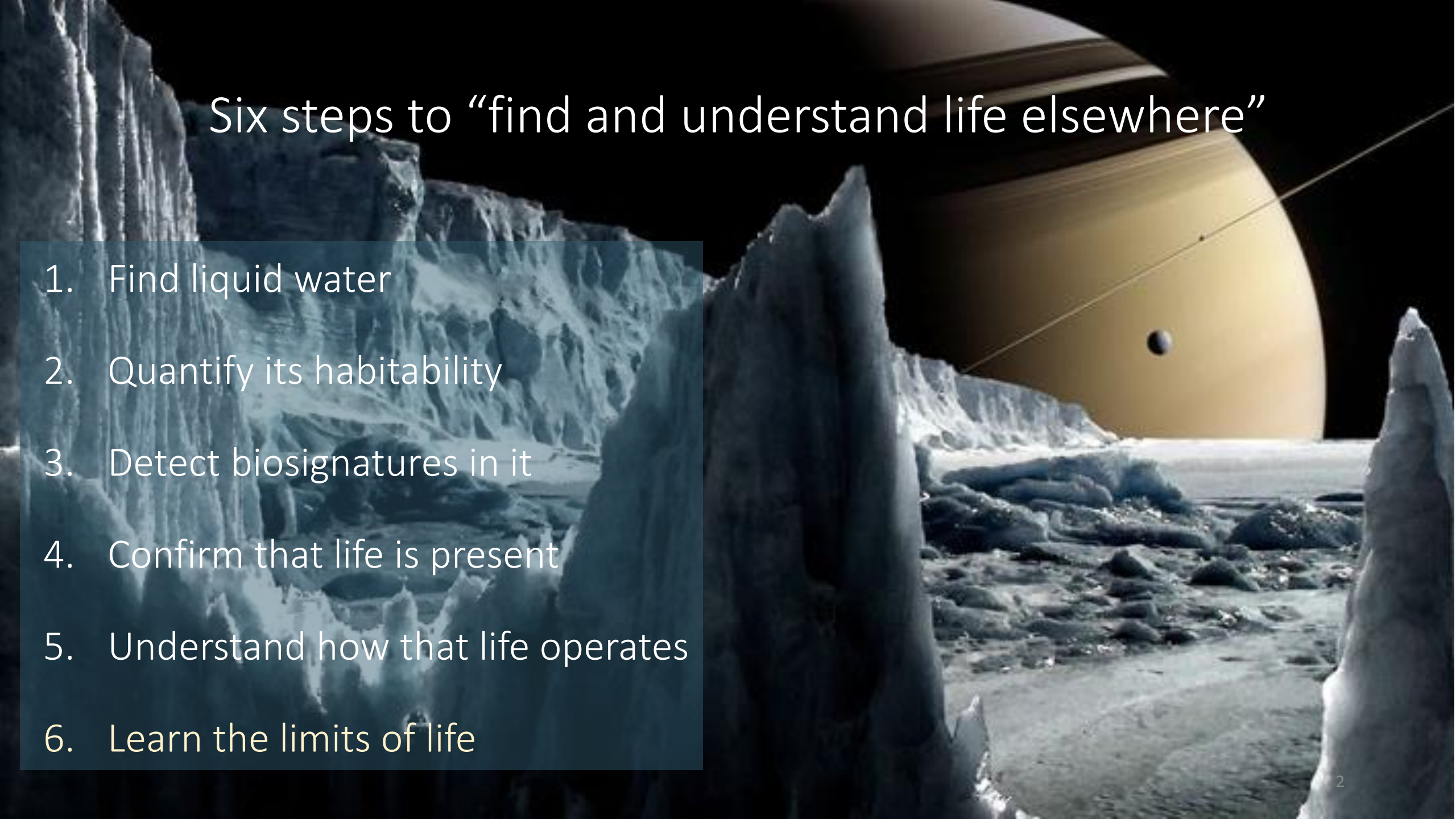
A focused ocean worlds strategy

based on Sherwood et al, GLEX, 2017*

Sherwood, B., Lunine, J., Sotin, C., Cwik, T., and Nadeiri, F. 2017 Program options to explore ocean worlds, Global Space Exploration Conference (GLEX 2017), Beijing, China, 6-8 June 2017. GLEX-17,6.4x36541

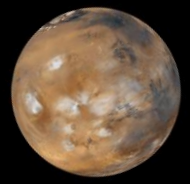
Six steps to “find and understand life elsewhere”



