Forward Contamination of Ocean Worlds

A Stakeholder Conversation

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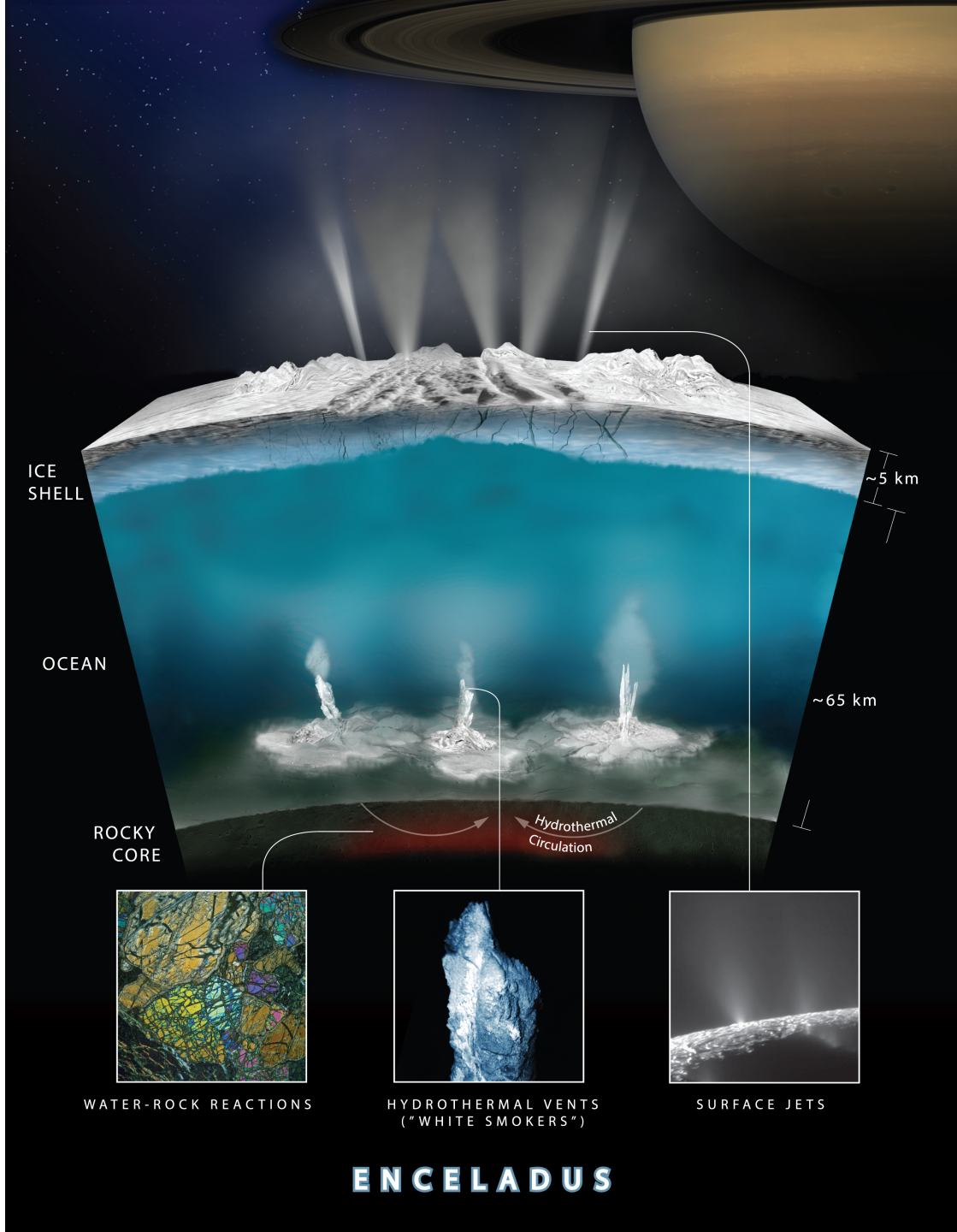


A conversation about forward contamination is becoming more urgent

Scientific and public interest in ocean-world exploration is intensifying

In this century, NASA and others are likely to explore worlds that contain vast water oceans, to understand principles of habitability and to search for evidence of alien life

