

# Europa Clipper: Update to CAPS

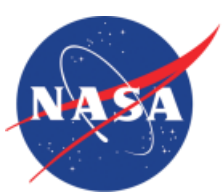
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**Bob Pappalardo and Dave Senske**

*Jet Propulsion Laboratory, California Institute of Technology*

**Sept. 12, 2017**

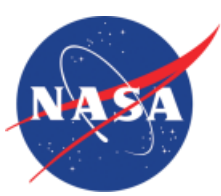


# Overview

- PSG #5 Recap
- Project-Level Schedule
- PDR Schedule
- Tour Update
- Instruments & Spacecraft
- Prototype Hardware
- Science Traceability and Alignment Framework







# 'Tis the Season for Preliminary Design Reviews (PDRs)

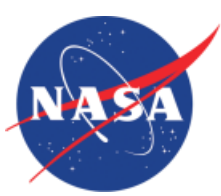
- **Propulsion Subsystem** 6/27-29/17 (Goddard)
- **Propulsion Module** 7/24-27/17 (APL)
- **Flight System** 10/17-20/17 (JPL)
- **Europa-UVS** 11/16-17/17 (SWRI)
- **PIMS** 12/6-7/17 (APL)
- **REASON** 12/11-12/17 (JPL)
- **EIS** 1/9-11/18 (APL)
- **SUDA** 1/17-18/18 (Univ. Colorado)
- **Solar Array** 1/22-23/18 (APL)
- **Power** 1/24-25/18 (JPL)
- **E-THEMIS** 1/30-31/18 (ASU)
- **ICEMAG** 2/14-15/18 (JPL)
- **Guidance, Navigation & Control** 2/7-8/18 (JPL)
- **Mechanical** 2/12-15/18 (JPL)
- **Thermal** 2/15-16/18 (JPL)
- **Radio Frequency Module / Telecom** 3/14-15/18 (JPL)
- **Radiation Monitors** 4/18 (APL)



- **Avionics** 4/30-5/4/18 (JPL)
- **MISE** 4/25-26/18 (JPL)
- **MASPEX** 5/15-16/18 (SWRI)
- **Fault Management** 5/15/18 (JPL)
- **Mission Design & Navigation** 6/4-5/18 (JPL)
- **Mission Operations System & Ground Data System** 6/6-7/18 (JPL)
- **Project PDR** 8/20-24/18 (JPL)

Spacecraft Payload	Mission System Project
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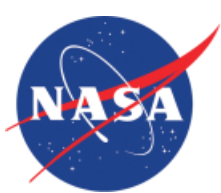