1. Find liquid water
2. Quantify its habitability
3. Detect biosignatures in it
4. Confirm that life is present
5. Understand how that life operates
6. Learn the limits of life

More than a dozen ocean worlds within reach, but three are of special interest

Ocean Relicts



Mars

Ceres

Jovian icy moons

Europa

Ganymede

Callisto

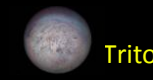
Saturnian icy moons

Enceladus

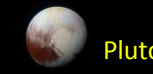
Dione

Titan

Kuiper Belt Objects



Triton



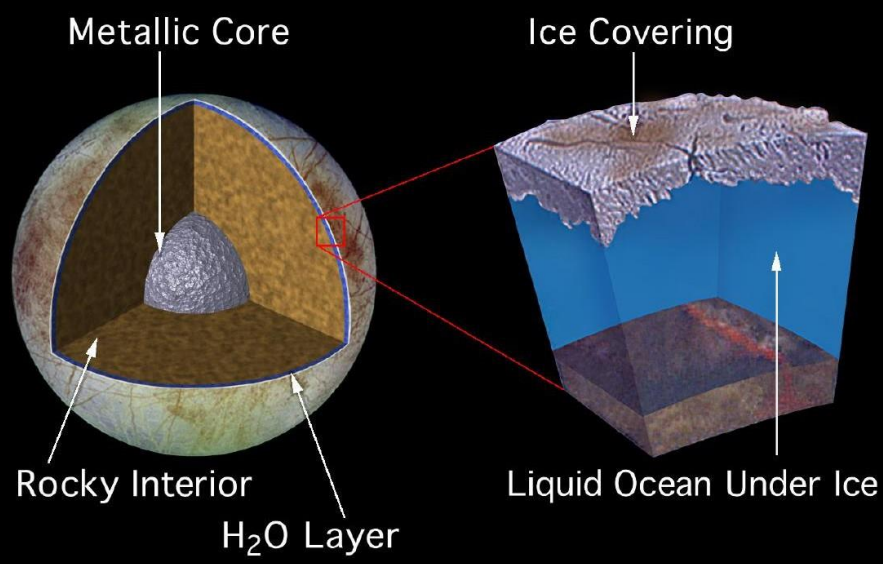
Pluto

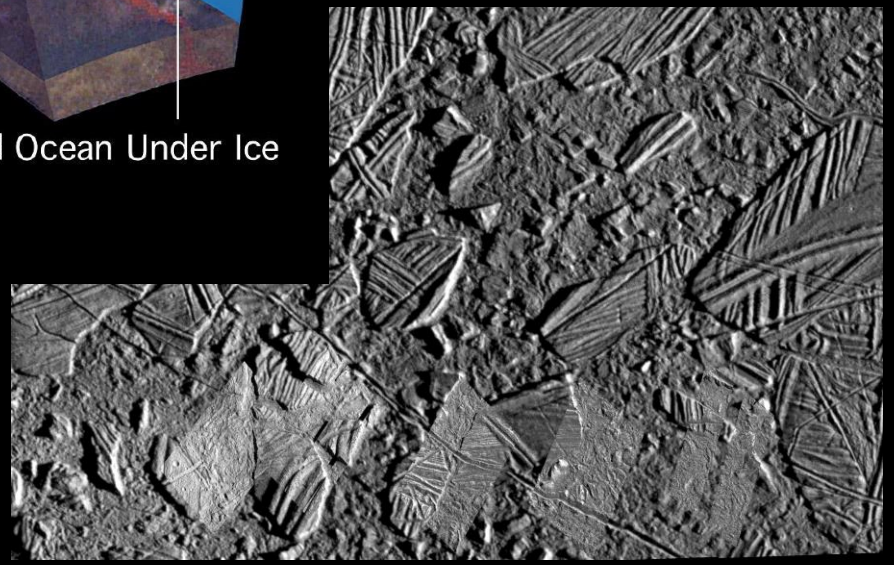
Charon

Craft an ocean worlds exploration program (OWEP) in response

Europa: best place for conventional life?

