Outer Solar System Sample Return

Enceladus and Beyond

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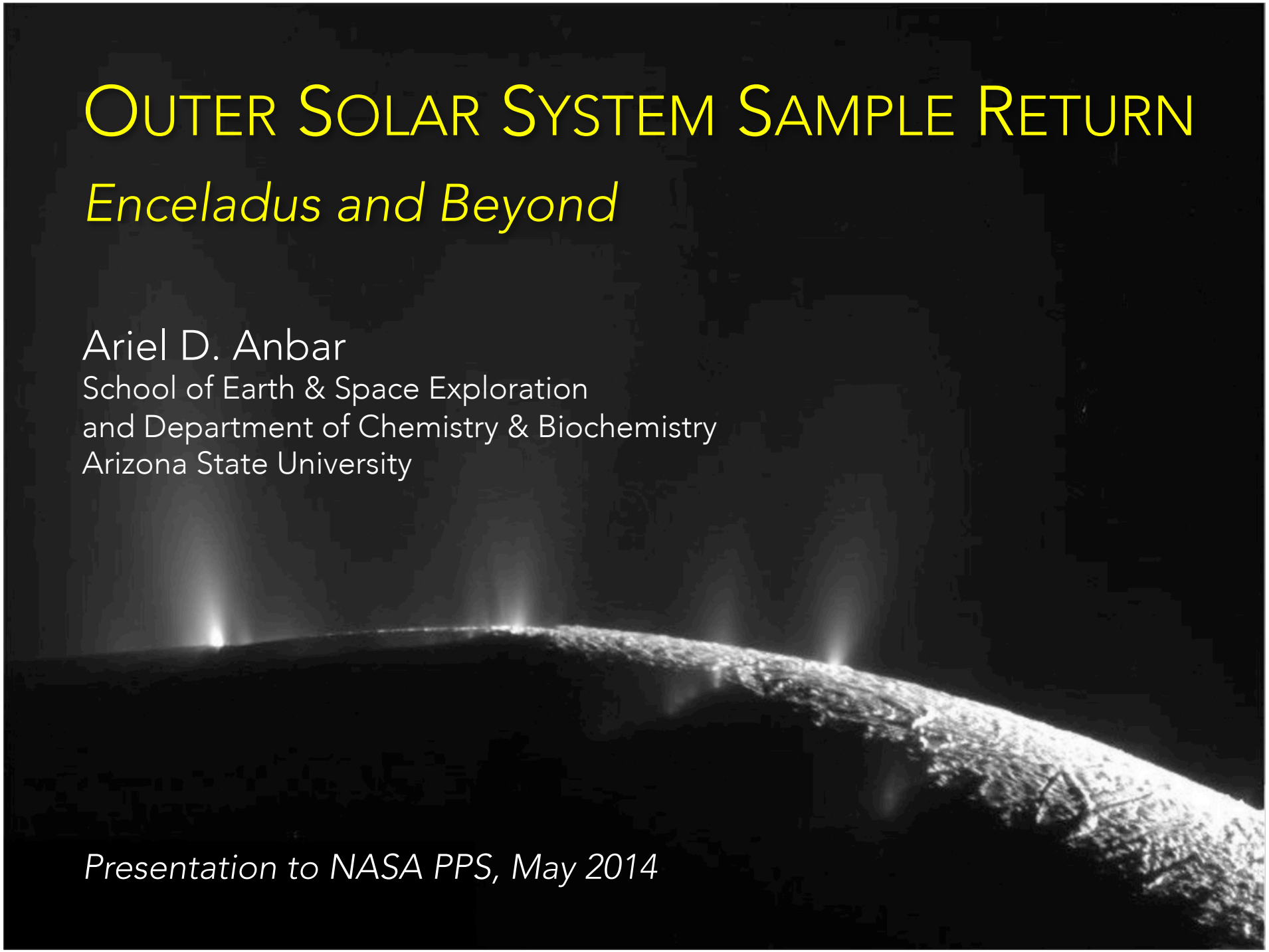


