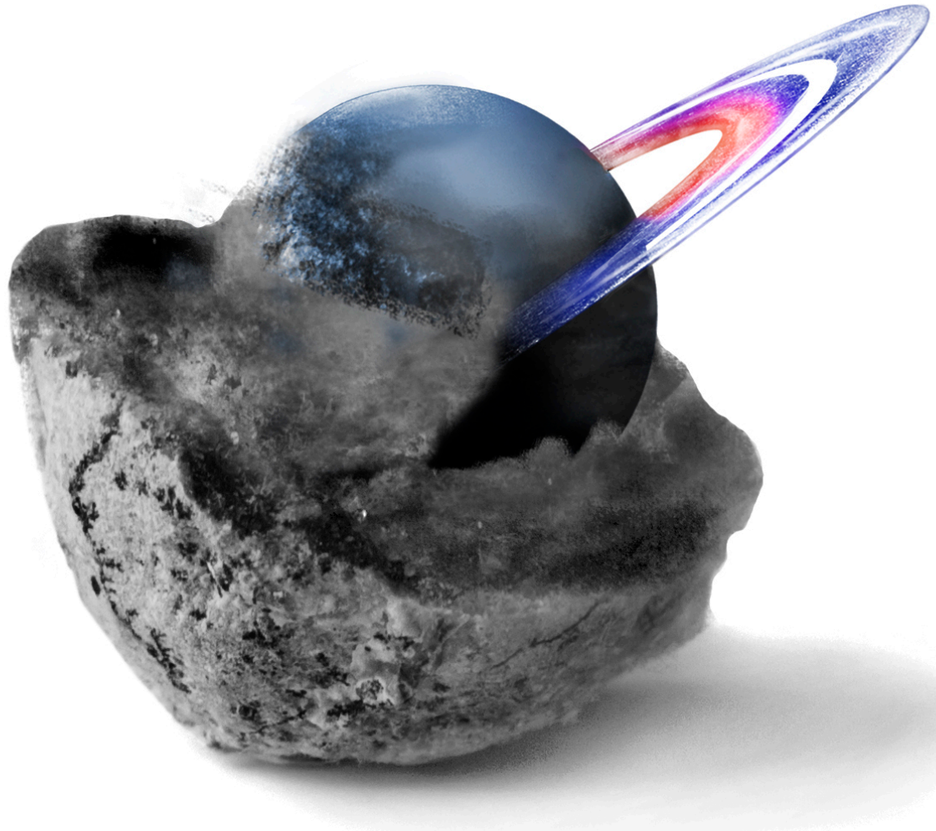

JPL Innovation Foundry

Exploring the Science Trade Space with the JPL Innovation Foundry A-Team

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Agenda

- Problem Statement
- Concept Maturity Levels (CML)
- Architecture – Team (A-Team)
- Developing a Science Story
- Science Return Diagraming (SRD)
- Science Value Matrix (SVM)
- Conclusion

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NASA Wants Focused and Compelling Proposals

- Problem:
  - NASA provided very little guidance for Pre-Phase A activities
  - Science portion of competed mission proposals were not focused and compelling

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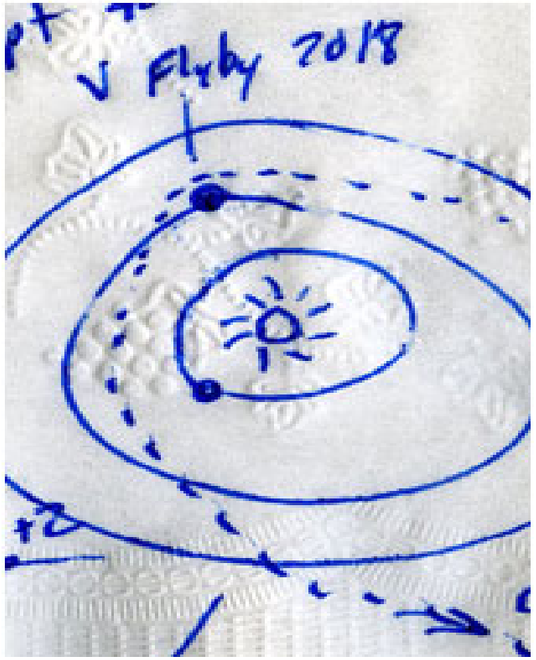
Absent: A Common Language for Concepts

- How mature is your concept?