# PSG Meeting #5 Recap

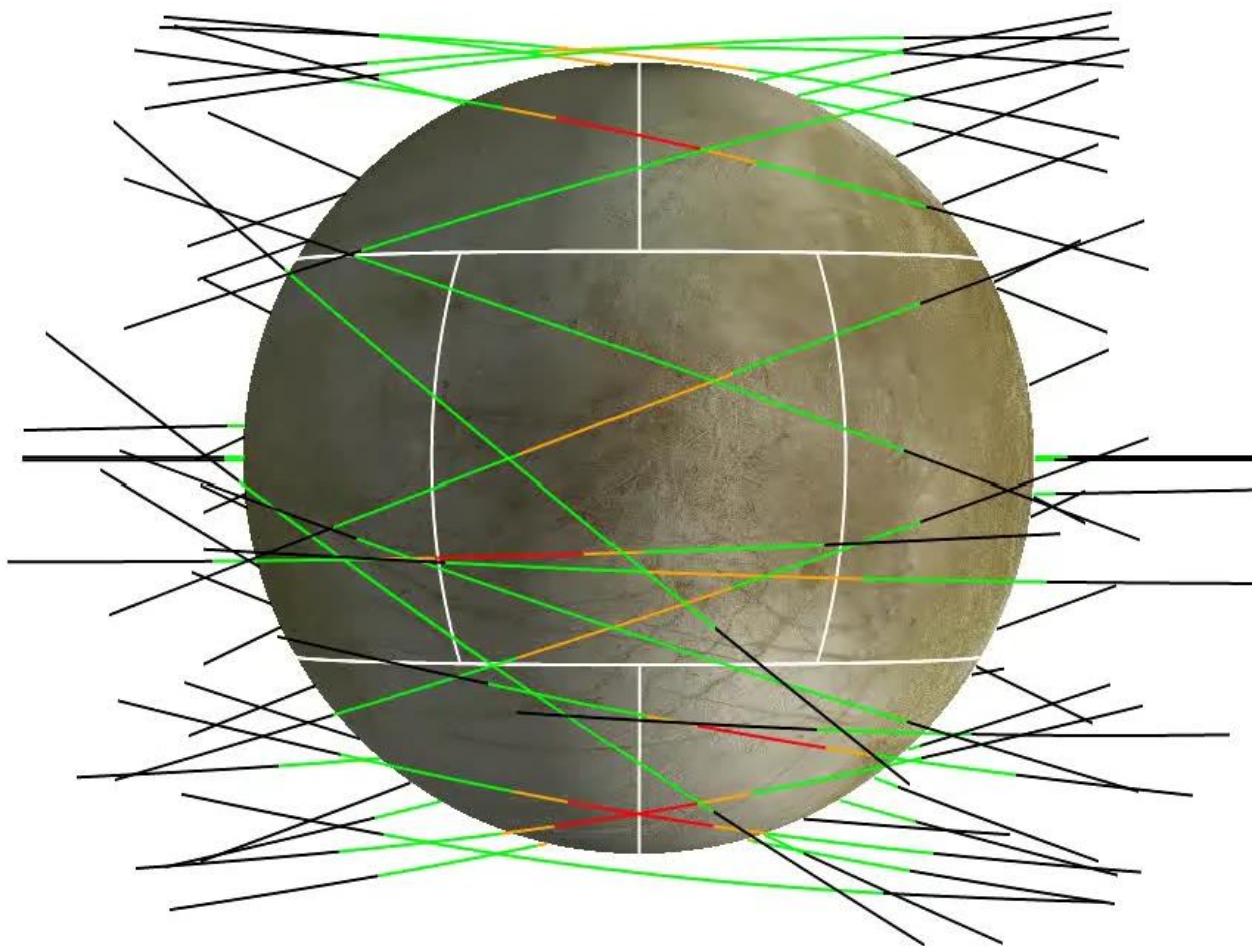
May 17–19, 2017

- Discuss science actions from MDR-SRR
- Evaluate tour options for Preliminary Design Reviews
- Outline Potential Collaborative Data Products
  - Quick-look and higher-level data products
- Establish foundation for Mission System plans:
  - Science observation planning & analysis tools
  - Data processing, analysis, & archiving
  - Feed-forward & latency
- Begin to define an Integrated Plume Search strategy
  - Established a new Plumes Focus Group
  - Co-Chairs: Matt Hedman & Carly Howett
- Confer on Rules of the Road development
- Discuss Project communications and remote collaborations
- Review Science Traceability and Alignment Framework for traceability from Level 1 science requirements to science observation types
- Nominate TWG Co-Chairs for rotation
  - Britney Schmidt (Habitability), Julie Rathbun (Geology), James Roberts (Interior), Murthy Gudipati (Composition)

