Formulation of New Architectures for Deep Space Exploration

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Pasadena, 22 October 2018

Advanced Power Systems for Deep Space Exploration

Jet Propulsion Laboratory
California Institute of Technology

Power frontiers for deep space missions

Solar

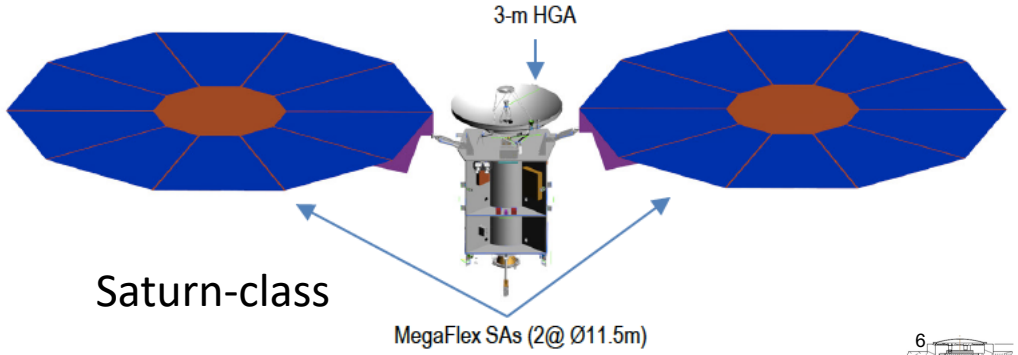
- LILT
- Ultra-lightweight

Chemical

- Combustion
- Regen fuel cells

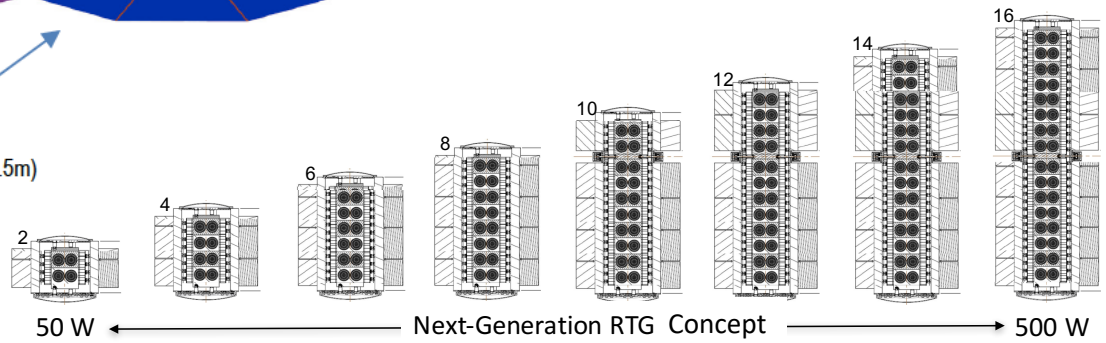
Nuclear

- Radioisotope systems
- Fission systems

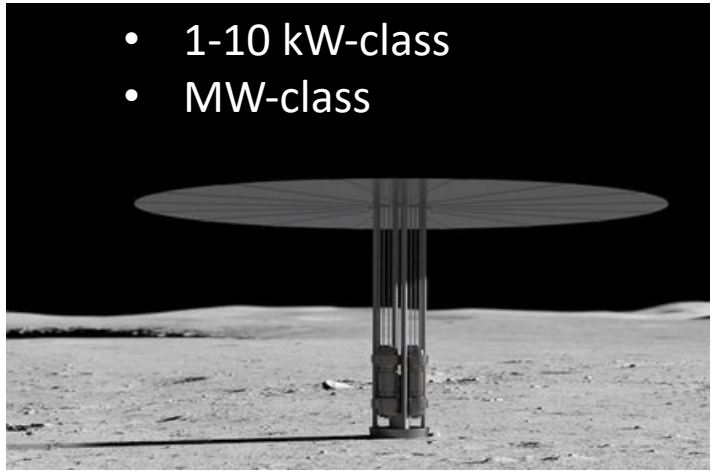


Saturn-class

- Stable materials
- Modular



- 1-10 kW-class
- MW-class



Lunar base buildup

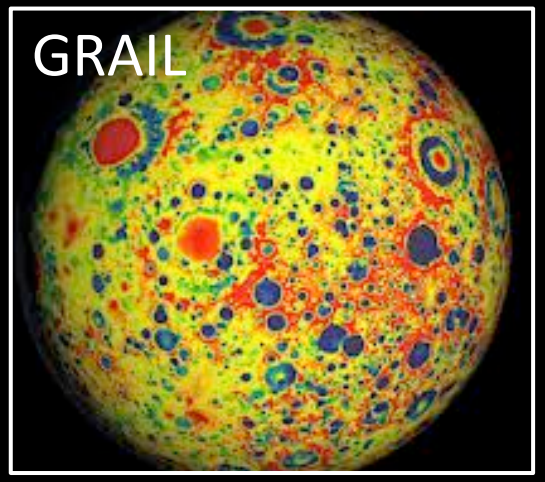
Solar power, batteries, regenerable fuel cells, energy management.

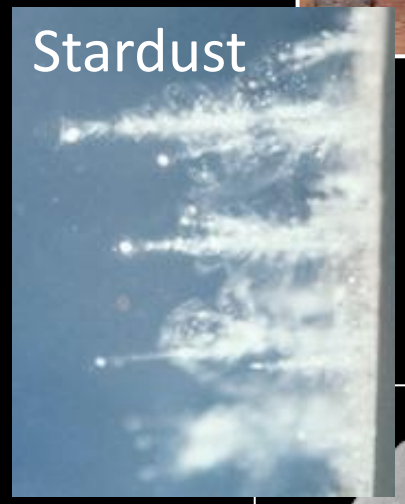
Nuclear power? Depends on goals and growth.