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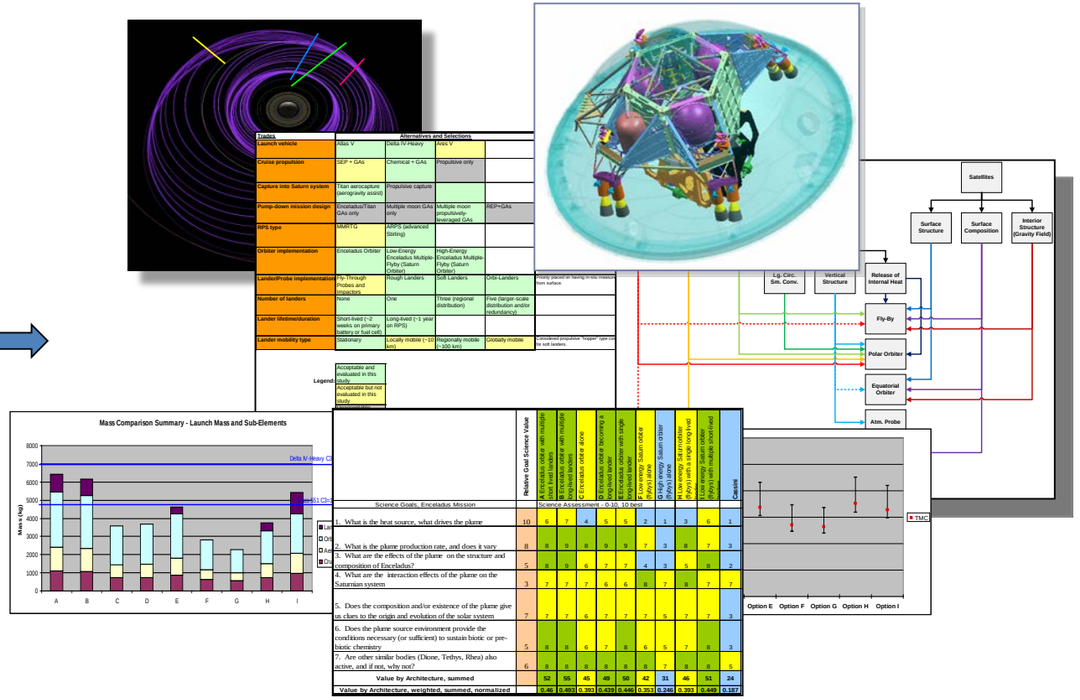