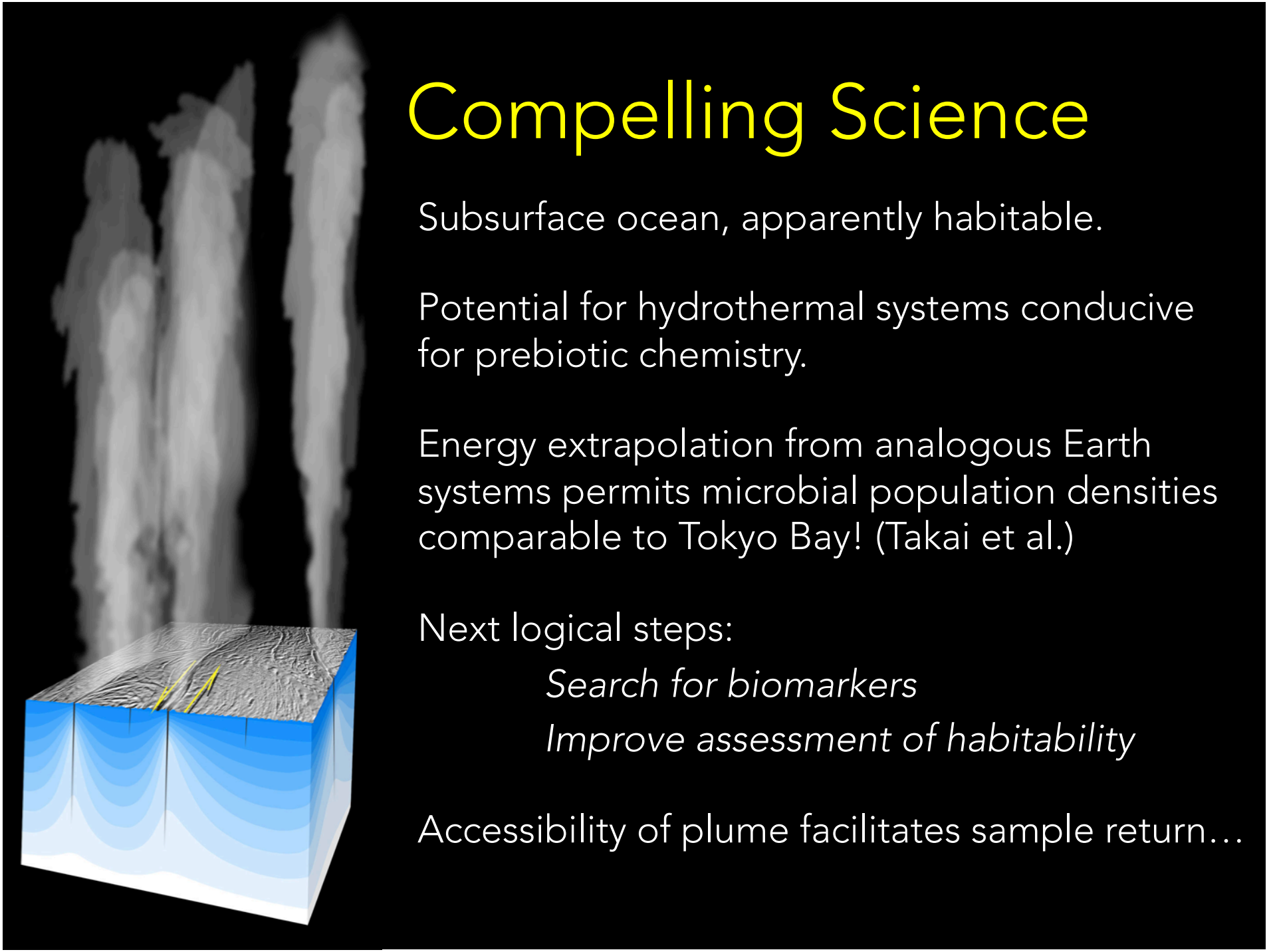
Presentation to NASA PPS, May 2014

Compelling Science

Cassini's remarkable discoveries at Enceladus:

- *Water*
- *Energy*
- *Bioessential elements*
- *Organic molecules*

Indications of habitability…



Compelling Science

Subsurface ocean, apparently habitable.

Potential for hydrothermal systems conducive for prebiotic chemistry.

Energy extrapolation from analogous Earth systems permits microbial population densities comparable to Tokyo Bay! (Takai et al.)

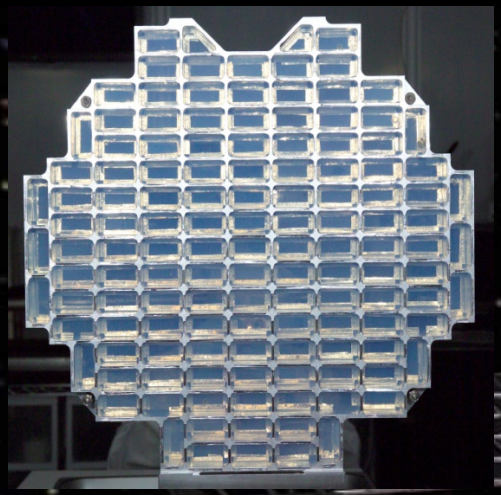
Next logical steps:

Search for biomarkers

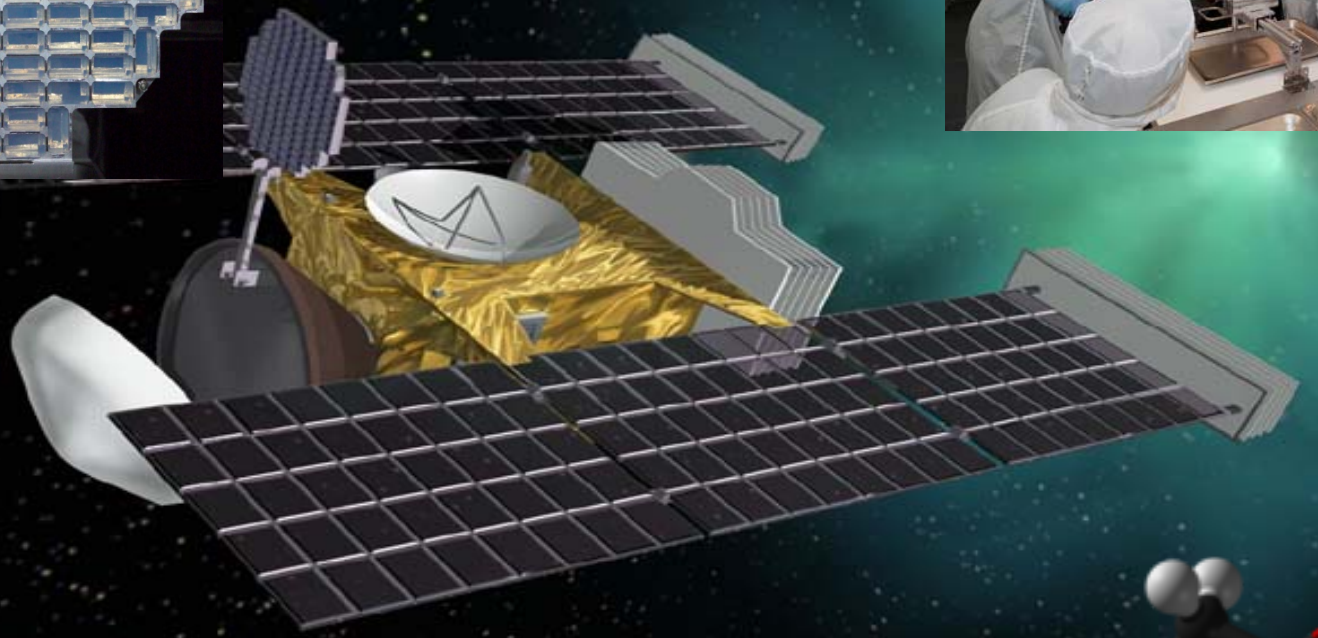
Improve assessment of habitability

Accessibility of plume facilitates sample return…

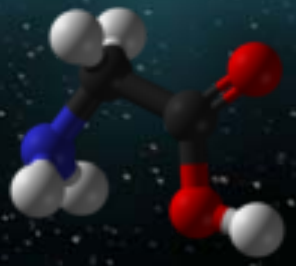
STARDUST: First Comet Sample Return



Dust grains (> 1000) and volatiles captured by aerogel and returned to Earth.