- Almost as large as Earth's Moon
- Ocean twice the volume of Earth's in contact with silicate rock
- Possible mechanism to sustain redox disequilibrium via radiolysis of surface ice
- A lot not known (pH, organics, hydrothermal activity…)

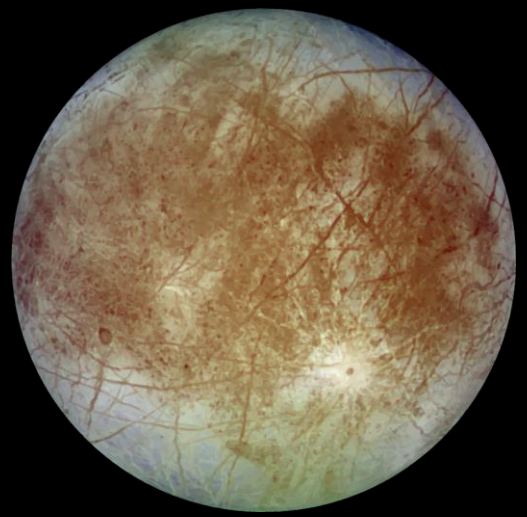




A Europa program in three steps

Comprehensive investigation of the icy moon's habitability

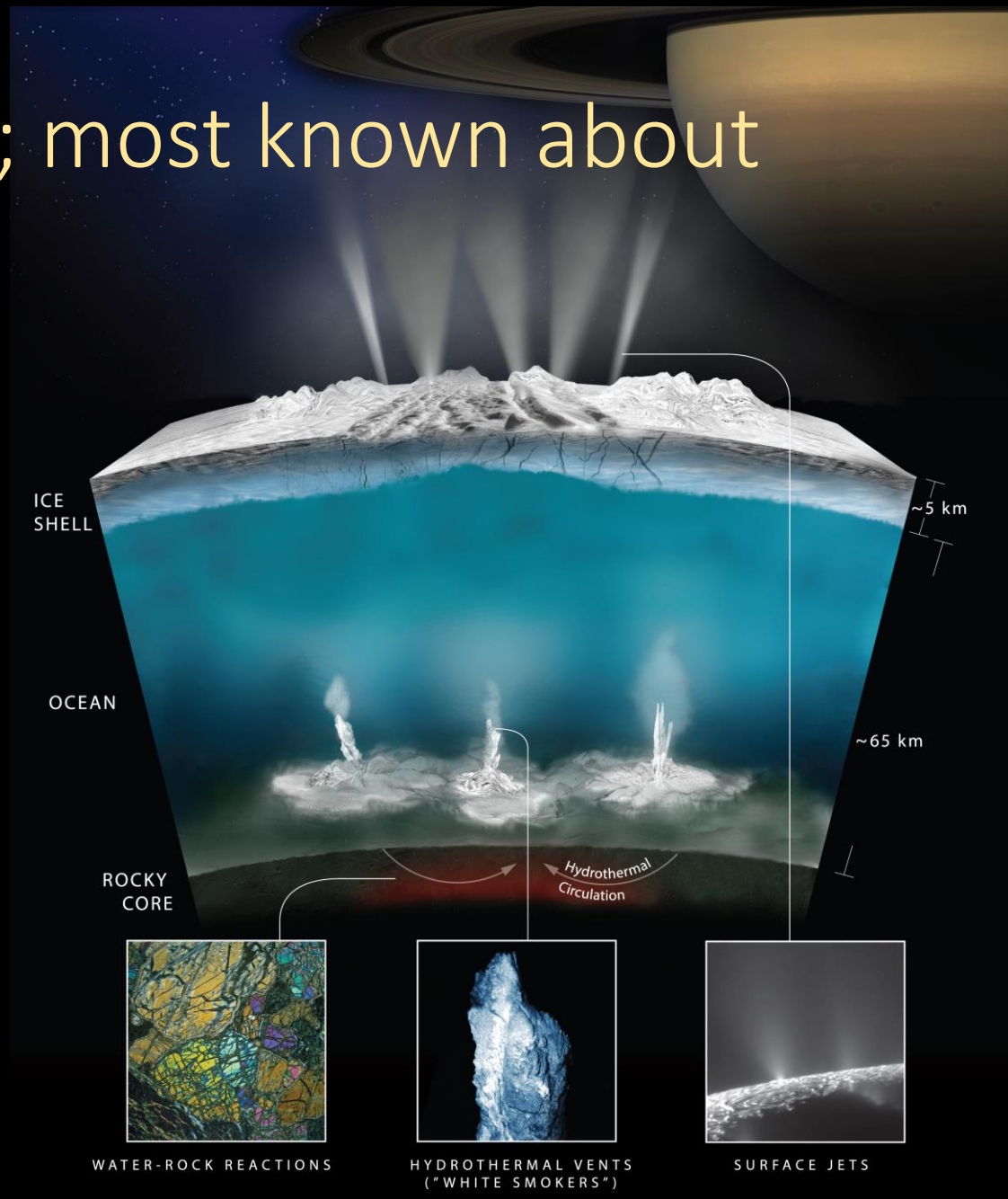
- Clipper suite for ocean habitability, history of crust
- Lander-scale surface imagery