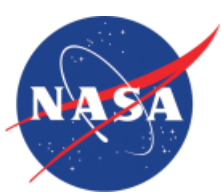




# 17F12\_V2 Trajectory



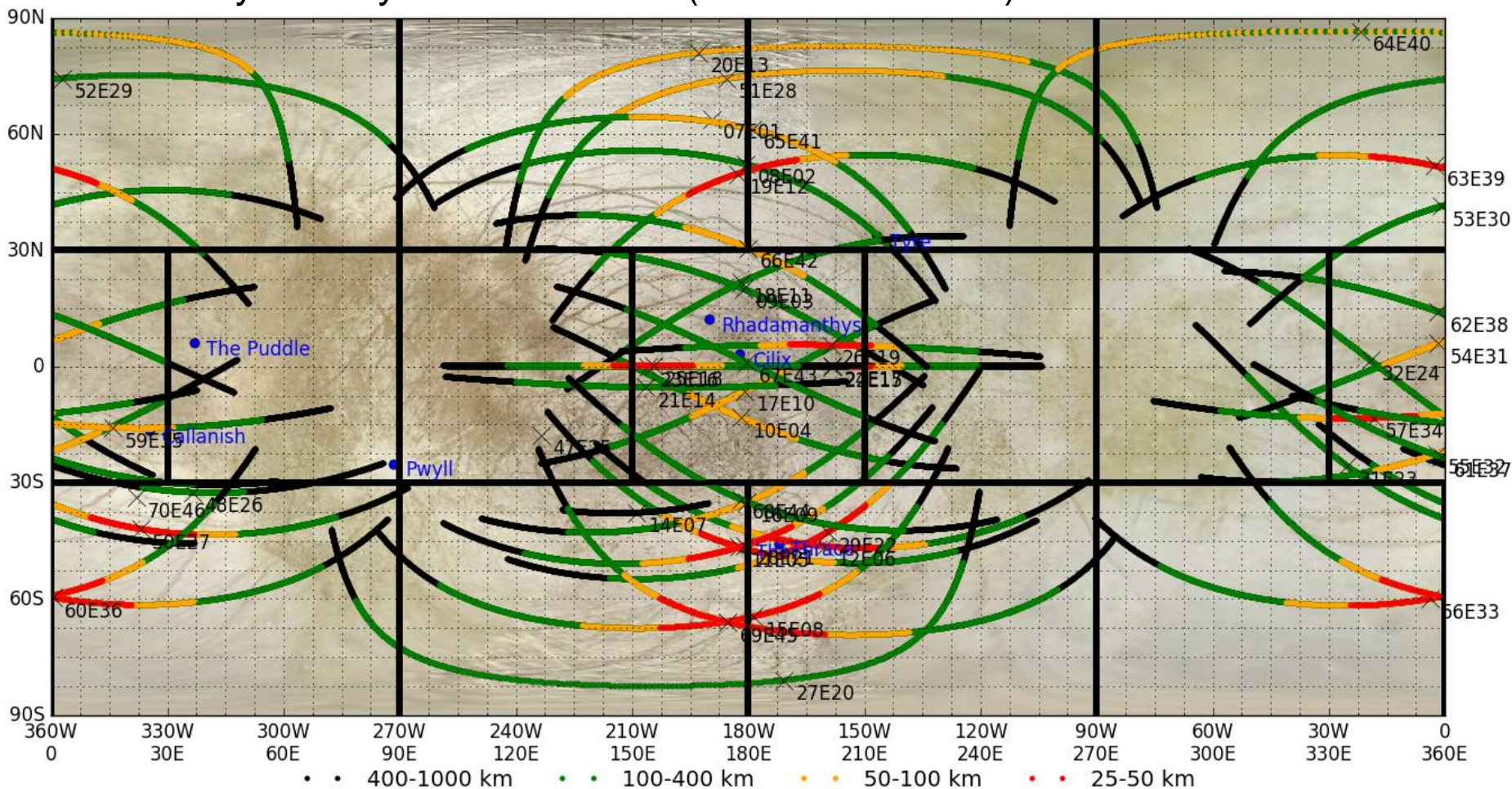


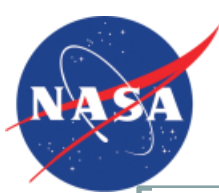


# Tour Update

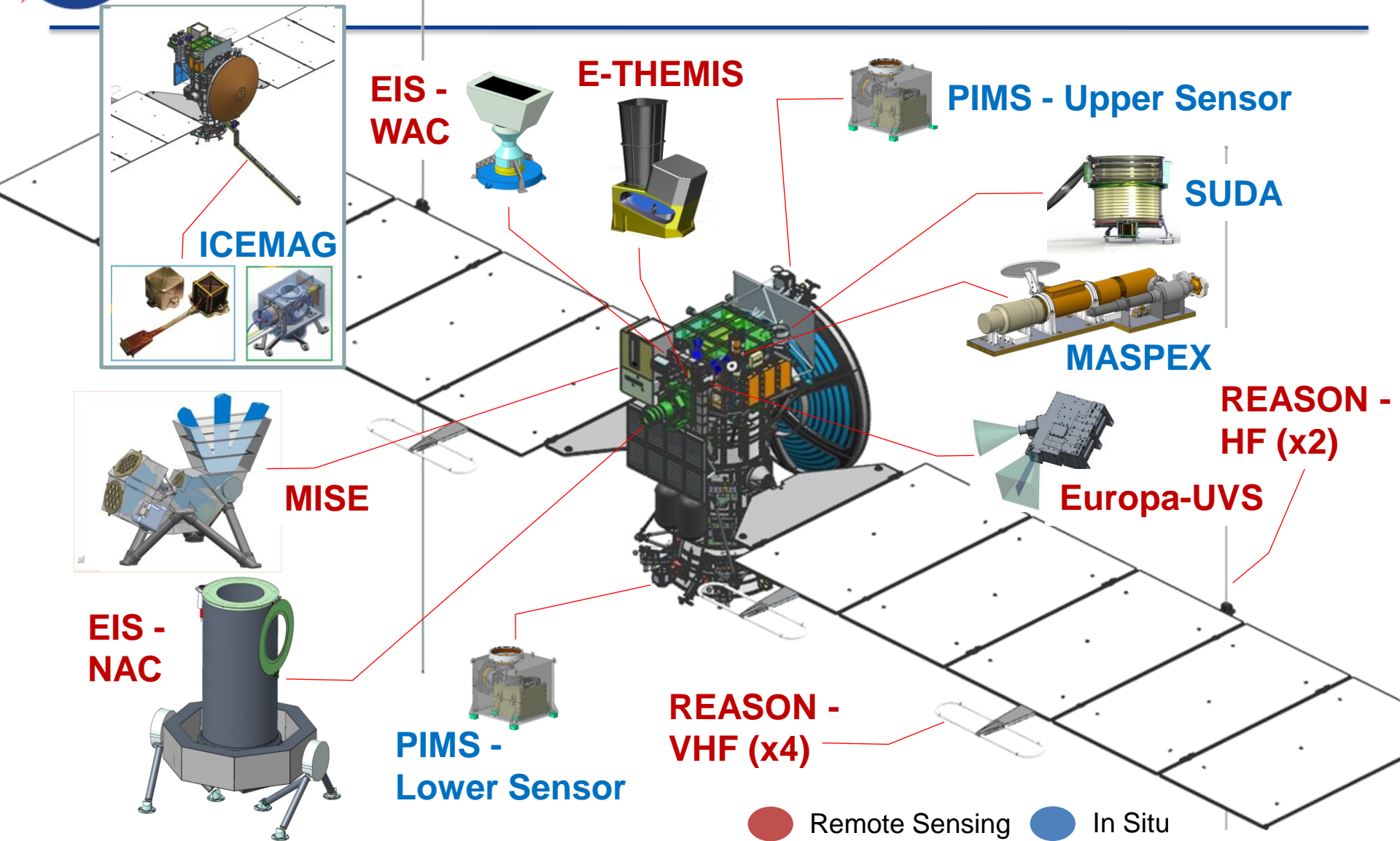
## 17F12\_v2

- Tweaked to include lower flybys in leading hemisphere
- Now fly directly over Callanish (<100 km altitude)!