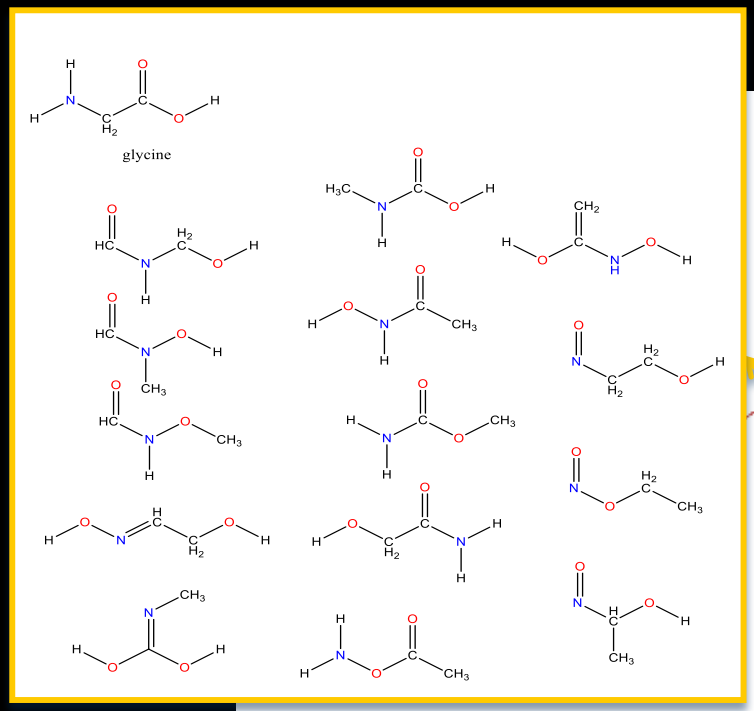
glycine



Lab analyses showed elevated levels of glycine.
First detection of a cometary amino acid.

The Need for Terrestrial Laboratories and Techniques

Stage 2: Chemical Derivatization



Stage 1: High Mass Resolution

RP > 10,000 is needed to differentiate glycine from other interferences at m/z 75 but cannot differentiate all structural isomers; this is true for many organic molecules of interest. RP of the best flight-qualified MS today is still a factor of 3-4 short. Derivatization is difficult and limited *in situ*. Ground-based capabilities unmatched.

LIFE INVESTIGATION FOR ENCELADUS

SAMPLES FROM ENCELADUS • FLAGSHIP SCIENCE • DISCOVERY BUDGET

CONTEXT

The Cassini Mission discovered water emanating from a subsurface liquid ocean on Enceladus. *In situ* analyses of this plume indicate the ocean is habitable, offering chemical energy, bioessential elements, and organic building blocks. *Is it inhabited? If not, why not?*

MISSION STRATEGY

- Capture, return, and characterize plume samples
- *In situ* analyses of volatiles that are not easily captured or retained

SCIENCE GOALS

- Understand the nature and sources of plume materials
- Search for biomarkers in organic molecules from the plume
- Quantify the capacity for life in the subsurface ocean

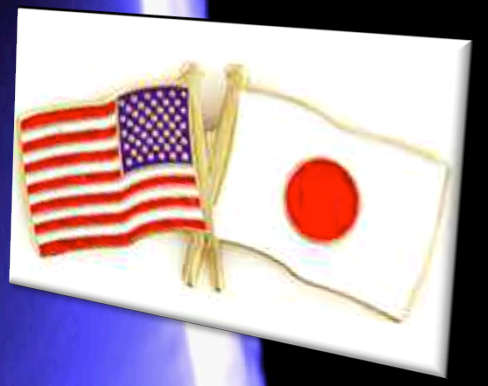
WHY SAMPLE RETURN?

- Ground-based labs offer unmatched characterization capabilities
- Enables complex, repeated, contingent, unanticipated investigations

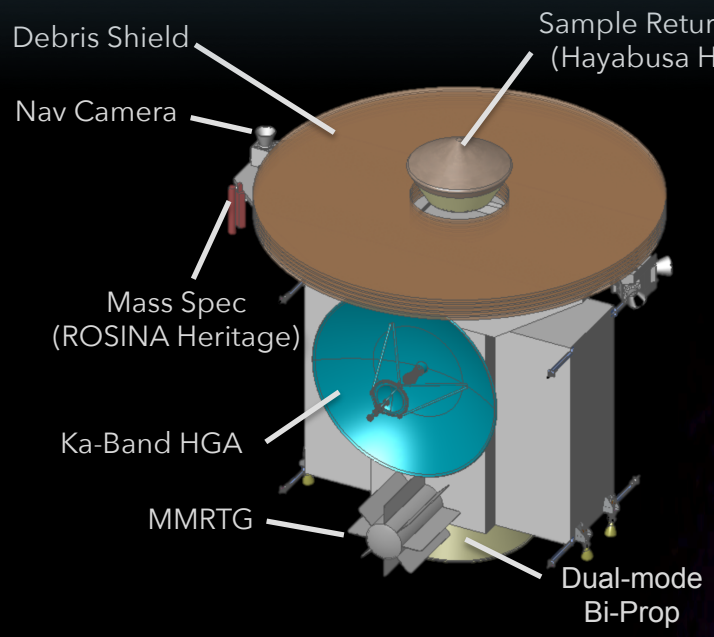
WHY NOT WAIT?

- Strategic partnerships are in place
- Enables key experience to be leveraged
- Technology is mature
- Uncertain plume longevity