- Land at ocean-surface exchange zone
- Mobility around touchdown point
- Subsurface access to pursue fresher material
- Trans-shell probe into ocean, sample return
- Under-ice exploration of ocean ceiling
- Open ocean exploration, including seafloor

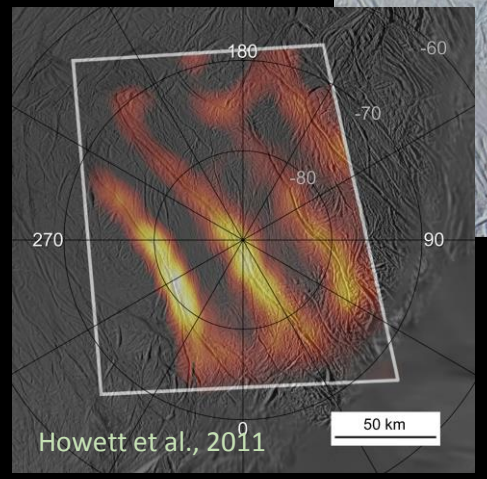
Enceladus: easiest to explore; most known about the ocean

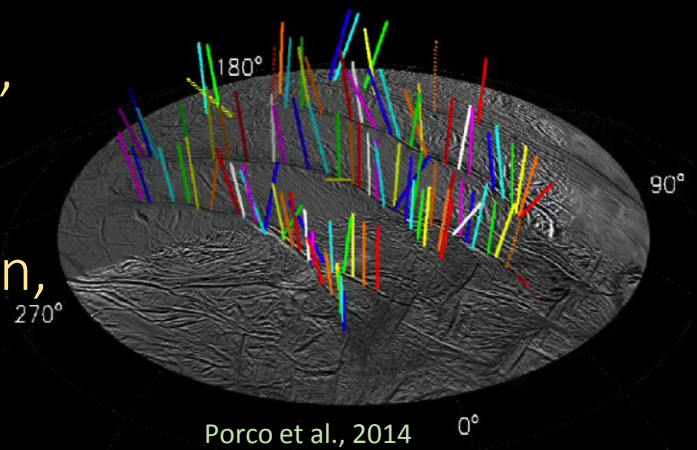
- Salt-water ocean with established hydrothermal activity
- Ocean reliably expressed into space by a big plume, ability to sample demonstrated by Cassini
- By today's standard, the most habitable place known off Earth