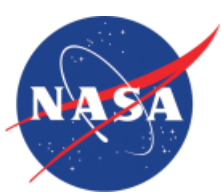




# Europa Clipper Science Instruments

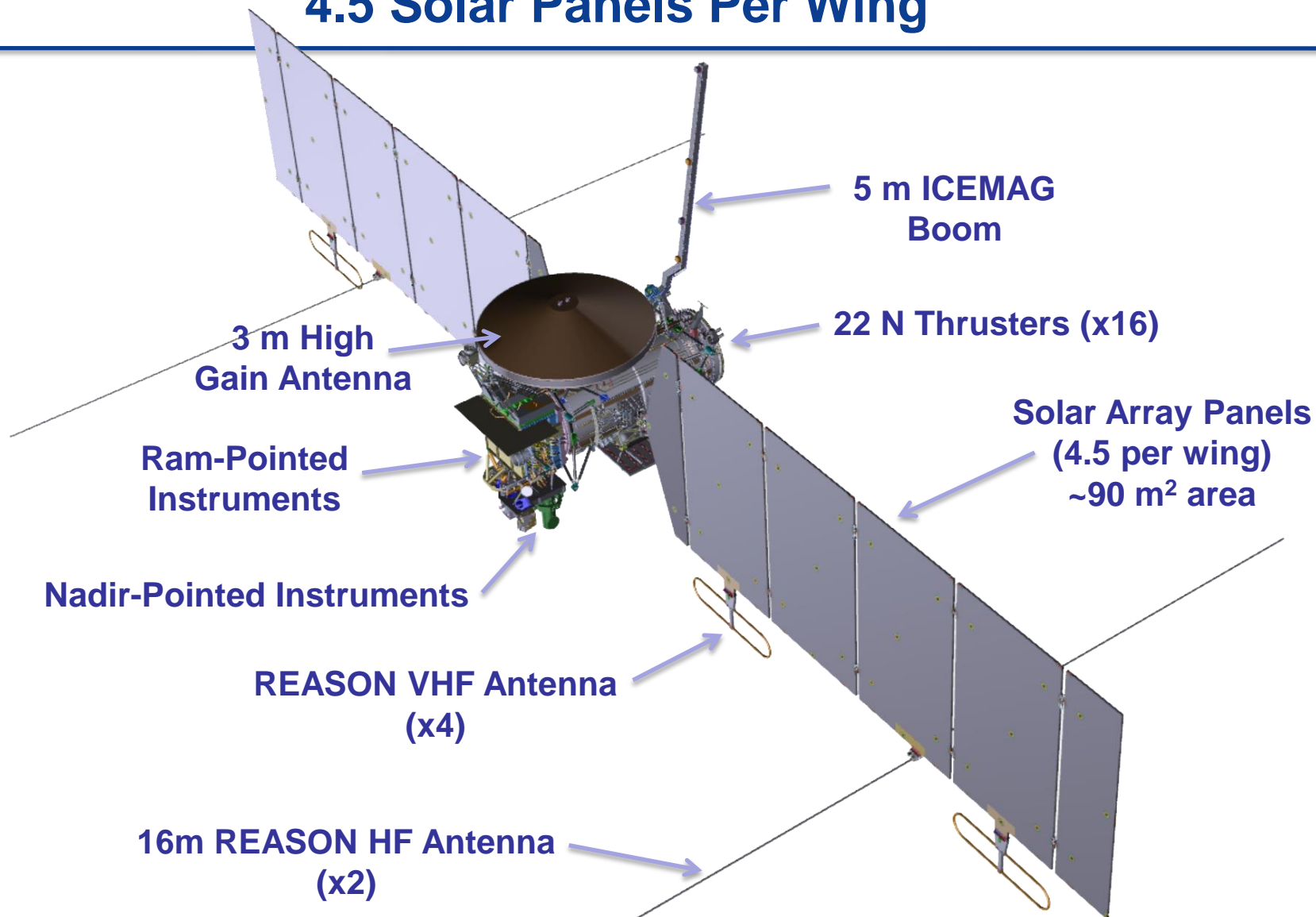


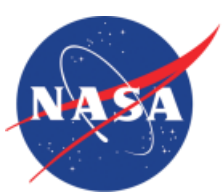




# Spacecraft Configuration Update:

## 4.5 Solar Panels Per Wing



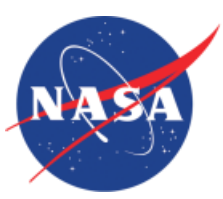


# Prototype Hardware

## Solar Array Panel Demonstrator

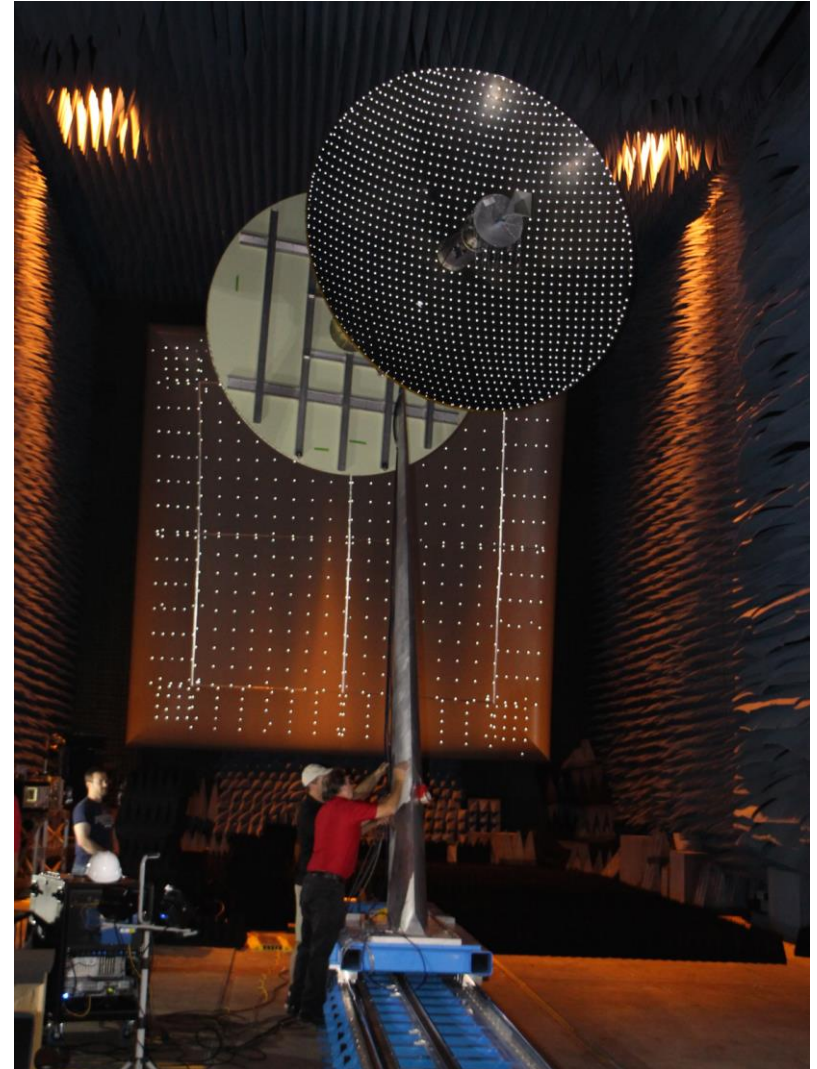
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# Prototype Hardware