LIFE INVESTIGATION FOR ENCELADUS

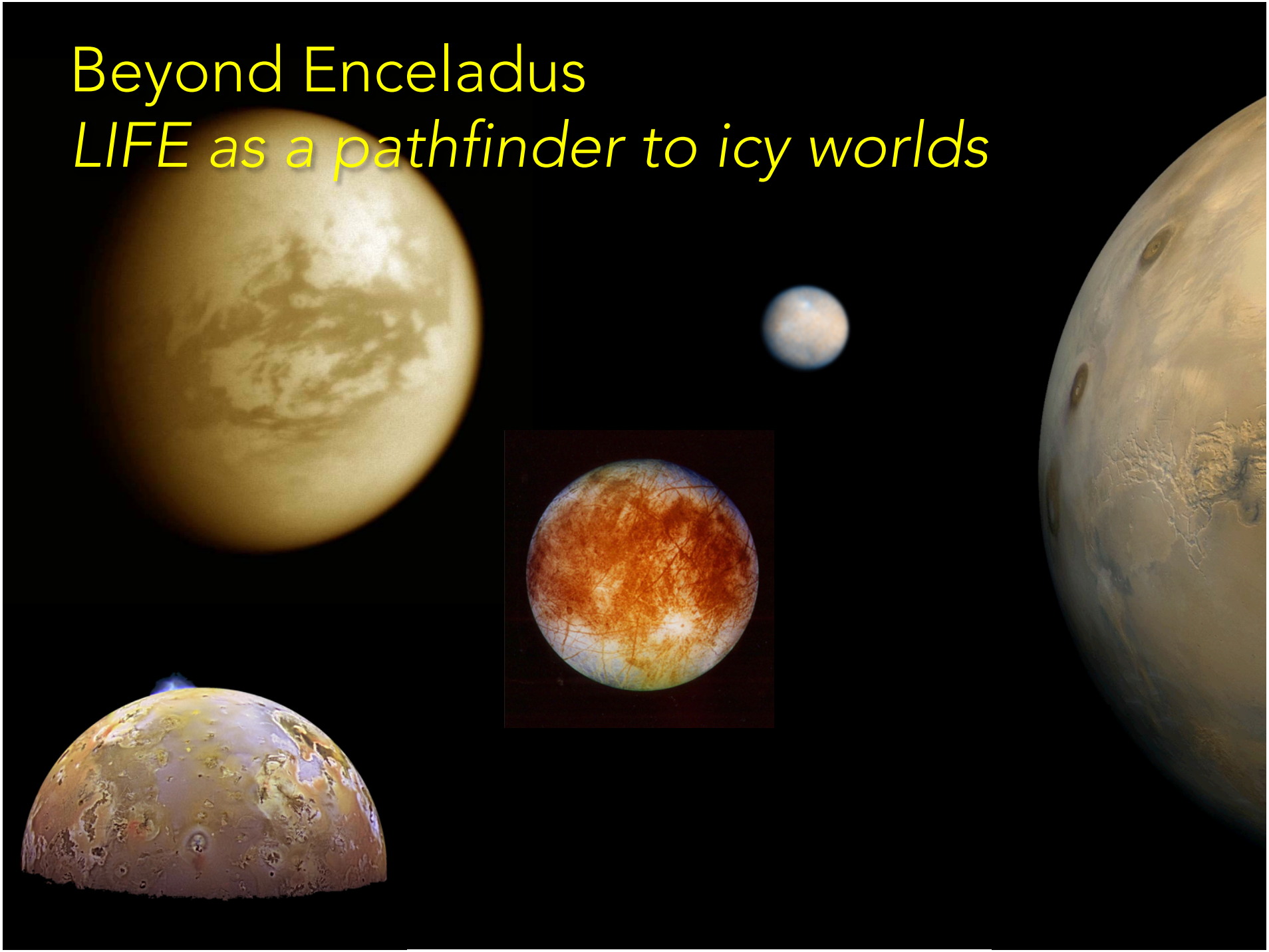


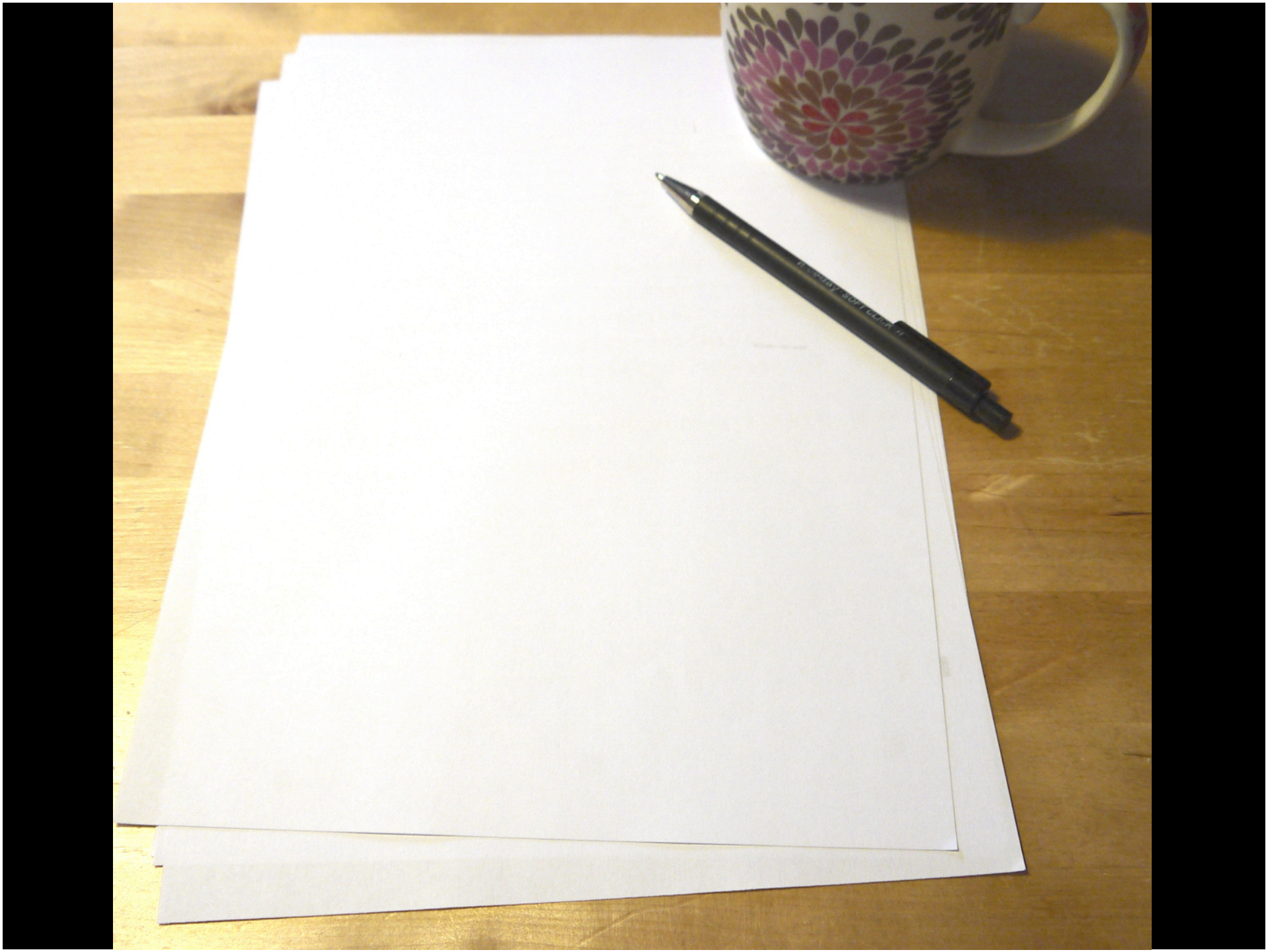
Flight System

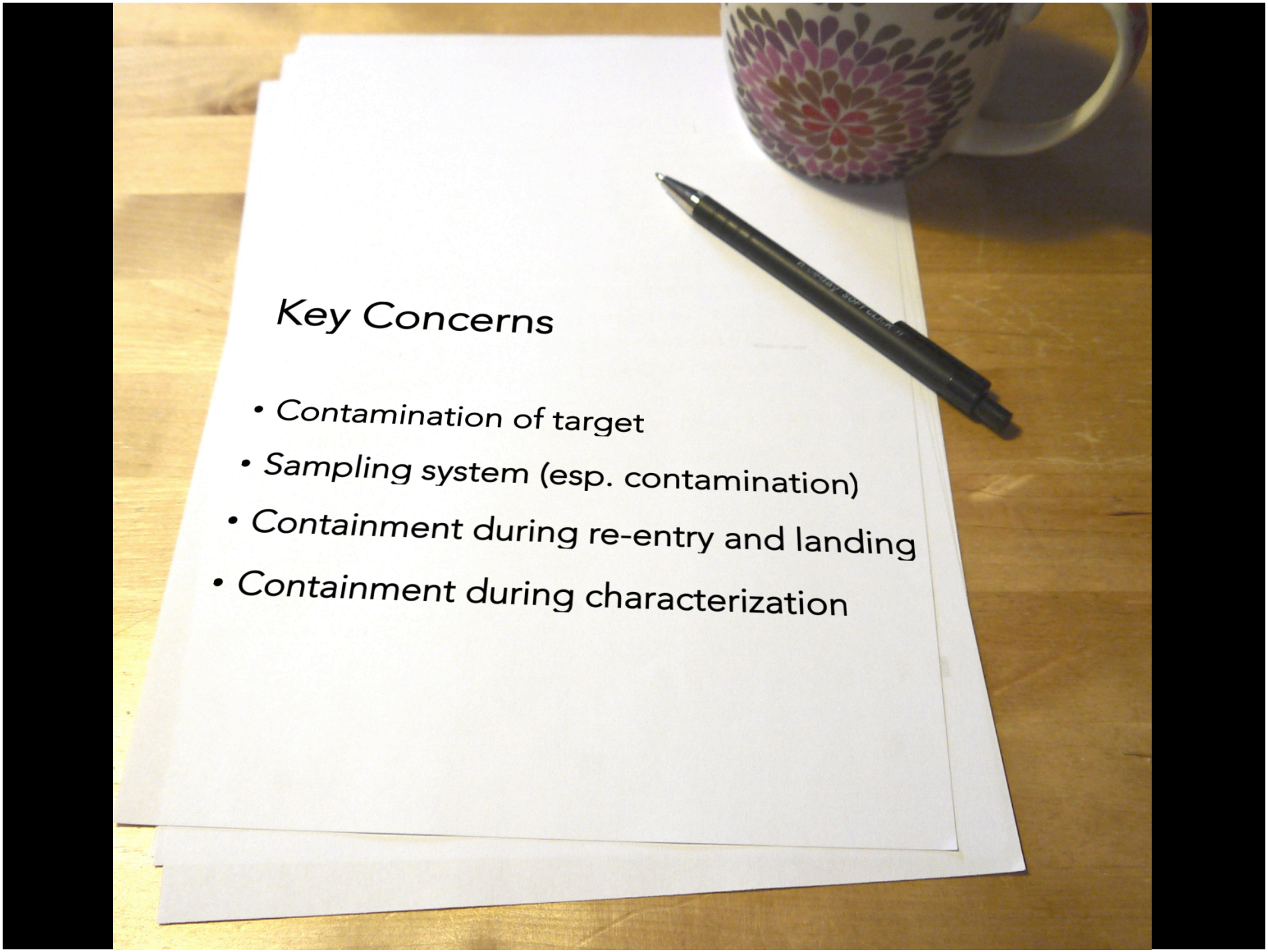


Beyond Enceladus

LIFE as a pathfinder to icy worlds