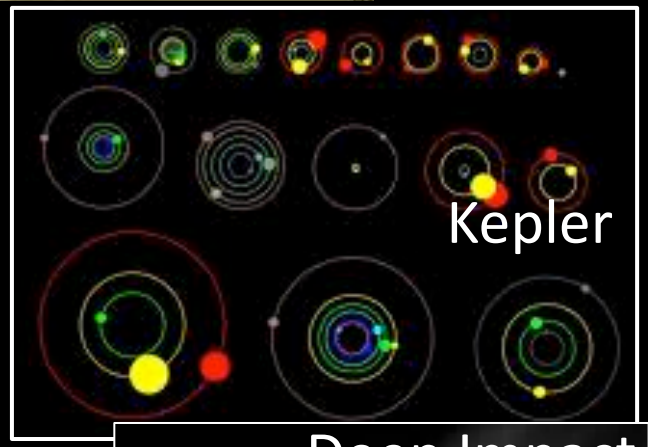
NASA planetary science missions are quantized

≈ $0.5B

0.1 unit	SIMPLEx	ad hoc
1 unit	Discovery	~ 3 per decade
2 units	New Frontiers	~ 2 per decade
3-4 units	‘small’ directed	MEP only, so far
5-6 units	traditional flagship	~ 2 per decade