The generations that would implement these missions, and live with the consequences, deserve the opportunity to weigh in

1. Humankind's potential to contaminate these worlds
2. The implications of doing so
3. Acceptable ways of managing this risk

Scientific motives dominate ethical dimensions

- In 1960s, capability-based requirement (10^{-4}) was thought to envelope both protection-of-science and ethical considerations
- The context around this requirement has changed significantly in a half-century, but the requirement has not
- Community discussions today focus only on protection-of-science
  - European PPOS project funded by European Commission H2020 includes biologists and aerospace professionals, but no ethicists

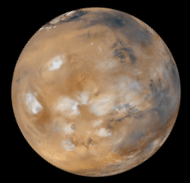
Today's requirement is simple and clear

For ocean worlds, limit to 10^{-4} the probability that any mission introduces a single viable Earth organism into a "potential habitat"

- Potential habitat = liquid water or warm ice
- Applies to all spacefaring enterprises
- Adopted by international consensus via COSPAR (Committee on Space Research, an International Non-Governmental Organization)
- Compliance enforceable through the issuance of launch licenses by states party to the 1967 Outer Space Treaty

Originally just Mars…now, many ocean worlds

Ocean Relicts



Mars

Ceres

Jovian icy moons

Europa

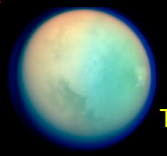
Ganymede

Callisto

Saturnian icy moons

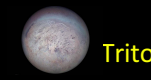
Enceladus

Dione



Titan

Kuiper Belt Objects

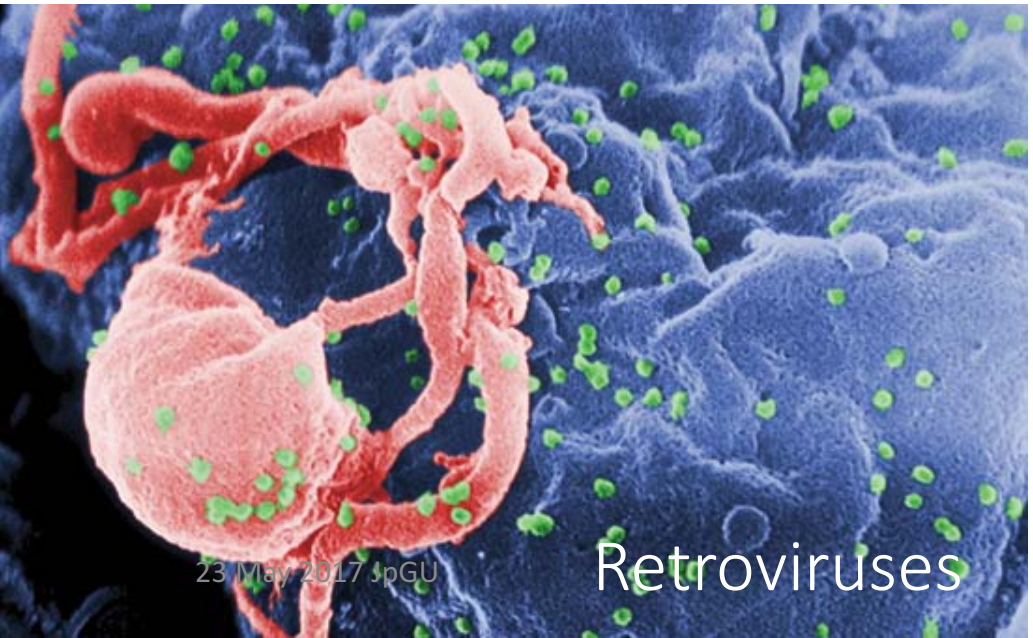


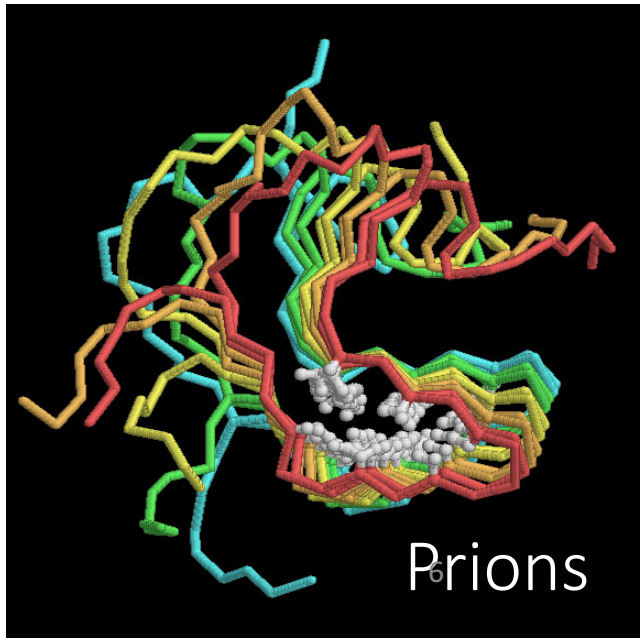
Triton

Pluto

Charon

Life is more diverse and tenacious, yet more interdependent, than we used to think





Wherein lies the forward-contamination risk?

Hazard = “a threat to people and the things they value”