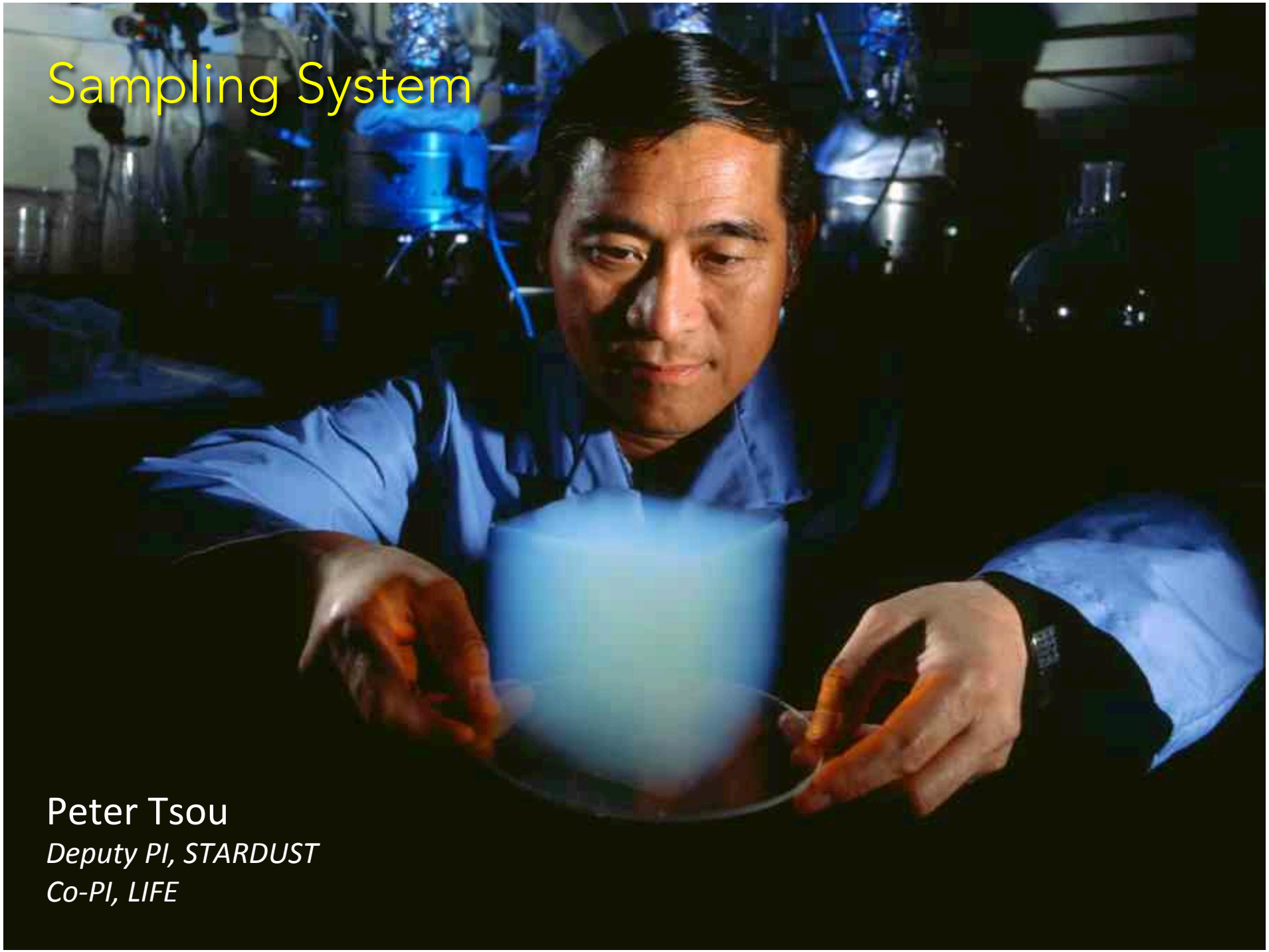





Key Concerns
• Contamination of target
• Sampling system (esp. contamination)
• Containment during re-entry and landing
• Containment during characterization