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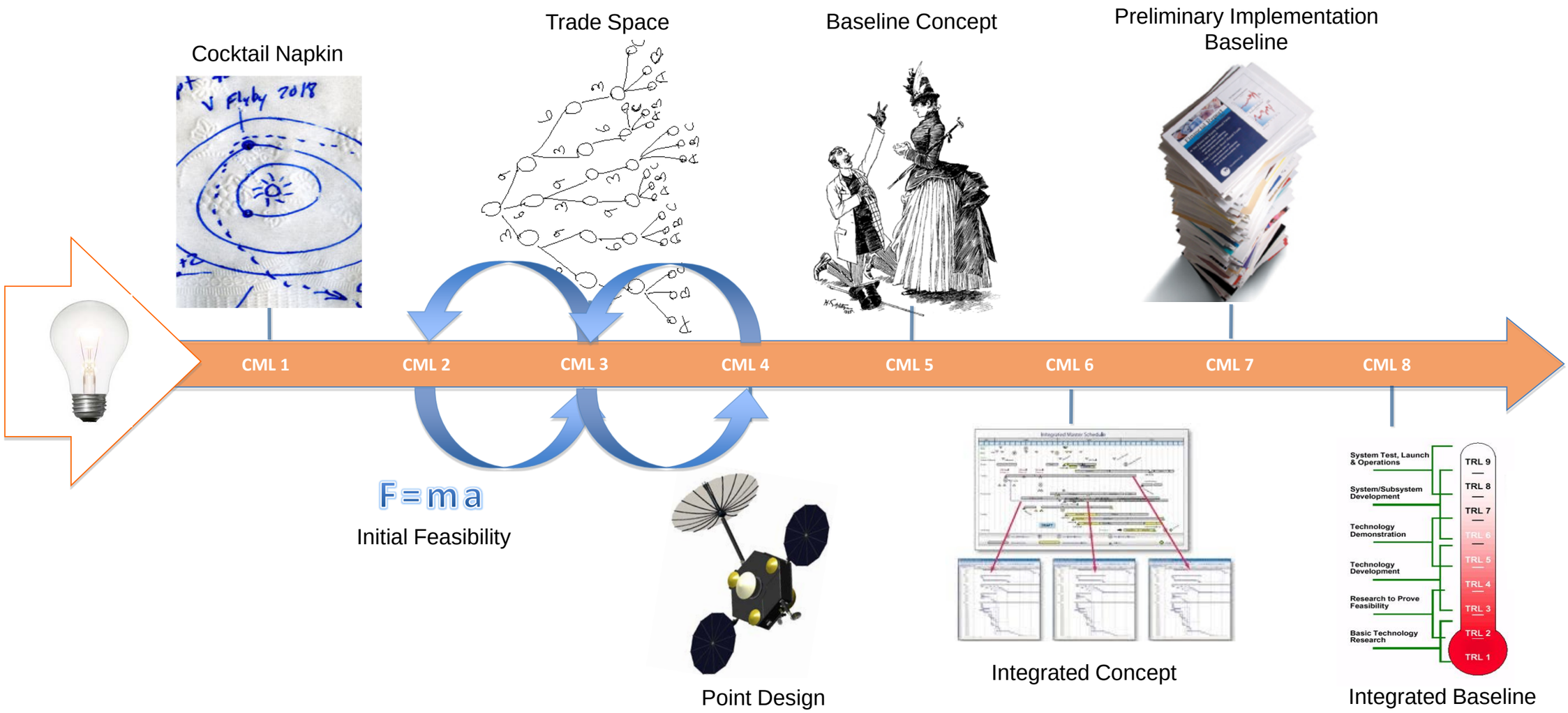
CMLs: A Powerful Communication Tool