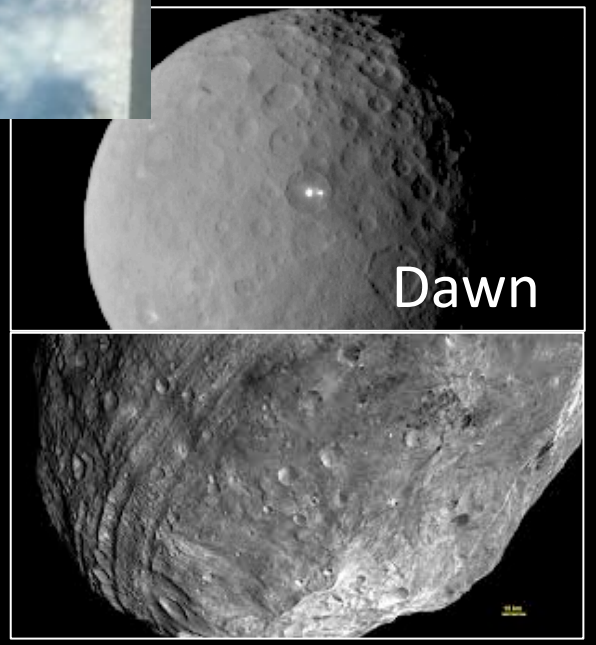






JPL

‘1-unit’ missions

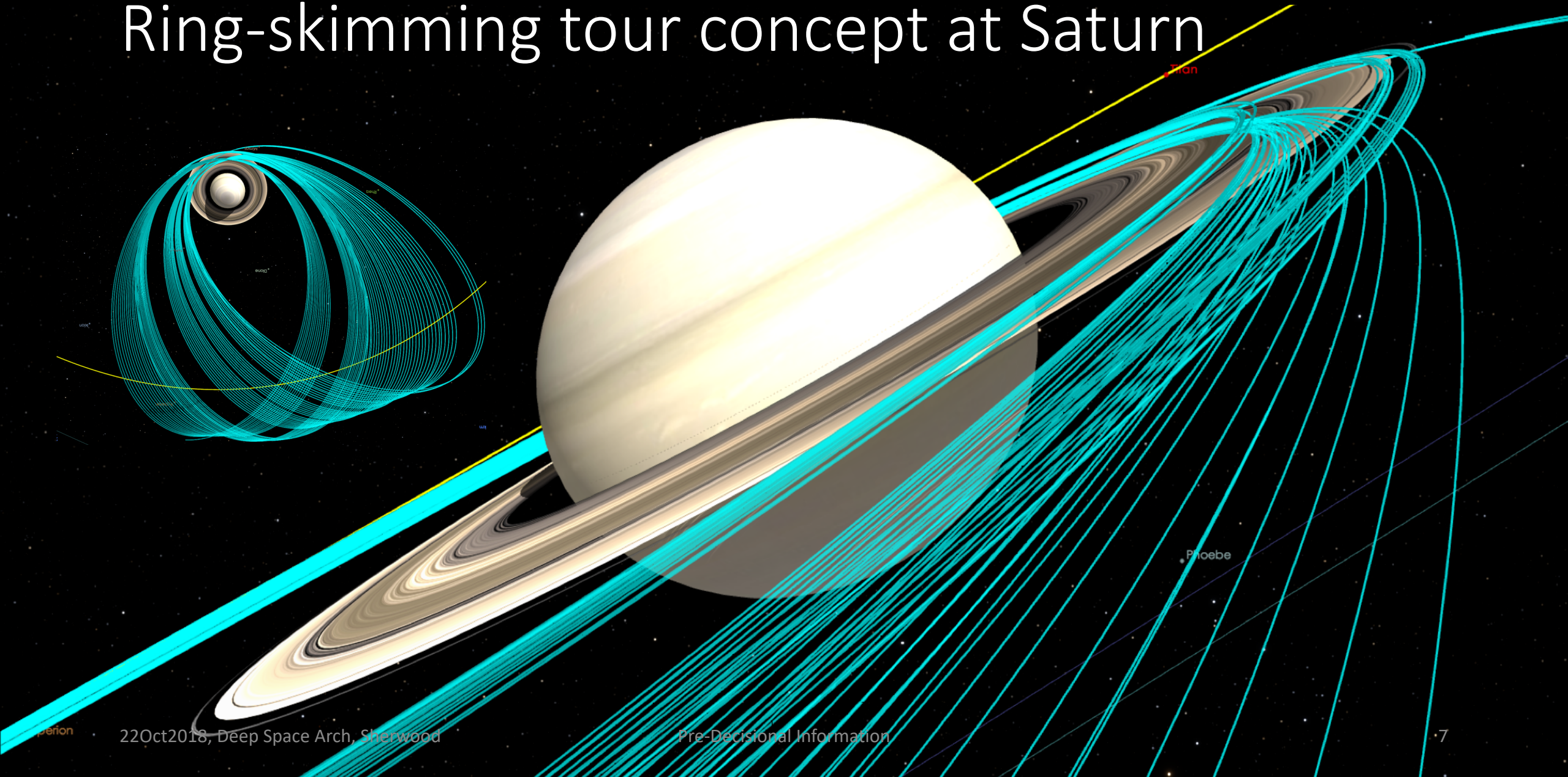


PSYCHE

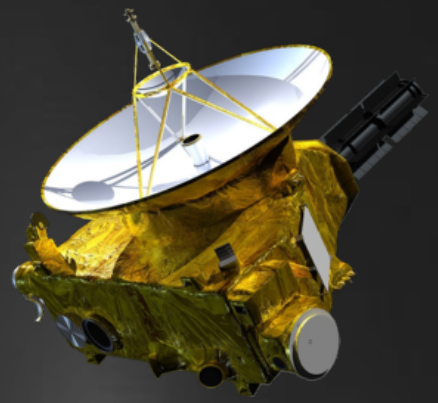
JOURNEY TO A METAL WORLD

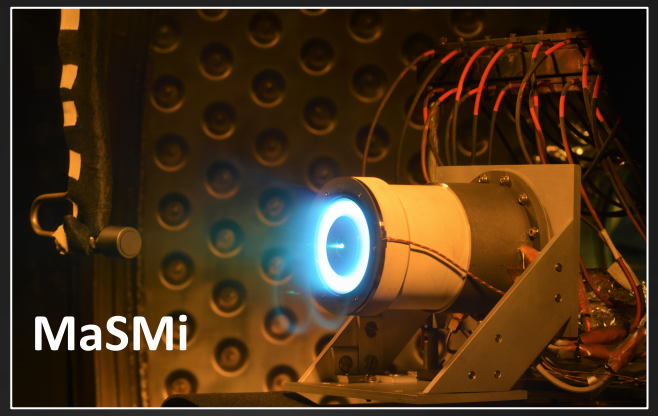
Pre-Decisional Information

Ring-skimming tour concept at Saturn

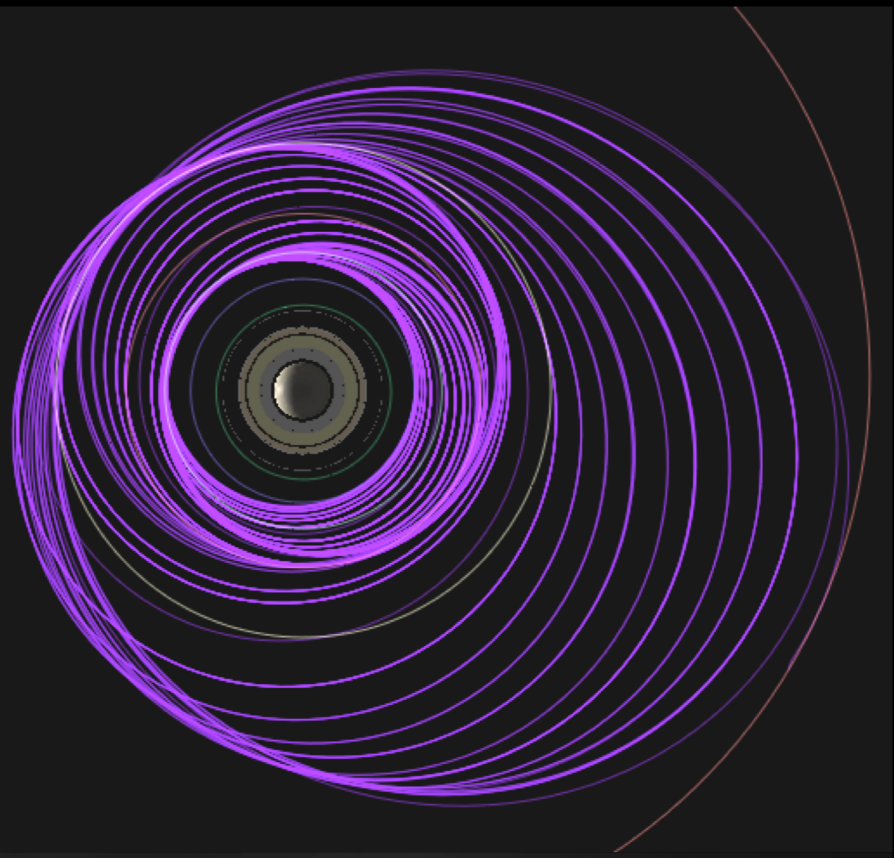


REP concept
(Radioisotope Electric Propulsion)