Contamination of Target

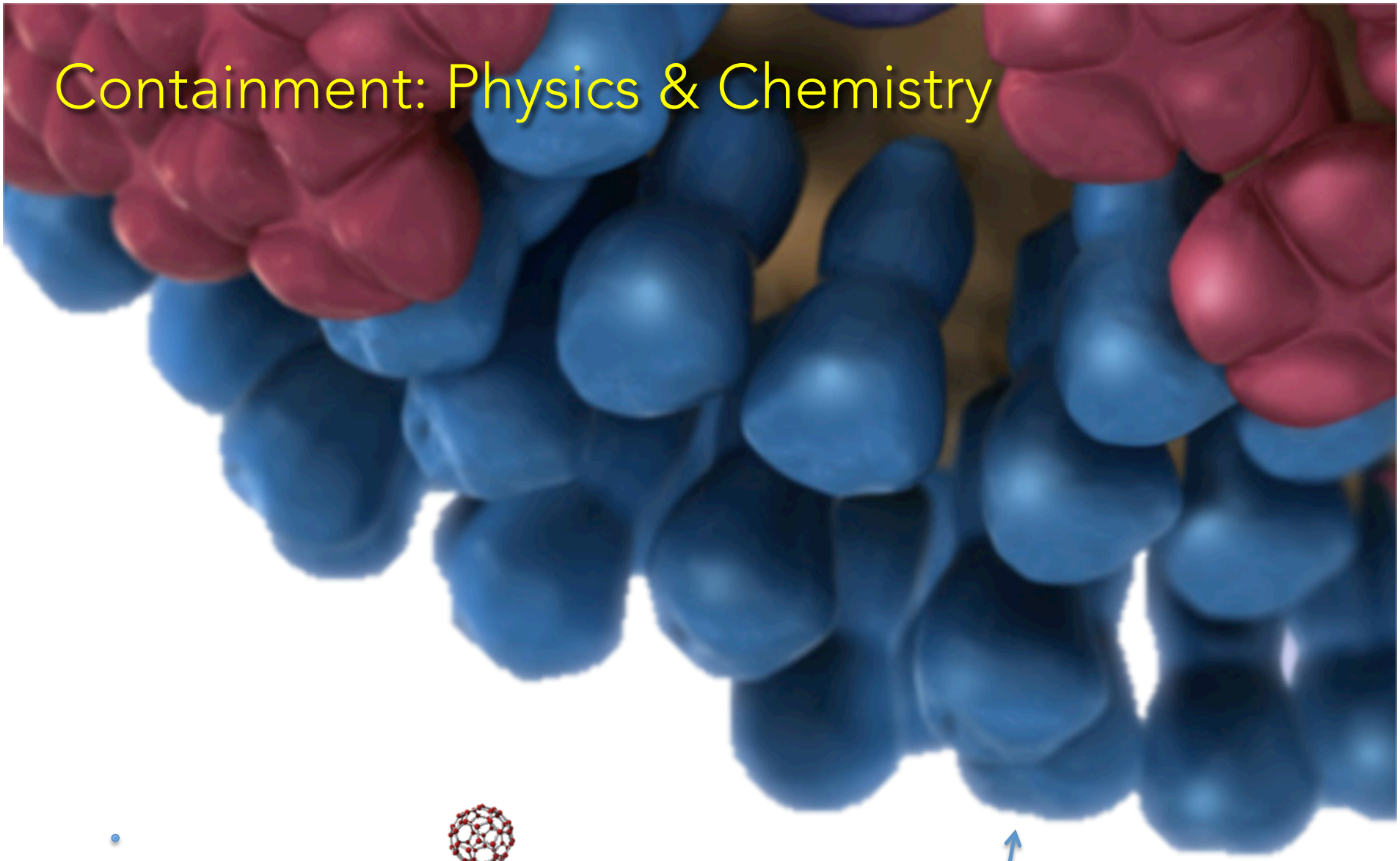
Sampling System



Peter Tsou
Deputy PI, STARDUST
Co-PI, LIFE

Breaking the Chain

Containment: Physics & Chemistry

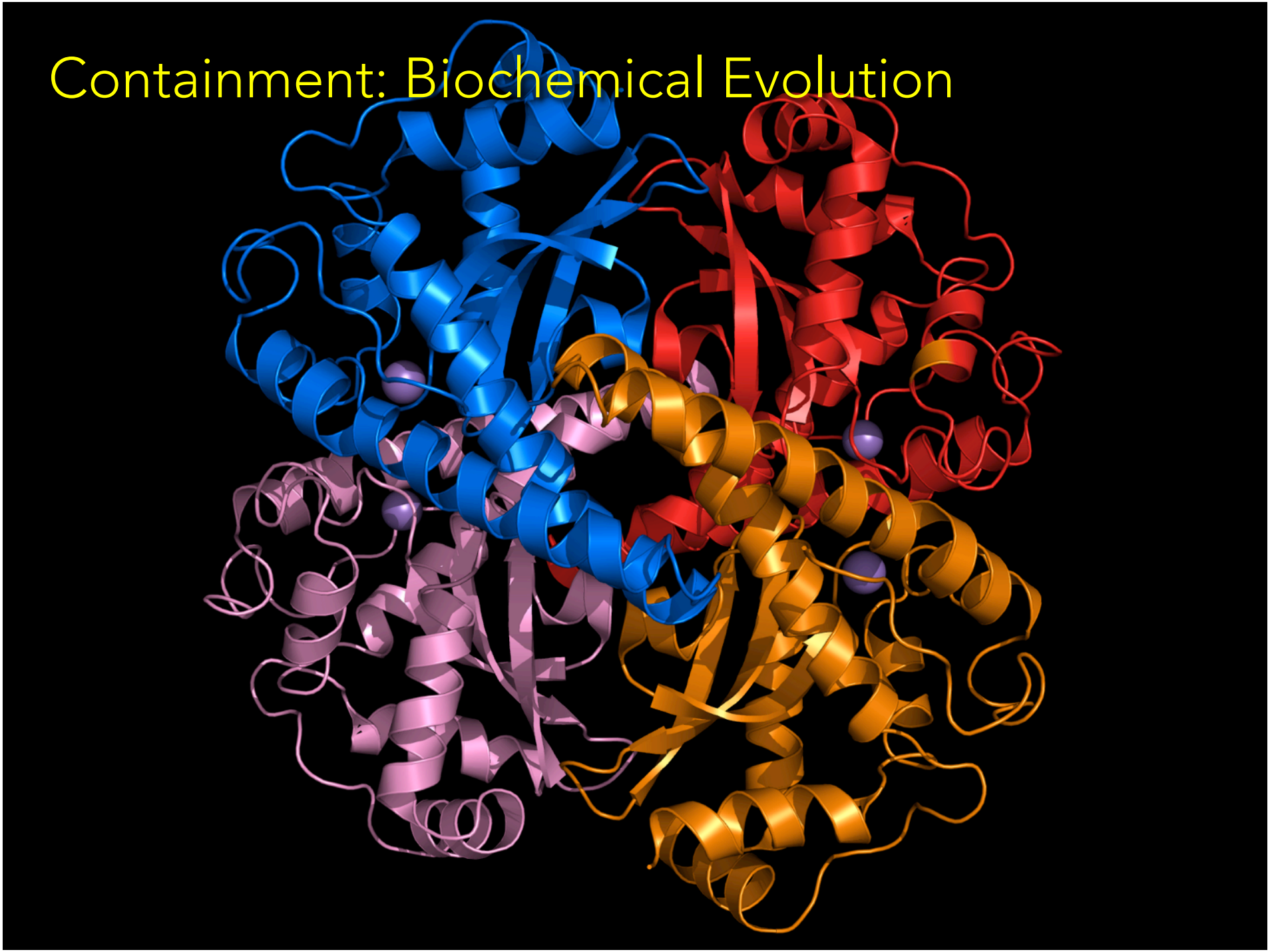


He atom
0.1 nm

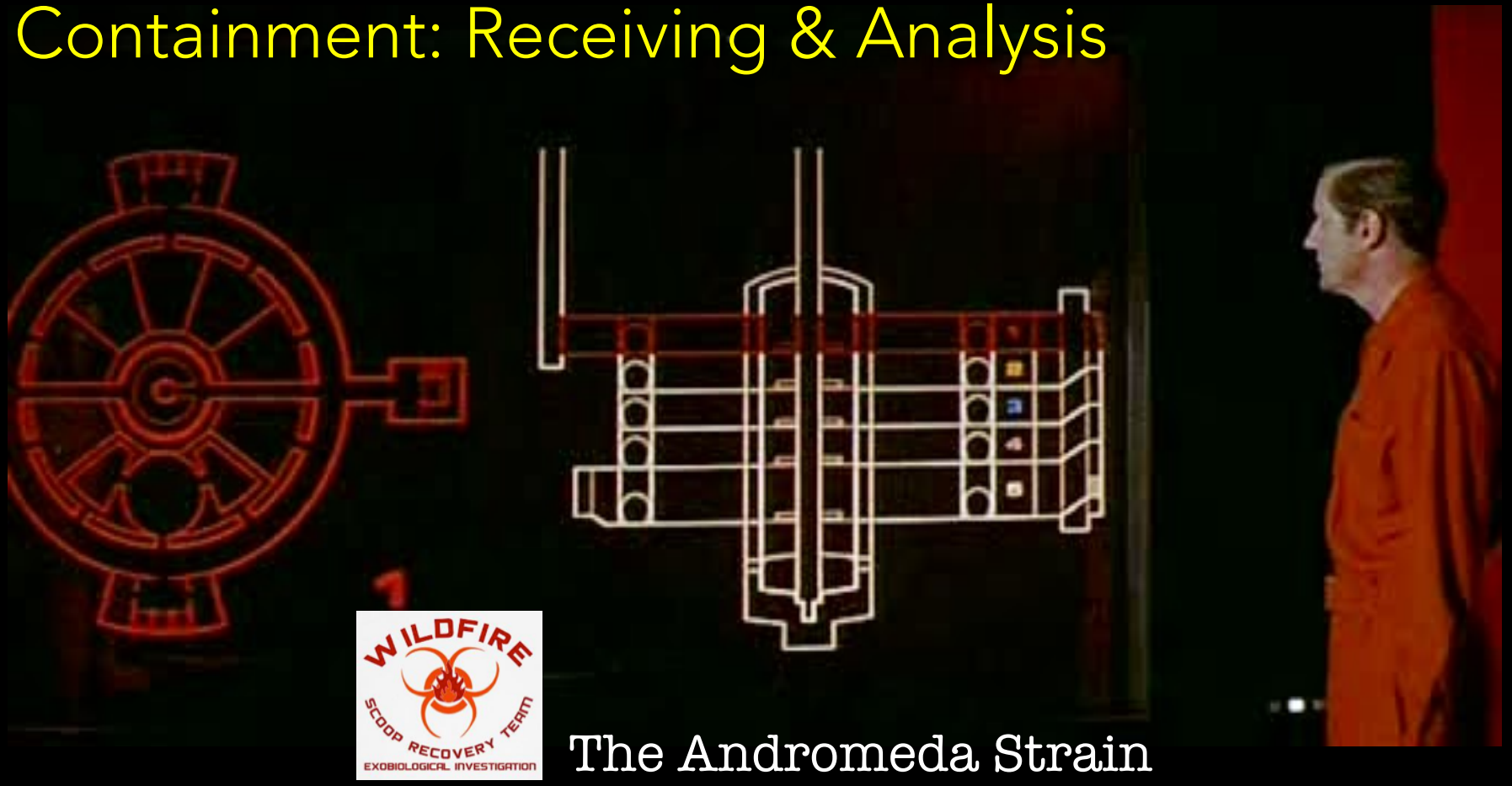
C60 Molecule
1 nm

Virus
50 nm

Containment: Biochemical Evolution



Containment: Receiving & Analysis



The Andromeda Strain

Spec from PPO: *Materials that are returned from Enceladus, including spacecraft surfaces exposed to the Enceladus environment, must be treated as potentially hazardous until demonstrated otherwise (i.e., a containment facility with Biosafety Level of 4 (BSL-4) or higher).*

Possible U.S. Pathways
from mild to wild

- U.S. sample return/planetary protection working group, coordinating w/ISAS working group in Japan;
- End-to-end design/cost study of a sample return mission (Enceladus as pathfinder);
- Planetary protection R&D effort focused on sample return issues
- Other?

Potential Working Group Members

Based on early expressed interest

Anbar (biogeochemistry, astrobiology) – ASU

Baross (marine microbiology) – UW

*Bradford (planetary protection) – ASU

Brownlee (ET sample microanalysis) – UW

Christensen (mission design) – ASU