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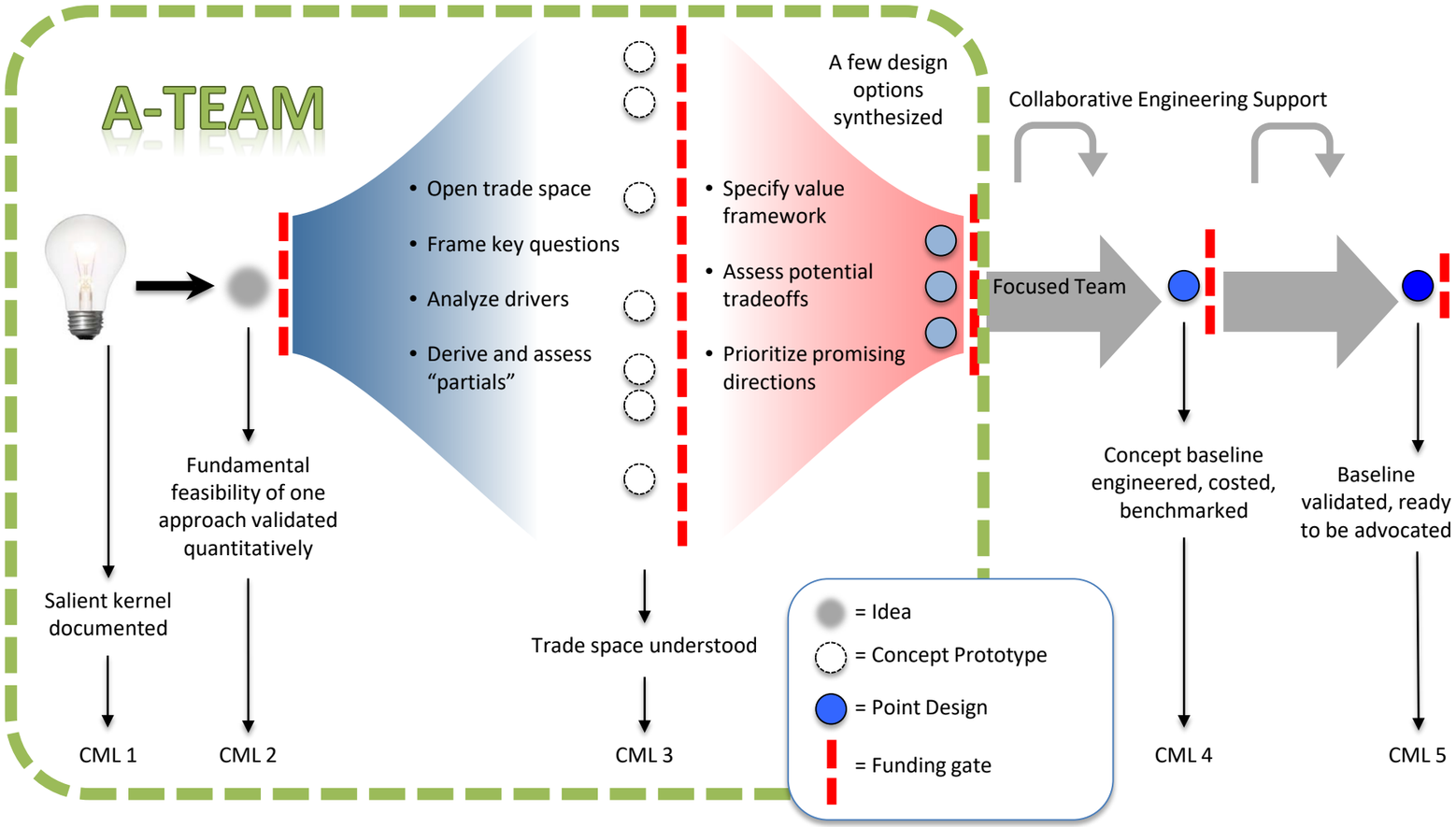
The Architecture Team (A-Team) Focuses on Early Formulation



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Challenges with Past Science Proposals

- There are a number of traps that PI(s) fall into that lead to Science Investigation Section and Science Traceability Matrix (STM) weaknesses:
  - PI(s) generate the STM by themselves without input from others
  - Science Investigation Section is written as if it's a science paper rather than selling the concept to the science reviewers
  - Mission concept includes too many objectives and is not focused
  - Proposal centers on an instrument in a new environment rather than top-down science

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The Science Story

- Science at CML 1: The Science Story and Traceability
  - "Why is this important?"
  - Link the proposal's science goal to NASA goals
  - Identify the "undiscovered country"

- Science at CML 2: Science Return Diagram
  - Remove science objectives that are out of scope or violate the laws of physics
  - Generate the science return gradient (e.g., state-of-art, enhancement, enabling, breakthrough)
  - Develop "boundary objects" – graphics that help a science team understand their concept