## High Gain Antenna

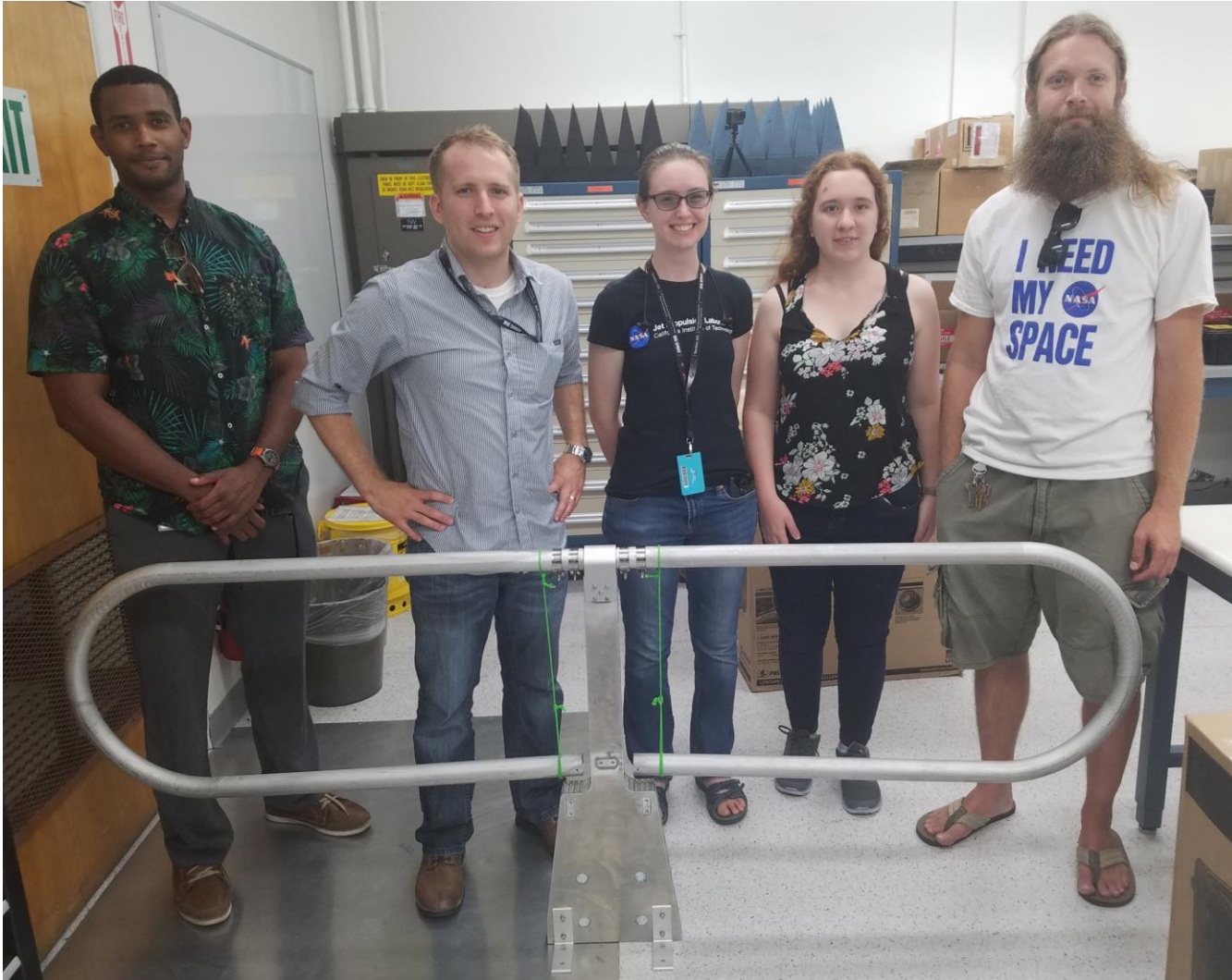






# Prototype Hardware

## REASON VHF Antenna

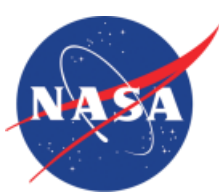




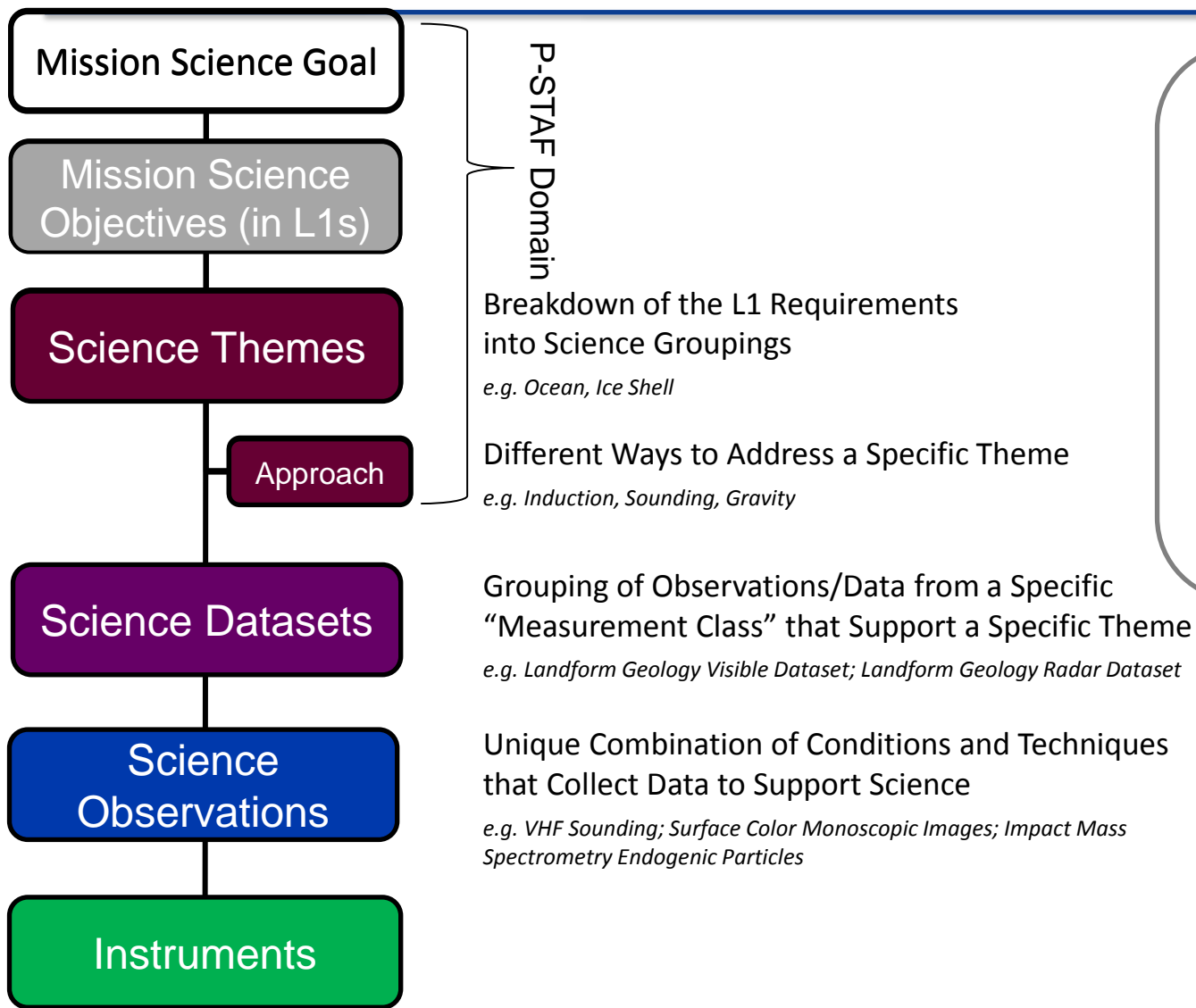
# Project Science Traceability and Alignment Framework (P-STAF): Introduction

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- The Project-Science Traceability and Alignment Framework (P-STAF) is a tool for codifying how the Europa Clipper science is planned to be achieved
  - Traces flow from the Level-1 Science Requirements to instrument measurements
  - Permits evaluation of instrument capability synergies and areas of overlap
- This P-STAF approach permits assessment of instrument contributions and robustness in achieving Level-1 Science Requirements, relevant to:
  - Deriving a decision framework to assess science impacts, when performing cost trades as part of instrument and mission development
  - Understanding implications of possible changes in instrument science scope
  - Evaluating implications of faults that might disrupt instrument observations during the science campaigns