Desch (cryovolcanism, astrobiology) – ASU

Glavin (organic chemistry, astrobiology) – GSFC

Glein (organic geochemistry) – CIW

Huber (marine microbiology) – MBL

Kanik (analytical chemistry, astrobiology) – JPL

Lin (planetary protection) – JPL

McKay (astrobiology) – ARC

*Monroe (organic analytical chemistry) – ASU

*Neveu (cryovolcanism, geochemistry) – ASU

Porco (planetary science) – CICLOPS

Sekine (planetary geochemistry) – Tokyo U.

Sherwood (mission design) – JPL

Shock (prebiotic chemistry) – ASU

Strange (mission design) – JPL

Takai (marine biogeochemistry) – JAMSTEC

Takano (bio/geo processes) – JAMSTEC

Tsou (mission design, aerogel) – SES

Wadhwa (sample curation) – ASU

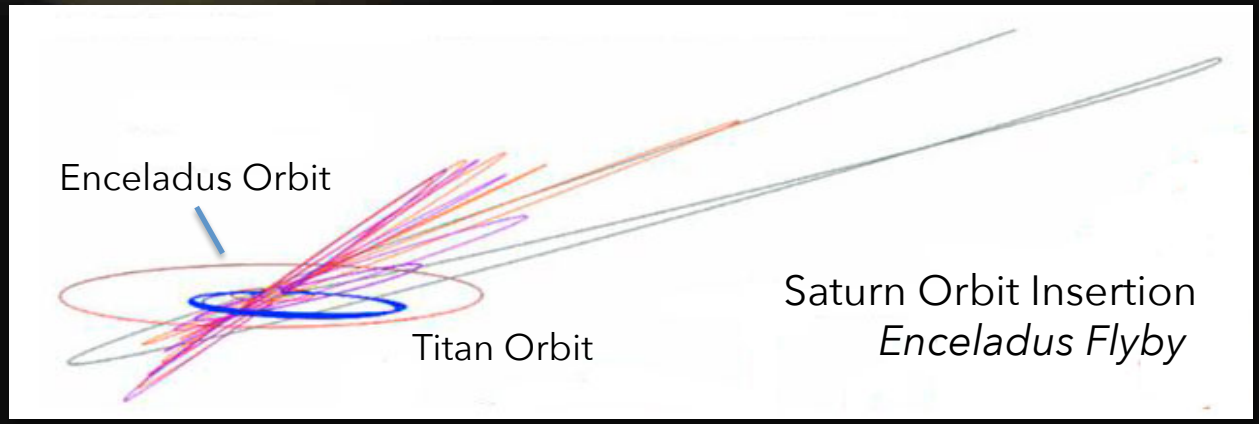
Williams (biomolecular microanalysis) – ASU

Vance (ocean dynamics, icy satellites) – JPL

Yano (sample return engineering) – JAXA/ISAS

* = graduate student

Tempting Trajectory



NOTES FROM MEETING WITH YING. SHOULD I WALK THROUGH THESE, WITH MAYBE 1 – 2 SLIDES EACH?

Forward

Sterilize (vs. care with trajectory + crash sterilization)
How can we do whole-system simply and cost-effectively? No mission design exists, so dry heat is where to start. Can we design a mission that just does this?

Sampling