- Science at CML 3: Payload and Mission Specifications
  - Develop science "seeds" (payload option sets) with architecture implementation "prototypes"
  - Science "seeds" cover the architecture trade space
  - Develop a science value matrix (SVM) – science objectives vs architecture

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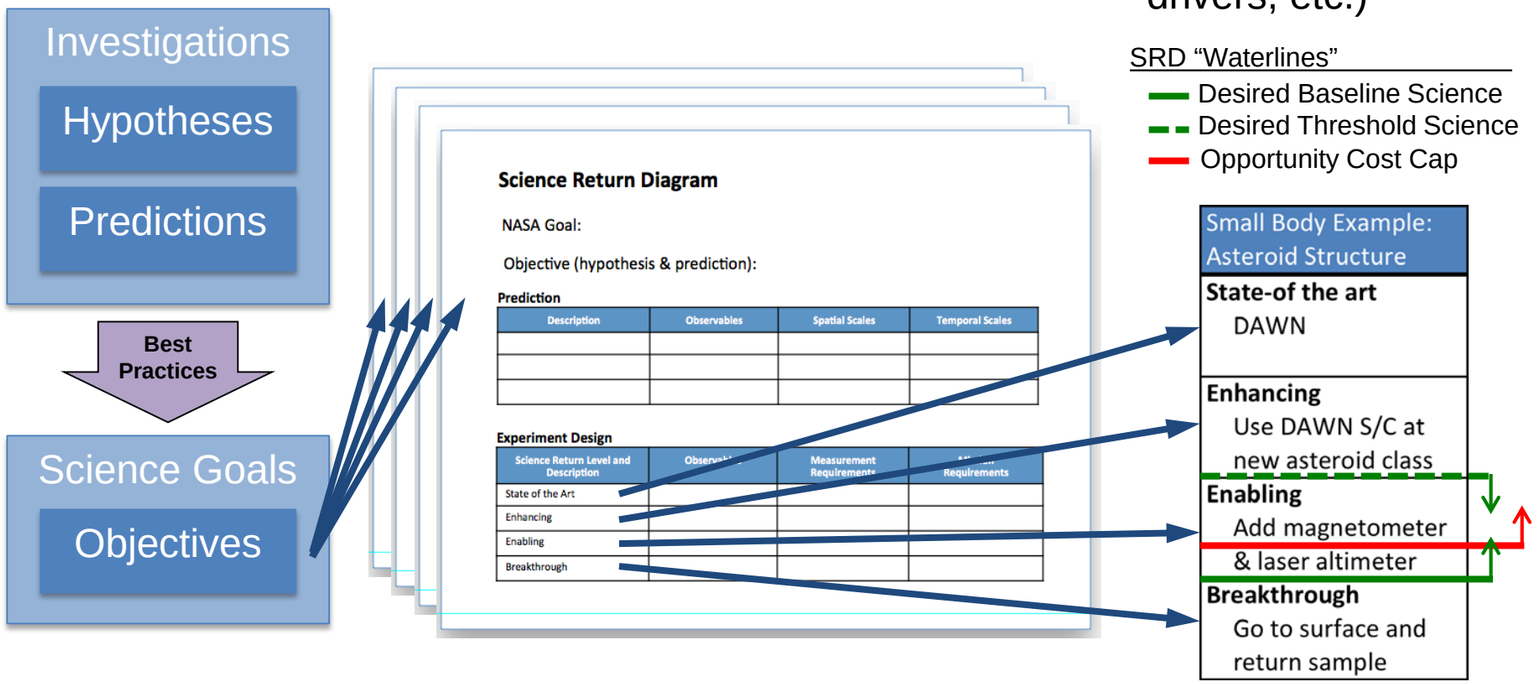
A Science Return Diagram Highlights the Science Trade Space

1. Map desired science investigations into "STM taxonomy" and prioritize
2. For each objective, identify science return *gradients & drivers* (e.g., resolution, coverage, etc.)
3. Next, examine implementation impact (e.g., on cost, technology, risk drivers, etc.)