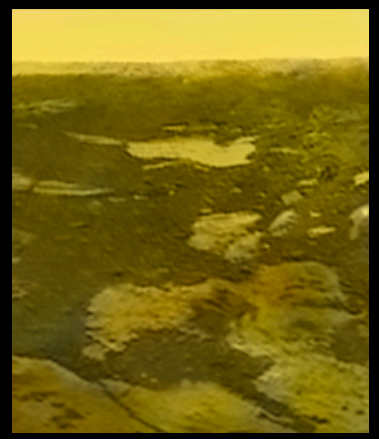




Low power magnetically-shielded Hall thruster



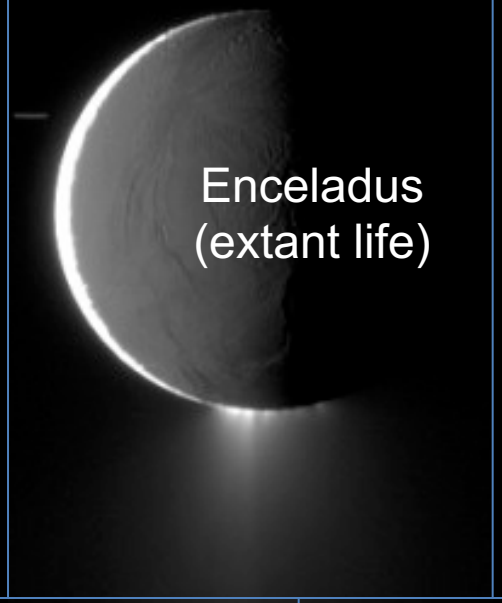
Typical '2-unit' objectives



Venus
In Situ Explorer

Comet Surface
Sample Return

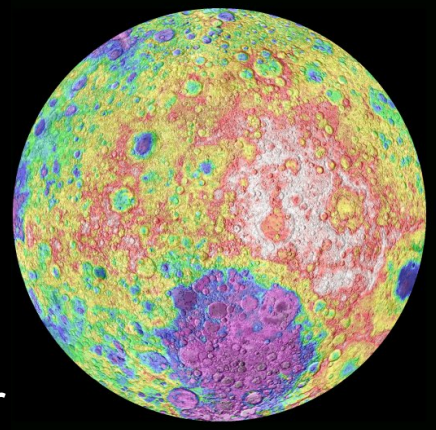
(CAESAR)



Enceladus
(extant life)

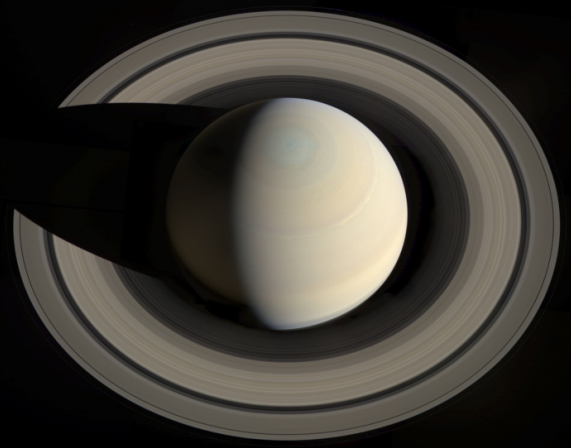
Titan
(habitability)

(Dragonfly)

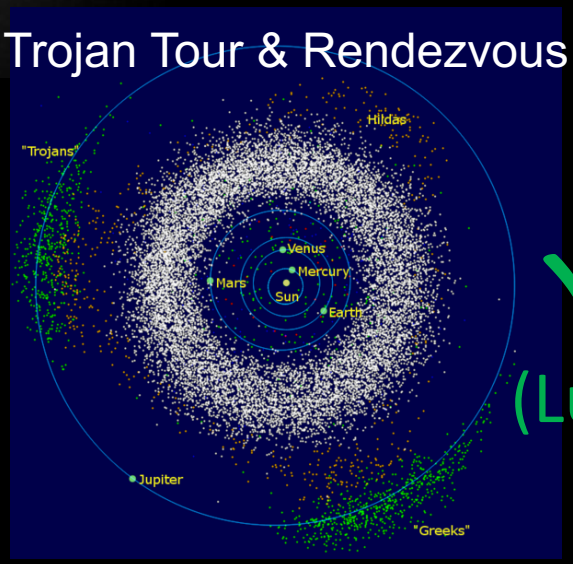


Lunar
South Pole – Aitken Basin
Sample Return

Saturn Probe



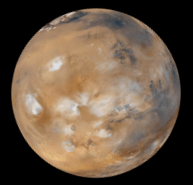
Trojan Tour & Rendezvous



(Lucy)

Our solar system has about a dozen ocean worlds. 3-4 and 5-6 unit missions could explore all of them.