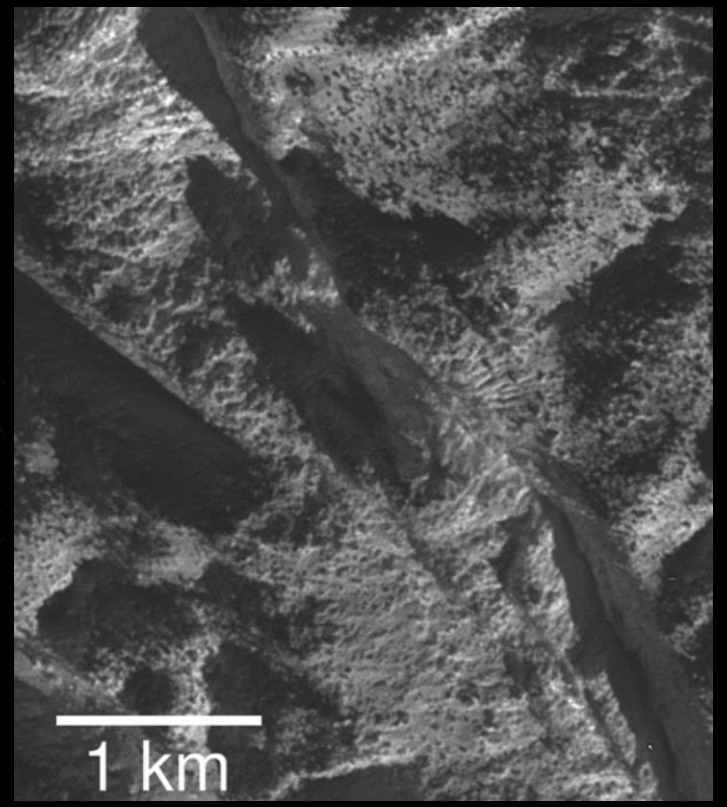


Awaiting focused missions

- Ice crust split by warm fissures
- > 100 jets or a complex of curtain eruptions send material far into space, plume is easy to transect
- Ice grains include silica nanograins, organics and frozen ocean spray
- Salt water, hydrothermal circulation, organic chemistry
- Next step is to look for signs of life







An Enceladus program in three steps

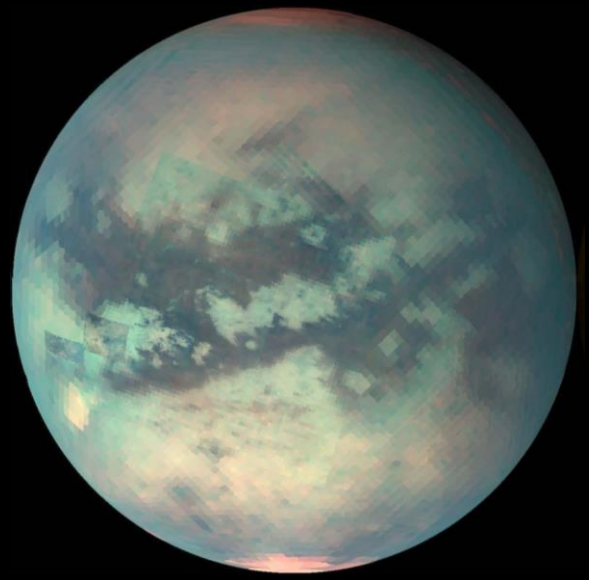
Direct access to material known to originate in a habitable ocean

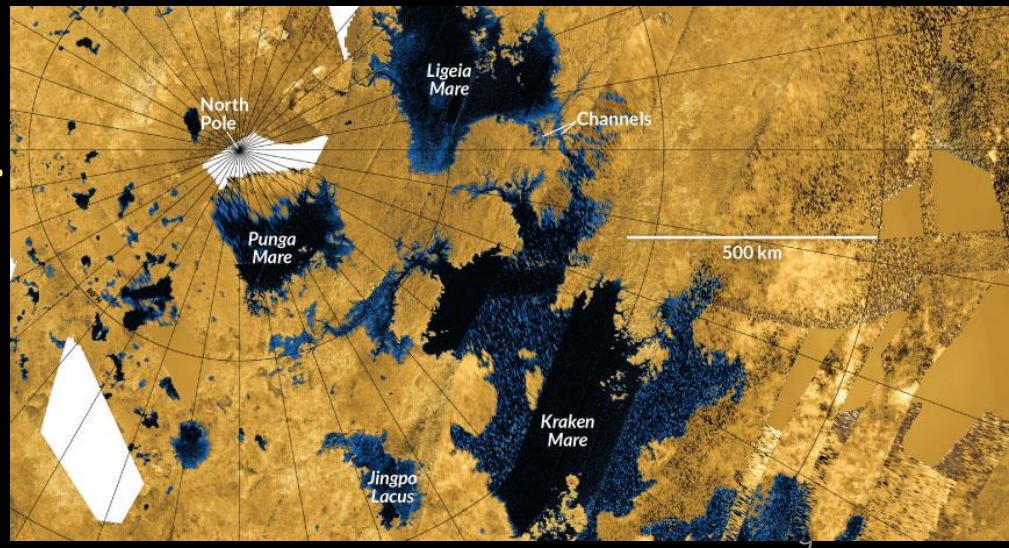
- Plume transects
- Sensitive and agnostic compositional analyzers

