	SS1	SS2	SS3
Priority Area A: atmos transport of materials	x	x	x	x	x		x	x
Q1: atmos controlled exchange, global/vert	x		x	x				x
Q4: mass flux volatiles	x	x	x	x	x			x
Q6: rates ice/dust on res caps	x	x	x				x	
Priority Area B: distr/volume of water ice	x			x	x			
Q8: subsurf water ice location/depth				x	x			
Q9: subsurf water ice volume/purity					x			
Priority Area C: vert structure ice reservoirs	x			x	x			
Q16: constituents in layered ice	x							
Priority Area D: surface activity and conditions	x	x					x	
Q19: layer formation processes	x	x					x	
Priority Area E: evidence of liquid water				x	x	x		

Tracing Concepts to High Priority Measurements

MEASUREMENTS	NF1	NF2	NF3	NF4	NF5	SS1	SS2	SS3
Priority Area A: atmos transport of materials	x	x	x	x			x	x
M1: wind global/PBL			x					
M2: water, dust, temp, pressure global/PBL			x					x
Priority Area B: distr/volume of water ice				x	x			
M6: map global near-surf structure					x			
Priority Area C: vert structure ice reservoirs	x			x	x			
M12: characterize layered material	x			x				
Priority Area D: surface activity and conditions	x	x					x	
M16: surface met conditions	x	x					x	
Priority Area E: evidence of liquid water				x	x	x		

Pre-decisional information, for planning and discussion only

Key points made 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 will greatly advance Mars science
  - Connection to astrobiology and human exploration interests, as well as high-priority planetary science questions
- 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)
  - 5 NF cost-class and 3 small spacecraft concepts are identified
- Specific technology development and laboratory/modeling studies could strategically enable more efficient acquisition of key science

See the Report

- Pre-print of our Final Report now available on the MEPAG Reports Page: https://mepag.jpl.nasa.gov/reports.cfm?expand=topical
- Final version expected ~end of June
  - will finish cleanup of e.g., references
  - will fix links
  - need to add Appendix C
- Supplemental Materials outlines the concept studies undertaken for ICE-SAG
  - Includes exploration of technical challenges and some architectural trades
  - Note that studied concepts do not map directly to ICE-SAG concepts -- studied concepts were chosen to explore specific trade space areas and do not reflect prioritization of the investigation or any specific implementation.

Additional Information

- Team Member Affiliations and Expertise
- Study/Workshop & Subject Matter Expert Presentations
- ICE-SAG work Timeline

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 and 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	U Colorado-Boulder	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

ICE-SAG Timeline