Ocean Relicts



Mars

Ceres

Jovian icy moons

Europa

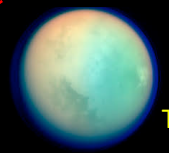
Ganymede

Callisto

Saturnian icy moons

Enceladus

Dione



Titan

Kuiper Belt Objects

Triton

Pluto

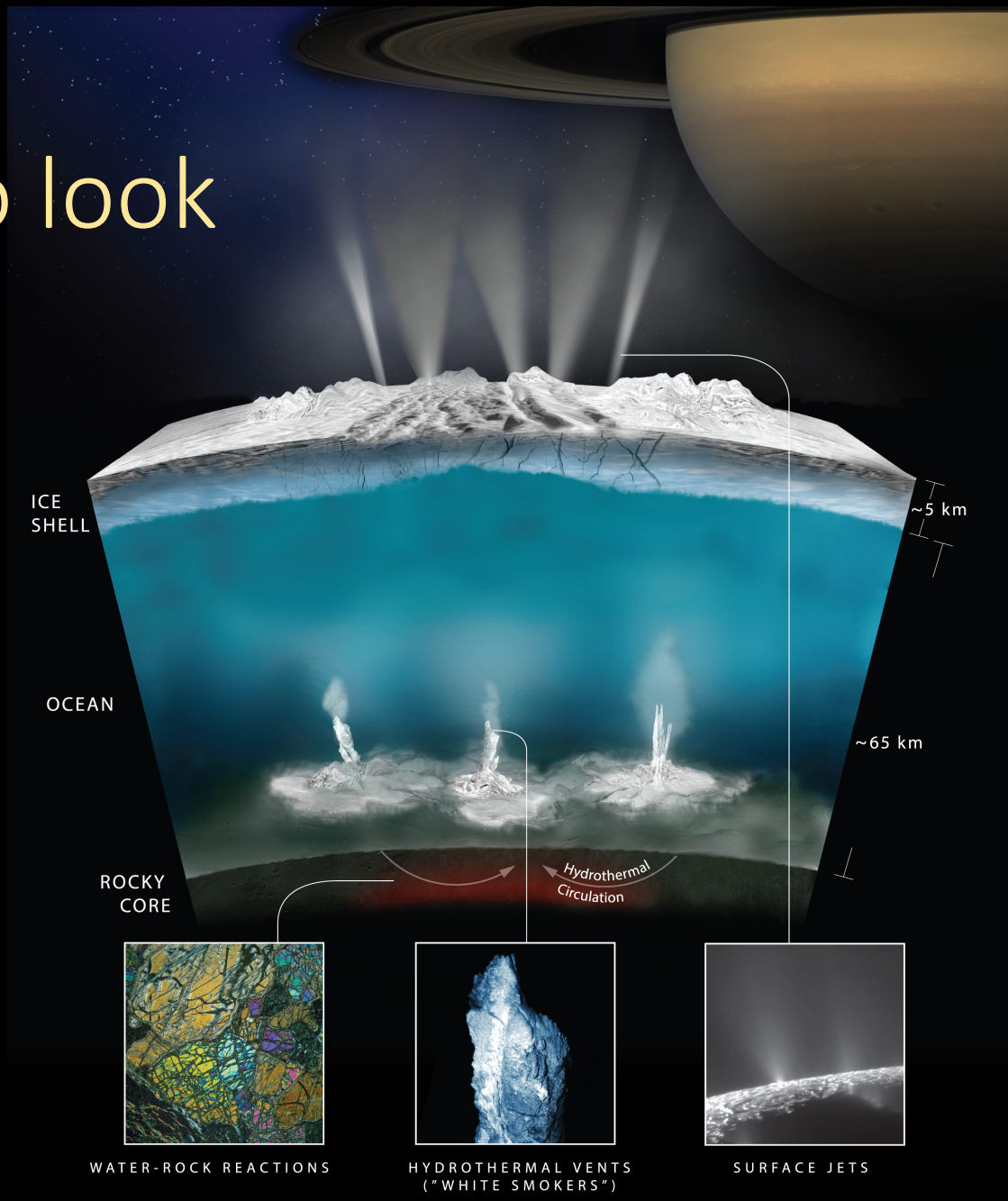
Charon

Key technologies common across the ocean worlds

- Planetary protection of and from ocean-world material
- “Life-detection” measurement techniques and instruments
- Sample acquisition, handling, preservation
- Cryogenic mechanisms and electronics
- Modular radioisotope power systems
- Autonomous, exploratory science investigations

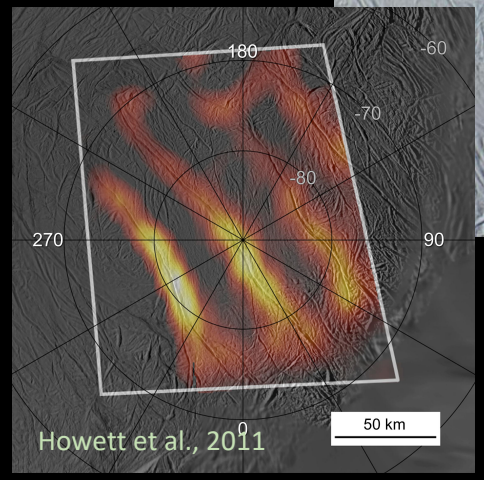
Enceladus: easiest place to look

- The most habitable place we know so far
- Salt-water ocean with hydrothermal activity
- Predictably expressed into space by a big plume, ripe for sampling