- 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

Titan is the once and future Earth

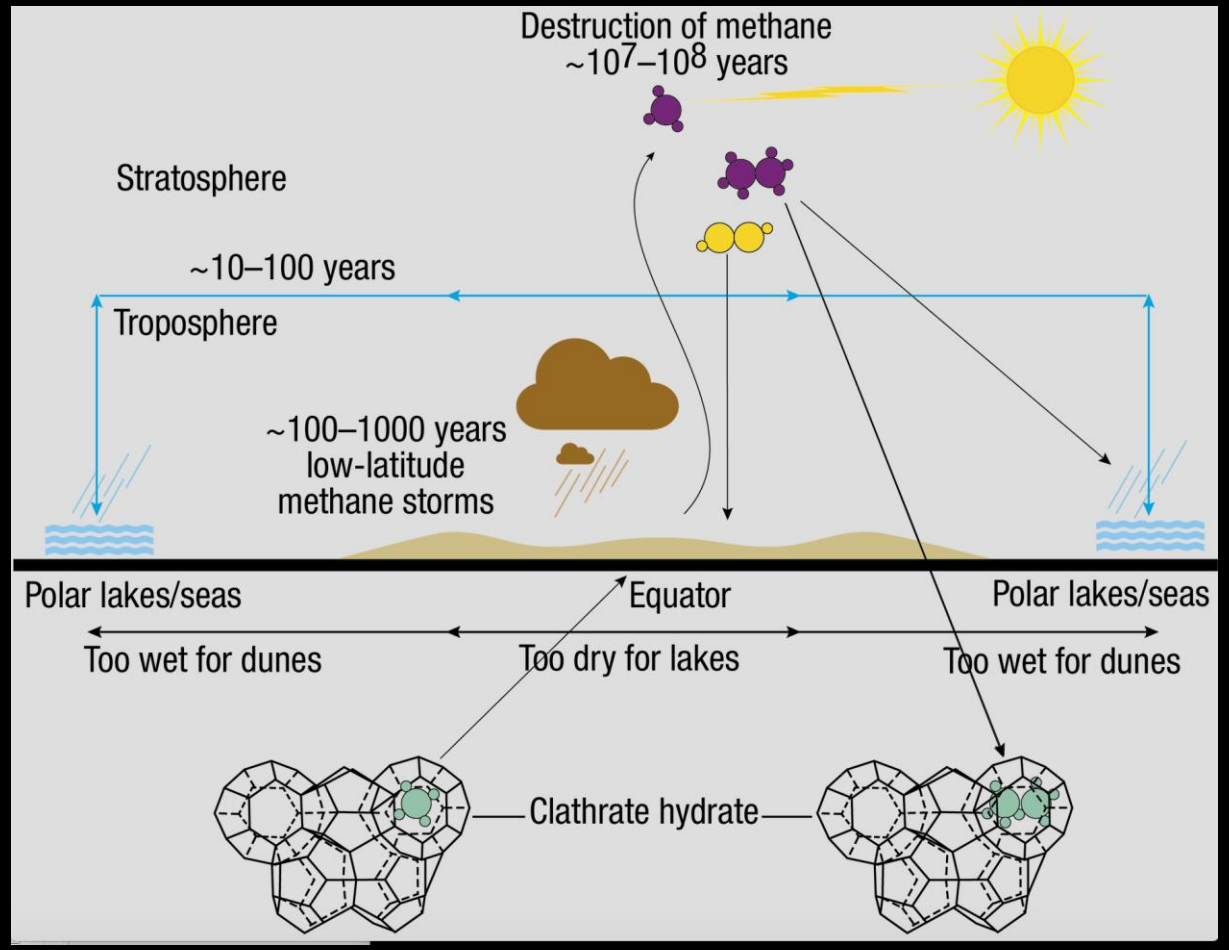
- Before Earth was a “pale blue dot” was it a pale orange dot?
- Titan may play out in methane the post-ocean hydrologic cycle of Earth’s far future.
- A world with a subsurface ocean of (salty) water and surface seas of methane, ethane…





Titan: best place to look for weird biochemistry?

- Organic molecules capture energy from sunlight in upper atmosphere
- Methanogenic cycle weathers ice and organic sediment on surface
- Stable surface seas of methane etc. How far can chemical evolution proceed in such systems? Across the life "threshold" ?(whatever that is)



A Titan program in three steps

Comprehensive reconnaissance of a complex world

- Atmospheric organics factory
- Global hi-res surface mapping
- Remote sense subsurface