# Project Science Traceability and Alignment Framework (P-STAF): Taxonomy

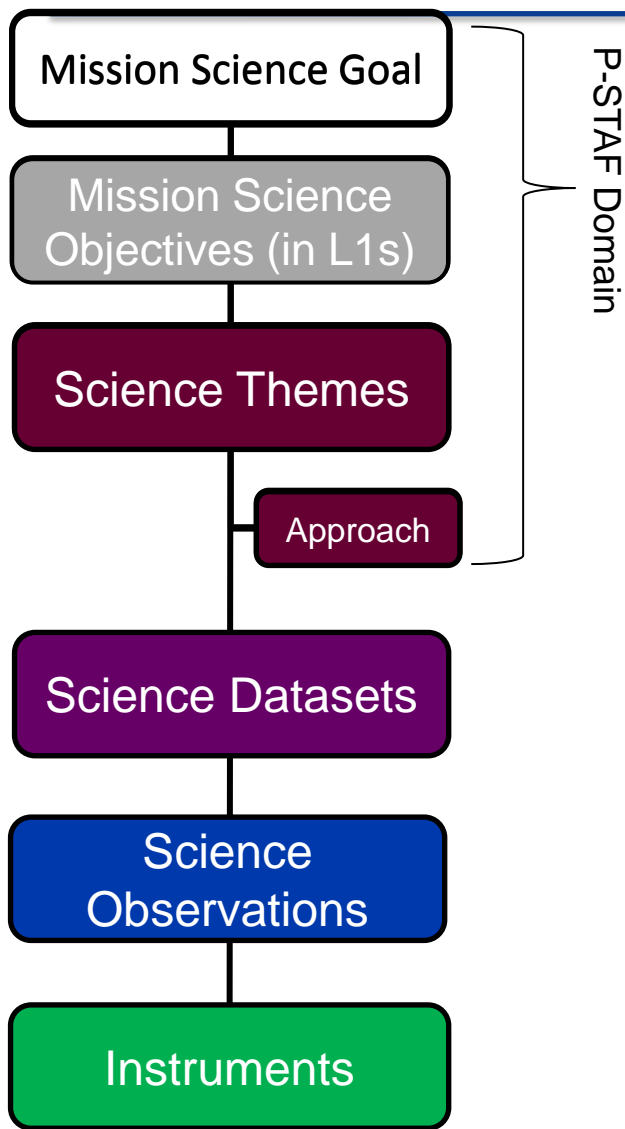


- STAF framework offers:
  - Traceability
  - Completeness
  - Consistency across instruments
- STAF provides efficiency:
  - Prioritization
  - Tour analysis
  - Mission robustness analysis

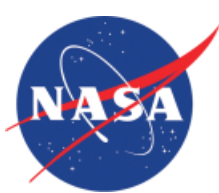




# Project Science Traceability and Alignment Framework (P-STAF)



Goal	Baseline L1 Req.	Science Themes	Baseline Approaches
Explore Europa to Investigate its Habitability	Subsurface structure of landforms ( $\geq 50$ )	Deep Subsurface Exchange	Sounding
		Shallow Subsurface Structure	Sounding
	Ice thickness; ocean salinity ( $\pm 50\%$ )	Ice Shell Properties	Induction, Sounding, Shape and Gravity
		Ocean Properties	Induction, Shape and Gravity
	Global comp. map ( $\geq 70\%$ )	Global Compositional Surface Mapping	Complex Species and Units, Simple Species and Units
	Landform comp. ( $\geq 50\%$ , $\leq 300$ m)	Landform Composition	Complex Species and Units, Simple Species and Units
	Gas, dust, & plasma composition	Atmospheric Composition	Plasma, Complex Volatile Species, Simple Volatile Species, Particulates
		Space Environment Composition	Plasma, Complex Volatile Species, Simple Volatile Species, Particulates
	Global imaging map ( $\geq 80\%$ )	Global Surface Mapping	Morphology
	High-res ( $\leq 25$ m) landforms ( $\geq 50$ )	Landform Geology	Morphology, Topography
	Local surface ( $\sim 1$ m, $\geq 40$ sites)	Local-Scale Surface Properties	Morphology, Roughness and Permittivity
	Search for and characterize any current activity	Remote Plume Search and Characterization	Volatiles, Particulates
		<i>In Situ</i> Plume Search and Characterization	Atmospheric Particulates, Atmospheric Volatiles, Plasma
		Surface Thermal Anomaly Search	Thermal Emission
		Surface Activity Evidence	Deposits, Surface Changes



# Science Synergy & Redundancy

## High Level Roll-Up to Baseline Level-1 Science Requirements

Baseline L1 Req.	Science Themes	Radar		Visible		Infrared	Thermal	UV	Magnetic	Plasma	IMS	NMS	Gravity
		HF	VHF	NAC	WAC								
Subsurface structure of landforms (≥50)	Deep Subsurface Exchange												
	Shallow Subsurface Structure												
Ice thickness; ocean salinity (±50%)	Ice Shell Properties												
	Ocean Properties												
Global comp. map (≥70%)	Global Compositional Surface Mapping												
Landform comp. (≥50%, ≤300 m)	Landform Composition												
Gas, dust, & plasma composition	Atmospheric Composition												
	Space Environment Composition												
Global imaging map (≥80%)	Global Surface Mapping												
High-res (≤25 m) landforms (≥50)	Landform Geology												
Local surface (~1m, ≥40 sites)	Local-Scale Surface Properties												
Search for and characterize any current activity	Remote Plume Search and Characterization												
	In-Situ Plume Search and Characterization												
	Surface Thermal Anomaly Search												
	Surface Activity Evidence												



Primary



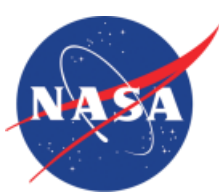
Independent



Supporting



Enhancing



# Full P-STAF Matrix (In Progress)

Mission Science Goal

Mission Science Objectives (in L1s)