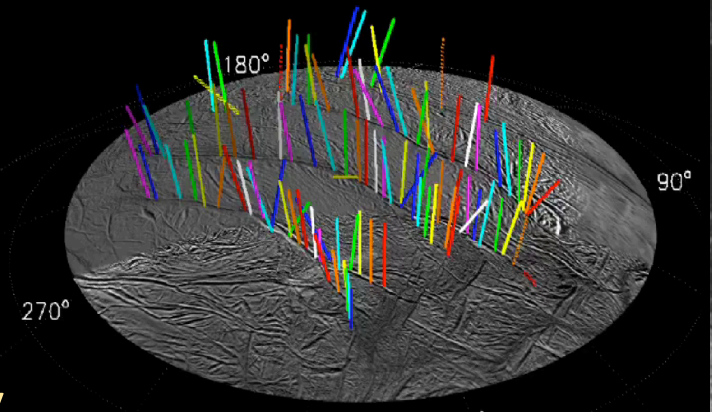


Awaiting focused missions

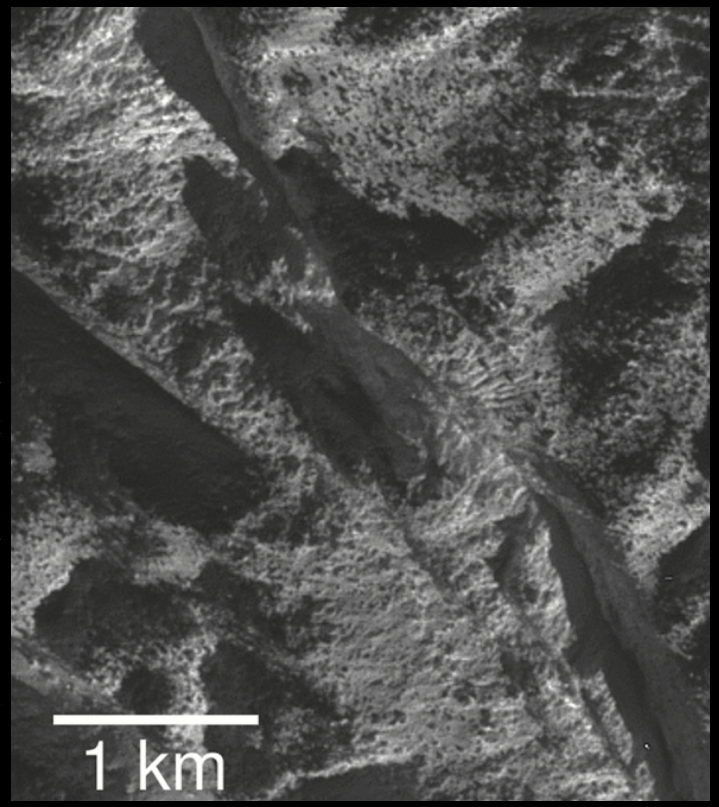
- Ice crust split by warm fissures
- > 100 geysers send large plume far into space, easy to transect
- Ice grains include silica dust and frozen ocean spray
- Salt water, hydrothermal circulation, organic chemistry



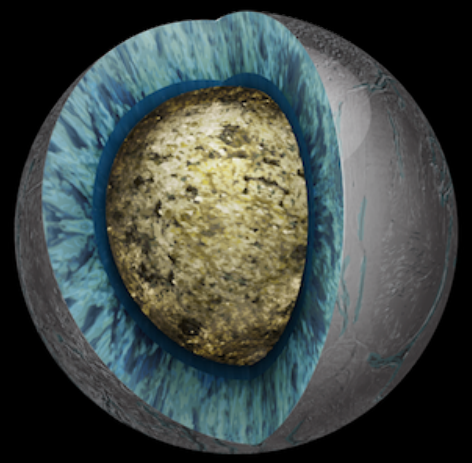
Howett et al., 2011



Porco et al., 2014



An Enceladus program in three steps

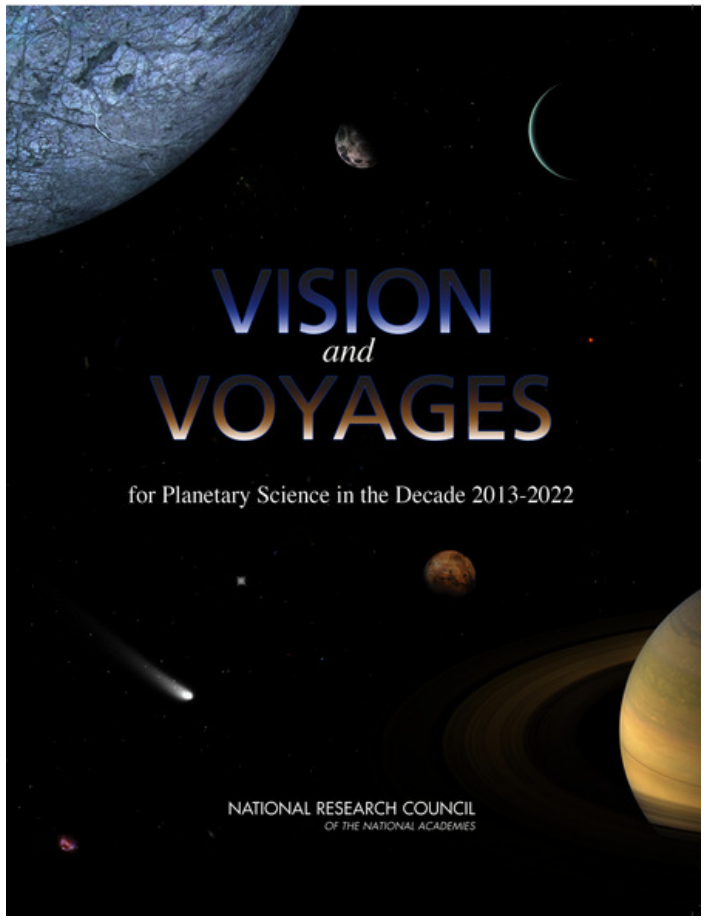


Direct access to material known to originate in a habitable place

- Plume transects
- Best compositional analyzers

- Wet-chemistry and microscopy of grain material
- Collection, preservation, and return of samples
- Surface collection of large amounts of material
- ‘Downhole’ access to the foaming interface
- Under-ice exploration of ocean ceiling
- Open ocean exploration, including seafloor hydrothermal systems known to exist

NASA scientific exploration guided by Decadal Surveys



Published
2011

Operative Period
2013 - 2022

Flagship priorities

Mars Sample Return

Europa

Ice Giants

Enceladus

Venus

"Next Planetary DS"