Aerial exploration

Buoyant sea exploration

Mobile surface exploration

In situ analysis of weathered organics

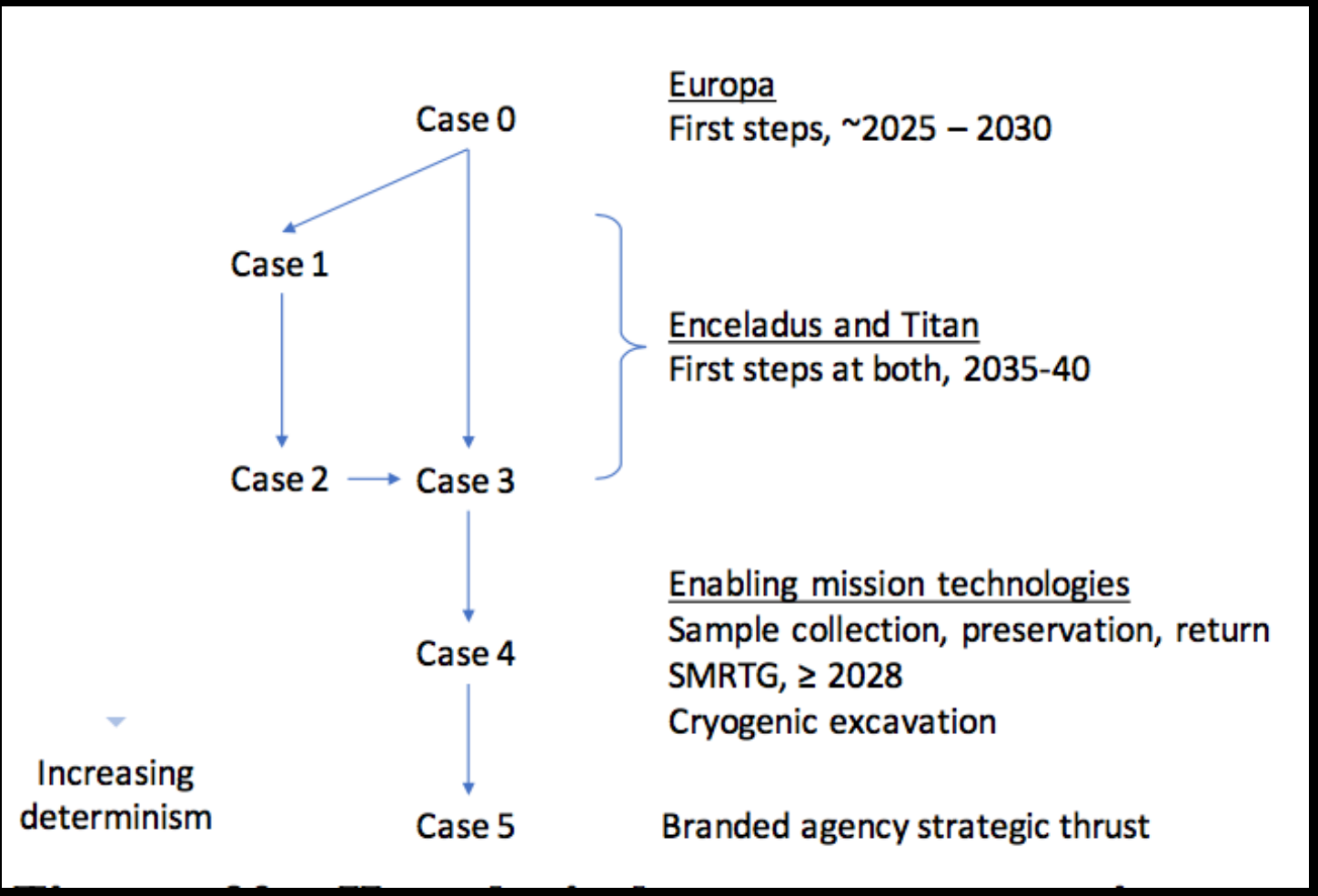
Sample return

Through-crust ocean access

Key technologies are common to all the targets (caution—some of these not needed in early steps)

- 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 exploration that conducts science investigations

Program options for an OWEP



Case 0 – Status quo today
Case 1 – Select two New Frontiers missions in 2019
Case 2 – Select two New Frontiers missions every 5 years
Case 3 – Create $1B directed-purpose mission class for OW
Case 4 – Add strategically managed OW Technology Program
Case 5 – Establish a formal Ocean Worlds Exploration Program

Issues

1. This OWEP vs ROW: focus on specific promising targets, or explore others to see if they are promising?

3. Our community’s love-hate relationship with the search for life beyond Earth: the case of the unimpressed undergra

4. What if we succeed?