Science Themes

Approach

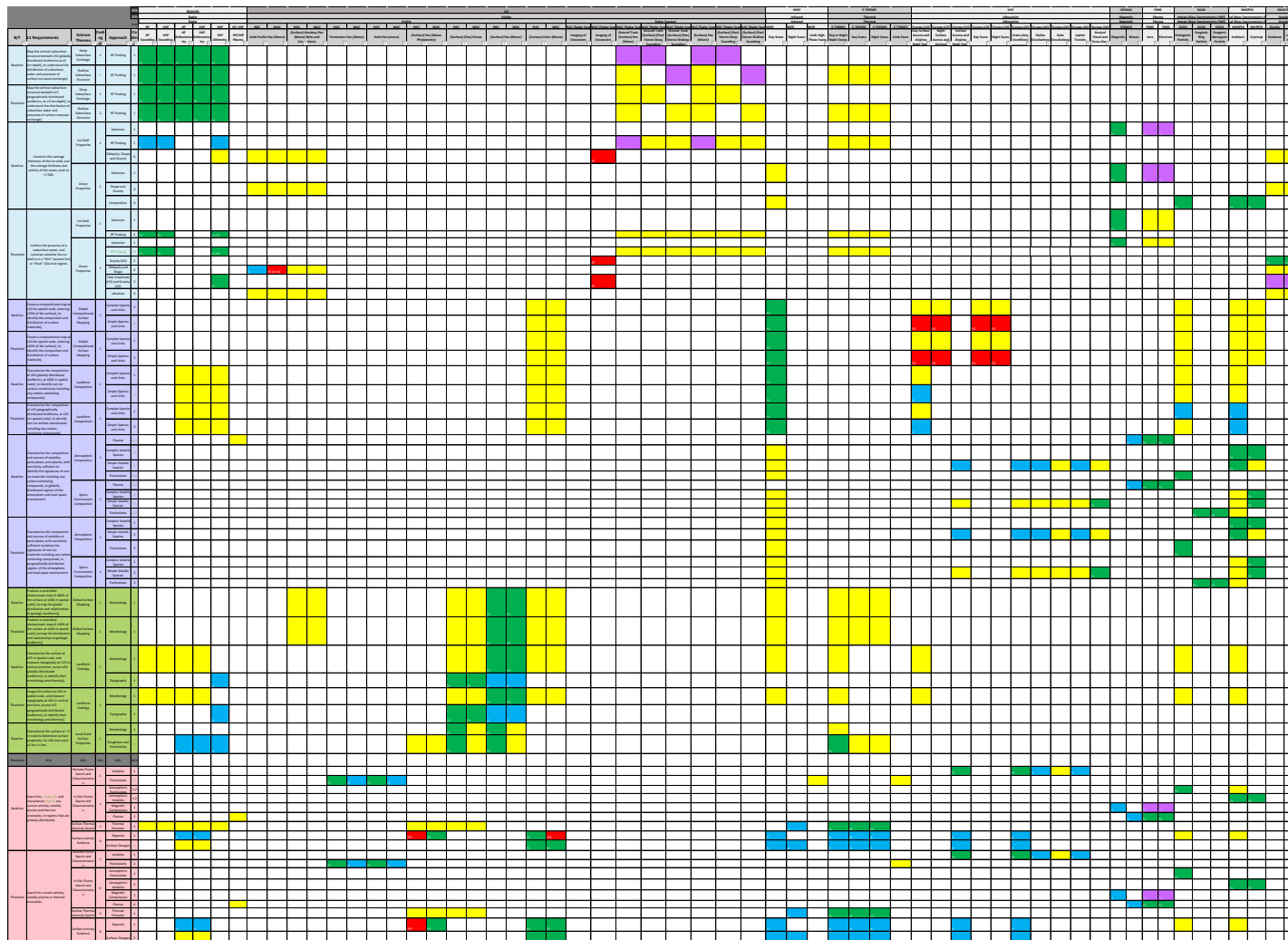
Science Datasets

Science Observations

Instruments

L1, Science Theme, Approach

Science Observations by Measurement Class



Primary



Independent



Supporting



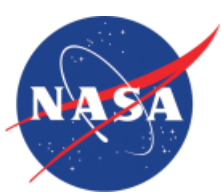
Enhancing



In Progress

- A primary instrument (P) is not required in every row.
- If an approach has no primary instrument, then that approach is considered less robust.





# P-STAF Analysis (Still To Come)

Once the inputs are reconciled and vetted, the P-STAF can be used to determine:

“Simple” queries to the network include:

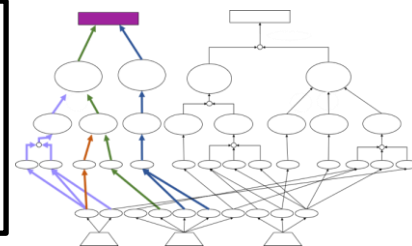
- In how many independent ways can each Level 1 be met?
- Which Level 1s have single points of failure?
- If an instrument or observation fails, which Level 1s are not achievable?
- How many paths does an instrument or observation affect?

“Complex” queries to the network include:

- How resilient is each Level 1 to failures?
- What is the impact of a given observation or instrument?
- What is the minimum set (of instruments or observations) necessary to meet a Level 1 or a group of Level 1s?
- Which Level 1s require the most resources to meet?

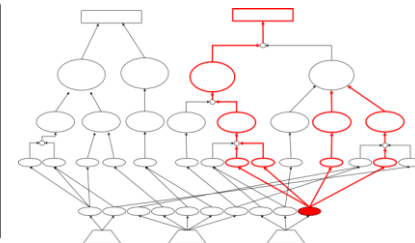
## Robustness

Number of Viable Paths



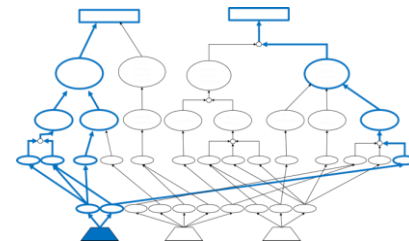
## Criticality

Single Point Failures



## Scope

Link Density of Nodes





# How the P-STAF Can Inform Decisions that Affect Science

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- P-STAF approach provides a standard format from which Level-1 Science requirements can be traced, via science themes, to instrument measurements
- Permits assessment of the contribution (Primary, Independent, Supportive, and Enhancing) of individual instrument measurements to each Science Theme, and thus each Level-1 Science requirement
- Provides a decision-tree structure that can aid assessment of the science impact when considering modifications to the instrument capabilities or complement
- In making capability trades as may be necessary for cost control, P-STAF provides a simple and concrete means to evaluate the potential impact to achieving Level-1 Science Requirements