Operative Period

2023 - 2032

Planning Schedule

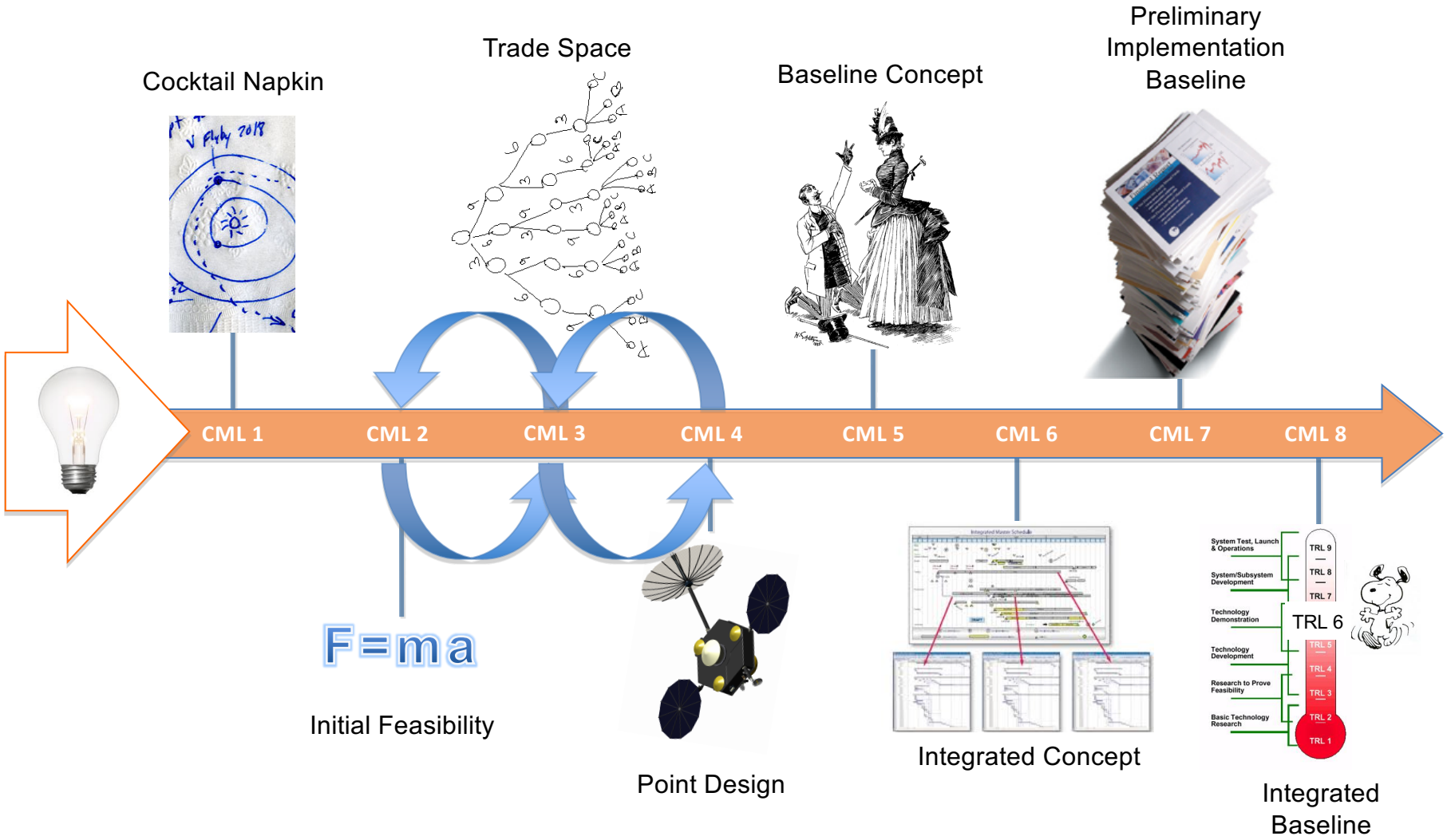
Tasked before Oct 2019

Reported out 1Q 2022

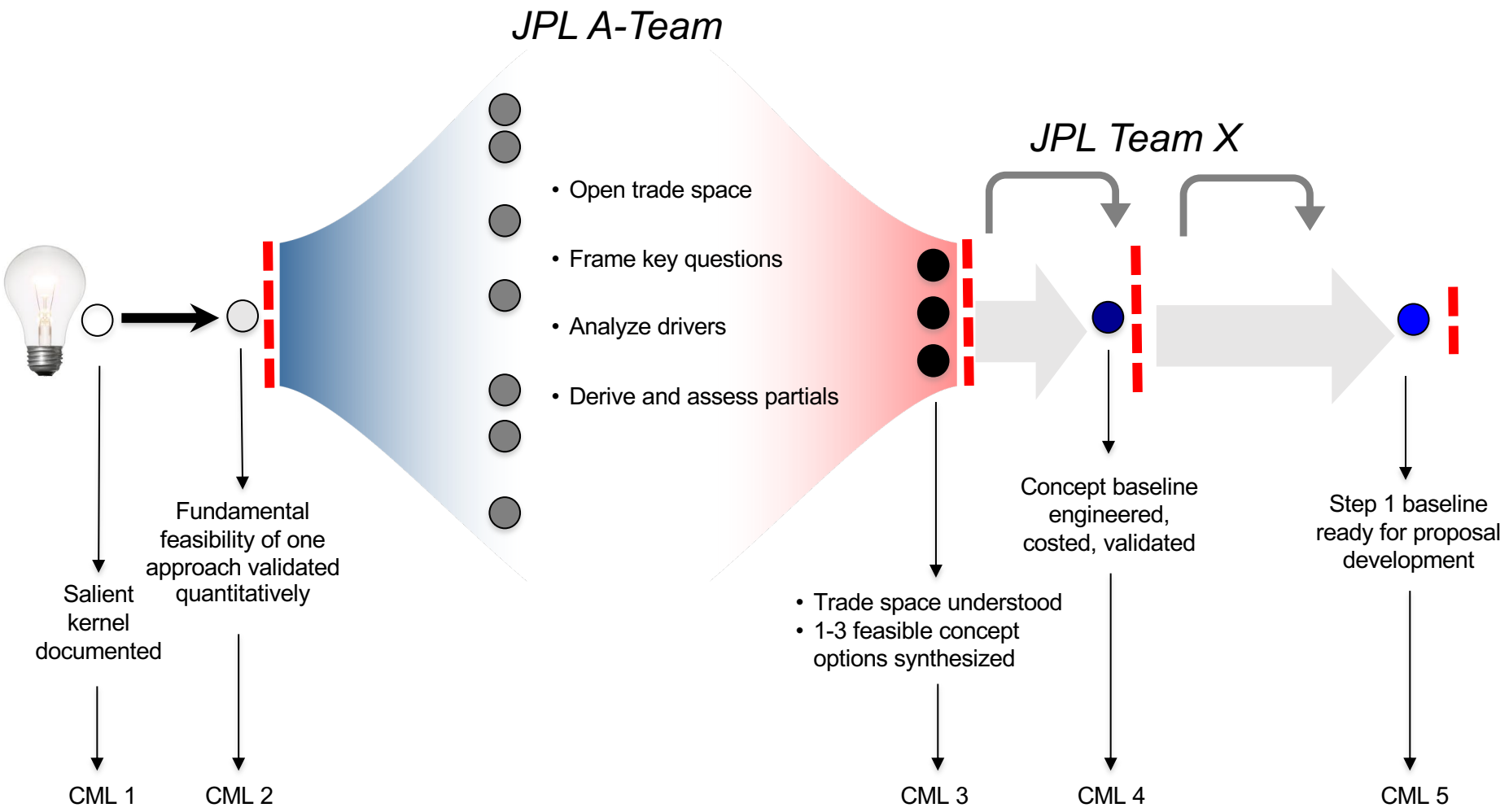
Potential deep-space science pursuits

- Search our ocean worlds for life
- Rewind our solar system's life story
  - Synergistic with human expansion onto the Moon
- Understand our 'local exoplanets'
  - How do "other Earths" evolve like Venus instead?