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The Science Story (cont.)

- Science at CML 1: The Science Story and Traceability
  - "Why is this important?"
  - Link the science goal to NASA goals
  - Identify the "undiscovered country"

- Science at CML 2: Science Return Diagram
  - Remove science objectives that are out of scope or violate the laws of physics
  - Generate the science return gradient
  - Develop "boundary objects" – graphics that help a science team understand their concept

- Science at CML 3: Payload and Mission Specifications
  - Develop science "seeds" (payload option sets) with architecture implementation "prototypes"
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Science Value Matrix Helps Identify Compelling Architectures

- The science value matrix:
  - Identifies and priorities each science objective numerically and evaluates how well it can be achieved with each architecture
  - Provides a quantitative metric to examine the relative science return of each architecture
  - Forms the science component of the mission concept science/cost/risk trade space assessment

Science value for architectural options - Ratings approach: 0 = "Architecture does not address science objective", 10= "Architecture completely fulfills objective". "Completely" is subjective, particularly since very few areas of research are ever complete	Relative Category Science Value	Goal Science Value Relative in Category	Cassini (for reference)	Saturn orbiter with E high speed flybys	Simple Enceladus Orbiter	Simple Enceladus Orbiter (shorter ops)	Enhanced Enceladus Orbiter	Simple Enceladus Orbiter (2a) + free-flying magnetometer	Simple Enceladus Orbiter (2a) + semi-hard seismic network	Simple Enceladus Orbiter (2a) + impactor	High Performance orbiter	High Performance orbiter + semi-hard seismic network	High Performance orbiter + instrumented lander/hopper	Titan-Enceladus Connection	Sample plume from Saturn orbit (nuclear), ~2 kms sampling velocity, 2GB/ samples	Sample plume from Saturn orbit (nuclear), ~2 kms sampling velocity, 2GB/ samples	Sample plume from Saturn orbit, ~4 kms sampling velocity, no temperature control	5a with enhanced payload (2a w/ laser altimeter)
Study option designator			0	1a	2a	2b	2c	2d	2e	2f	3a	3b	3c	4a	5a	5b	5c	5d
Nature of Enceladus; cryovolcanic activity	6		2.8	4.7	5.3	4.9	6.5	6.2	6.6	6.6	6.9	7.2	7.7	6.4	6.9	6.9	6.9	7.7
Physical conditions at the plume source		4	2.5	4.6	4.7	4.5	5.9	4.7	5.2	5.5	6.2	6.3	6.6	5.9	6.3	6.3	4.9	7.5
Chemistry of the plume source		4	2.7	5.2	5.9	5.6	7.6	6.6	5.9	6.1	7.7	7.7	8.5	7.3	8.5	8.5	7.2	9.8
Presence of biological activity		1	0.0	2.4	3.0	2.0	3.3	3.0	3.0	3.0	5.1	5.1	6.4	4.3	6.3	6.3	6.7	8.3
Plume dynamics and mass loss rates		2	4.5	5.0	5.5	4.8	6.3	5.5	5.5	5.5	7.5	7.5	8.0	6.3	6.7	6.7	6.3	7.0