Minimize contamination. What is the nature of sampling system, how can it be assured to be contaminant free? This has not been studied in outer SS context.

Containment. Hermetic seal or no? How to validate? Diversity of approaches to hermetic seal? Icy volatile rich stuff – not like Mars, which is dry. Mars is dusty, which poses sealing challenges – not the case here. None of this has been comprehensively studied.

Back

"Break the chain" – flying through a plume, so how to do? No studies.

BSL facility – elephant in the room. Different from Mars? Or synergy?

Quarantine

Can sample be sterilized without destroying desired information? Probably not but has this been thought through enough? Example: Barross oxidation

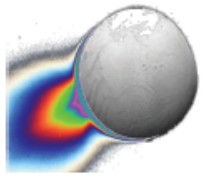
Containment

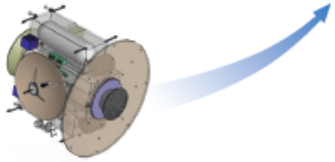
Spec from PPO: *The probability that a single particle of unsterilized Enceladus material > 50 nm in diameter is released into the terrestrial biosphere is* $< 10^{-6}$

Massive Molecules Are Not Volatile!


LIFE
Life Investigation For Enceladus

LIFE Mission Life Cycle – 13th Discovery





SDI

Gate	AO	ΦA	Sel ΦB	ΦC	ΦD	ΦE	SOI	SDO	Return	PE	EOM

CY	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
PI	Tsou							McKay											Anbar							