  - Ice Giants Uranus and Neptune: the most common planet type in the galaxy
- Explore the Outer Limits of our solar system

CML: concept maturity level



CML 3 enables Decadal ‘decision support ‘

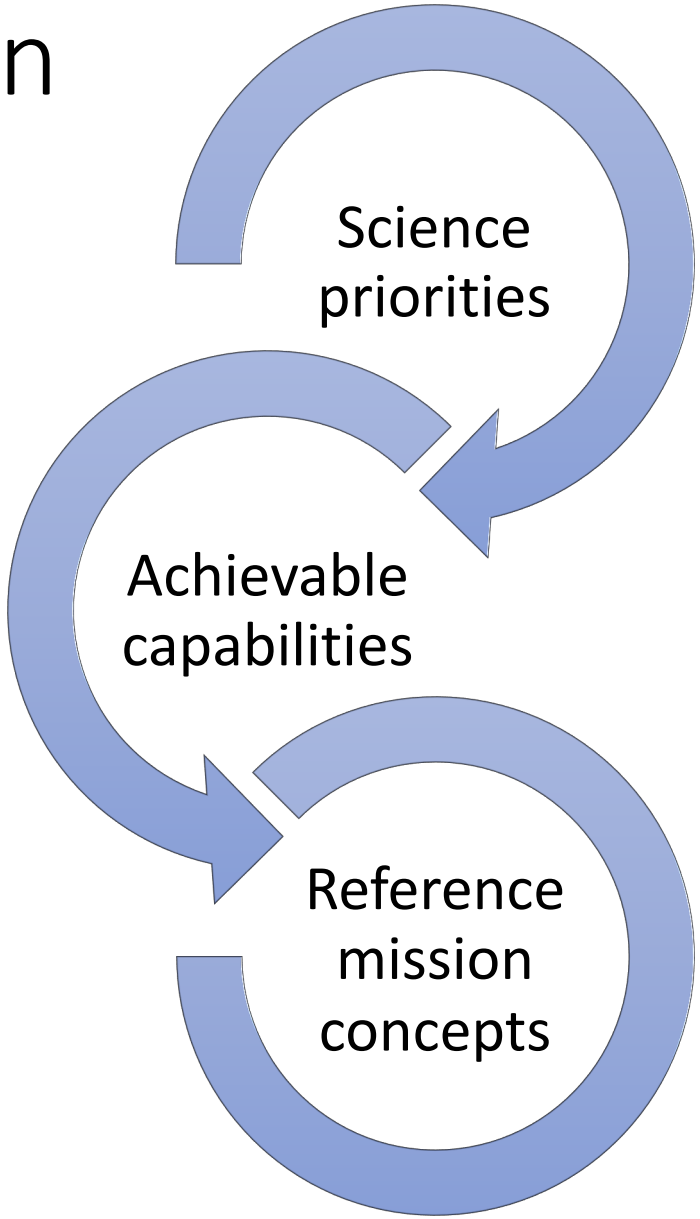


Setting course requires vision

Decadal Surveys operate with what they believe can be real...

...typically based on today's capabilities.

Could strategic studies be based on projecting evident trends?



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