Origin of south polar surface features		2	3.0	4.3	6.0	5.3	6.7	5.7	7.0	6.0	7.3	8.3	9.0	6.7	4.3	4.3	4.3	6.0
Internal structure and chemistry of Enceladus	4		2.4	4.0	5.5	4.8	6.9	6.9	7.2	6.3	7.2	8.3	8.2	6.7	4.8	4.8	4.5	6.0
Internal structure		3	1.0	2.0	4.7	4.0	6.7	7.0	7.7	6.0	7.0	8.7	7.3	6.7	2.3	2.3	2.3	3.0
Presence, physics, and chemistry of the ocean		4	2.8	4.6	6.1	5.0	7.8	7.4	7.6	6.9	7.8	8.8	9.0	7.3	7.0	7.0	6.5	7.6
Tidal dissipation rates and mechanisms		3	3.0	4.3	6.3	5.0	6.0	6.7	7.3	5.7	6.3	8.0	7.7	5.7	2.3	2.3	2.3	5.0
Chemical clues to Enceladus' origin and evolution		2	2.9	5.2	5.6	5.4	6.8	6.9	5.6	5.6	7.4	7.4	8.5	6.9	7.8	7.8	7.1	8.8
Geology of Enceladus	3		3.0	4.7	5.7	5.0	7.3	5.7	6.7	6.3	7.7	8.7	9.0	7.0	3.0	3.0	3.0	4.7
Nature, origin and history of geological features		4	3.0	4.7	5.7	5.0	7.3	5.7	6.7	6.3	7.7	8.7	9.0	7.0	3.0	3.0	3.0	4.7
System Interaction	2		1.8	3.5	3.9	3.4	5.7	4.3	3.9	4.1	5.9	5.9	6.0	5.7	4.3	4.3	4.1	4.9
Plasma and neutral clouds		4	4.0	2.3	2.7	1.7	5.7	3.7	2.7	3.3	6.0	6.0	6.0	5.7	1.7	1.7	1.7	2.3
E-ring		4	4.0	4.7	4.7	4.7	5.3	4.7	4.7	4.0	5.5	5.5	5.5	5.3	7.8	7.8	6.7	7.8
satellites		2	3.0	3.7	4.7	4.3	6.3	4.7	5.0	4.8	6.5	6.5	6.8	6.7	4.3	4.3	4.0	5.7
Other satellite science	2		1.0	2.3	3.0	3.0	4.5	3.0	3.0	3.0	5.0	5.0	5.0	6.8	6.3	6.3	0.3	6.7
Nature of Titan's geological processes		4	3.0	1.3	1.3	1.3	3.3	1.3	1.3	1.3	4.7	4.7	4.7	6.7	0.0	0.0	0.0	0.0
Surfaces and interiors of Rhea, Dione, and Tethys		4	3.0	3.3	4.7	4.7	5.7	4.7	4.7	4.7	5.3	5.3	5.3	5.0	6.7	6.7	0.3	1.3
Preparation for follow-on missions	1		2.0	3.0	5.0	4.7	6.7	5.0	6.7	7.0	7.3	8.0	9.0	6.3	2.7	2.7	2.7	4.3
Nature of potential landing sites		4	2.0	3.0	5.0	4.7	6.7	5.0	6.7	7.0	7.3	8.0	9.0	6.3	2.7	2.7	2.7	4.3
Category value by Architecture, summed			17.0	22.7	28.7	25.7	37.6	30.0	33.6	32.7	39.9	43.8	44.9	39.6	22.0	22.0	20.3	28.2
Category Value-weighted, summed, normalized			0.85	1.21	1.45	1.26	1.93	1.50	1.71	1.64	2.04	2.29	2.28	1.96	1.36	1.36	1.23	1.66
Normalized to Reference Architecture			1.00	1.44	1.76	1.60	2.29	1.88	2.03	1.94	2.41	2.69	2.70	2.32	1.61	1.61	1.45	1.97

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Conclusion

- A-Team studies provide a proven way for Earth, Planetary and Astrophysics Program Directorates to:
  - Generate new and innovative mission concepts
  - Establish early concept feasibility
  - Explore and understand critical elements of the concept's trade space
- Science Return Diagram and Science Value Matrix allow early concept formulation teams to:
  - Bound the science in mission concepts
  - Focus on compelling science objectives
  - Efficiently explore the architecture trade space to identify compelling science missions that fit within acceptable cost and risk
- 150 studies completed in 5 years is a testament of the value of A-Team studies to the science community, JPL and NASA

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