R.W. Kates & J.X. Kasperson, 1983. Comparative risk analysis of technological hazards. *Proc. Nat. Acad. Sci. USA* Vol 80, pp.7027-7038 (cited in Pidgeon et al., 1992).

Scientific integrity

Avoid destroying or irreversibly complicating the opportunity for future scientific analysis of a potential habitat

A soft cost

Moral obligation

Avoid interfering with a living system or habitat upon first contact

The Prime Directive

Scientific reasoning alone cannot resolve both branches

Why is there an ethical dimension?

A decision becomes an ethical problem when at least two positive values are weighed against each other

- No alternatives, no ethical problem
- No positive values, no ethical problem

Forward planetary protection has diffuse positive values

- The value of research in an uncontaminated pristine environment
- A possible human obligation toward extraterrestrial life
- The value of untouched environments in themselves
- The value of minimizing cost and other obstacles to progress

Positive values may cluster, in tension

Care Prime Directive Studying a pristine environment	⟺	Mission publicity Mission approval Low cost
Scientific inquiry Caution Adaptable rules	⟺	Exploratory curiosity Lack of delay Verifiable requirements
Technological advancement	⟺	Less complexity High assurance of success
Cosmic diversity	⟺	Spreading Earth life
Ideology	⟺	Ideology

Labile value perceptions – an ethical sliding scale

✓

Case 1 – Non-habitable environment

- Such environments are already being explored

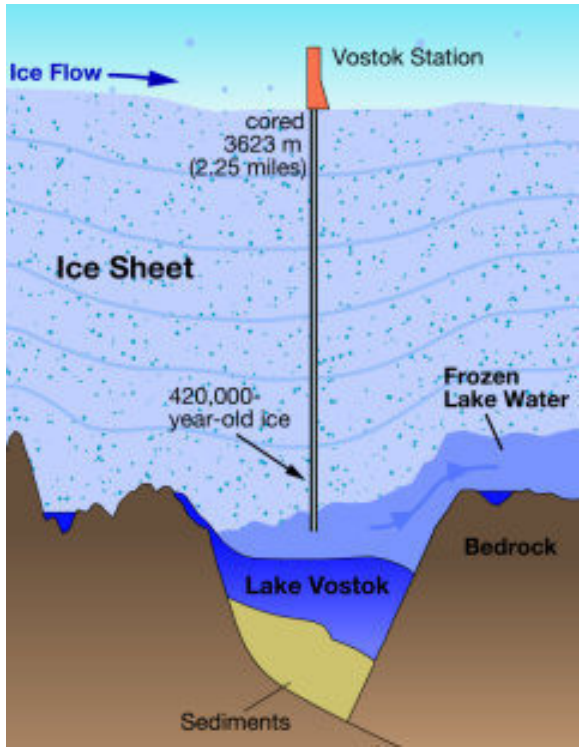
Case 2 – Habitable and possibly inhabited

- At first, go slow – lesson from Lake Vostok
- Studying alien life – observing, culturing, experimenting
- Reassembling life – CRISPR/Cas
- Mixing, hybridizing life from different ocean worlds
- Terrestrial-alien chimeric life

?

Case 3 – Habitable but uninhabited

- Expand the reach of terrestrial life?



Lessons from the Risk Management field

- Low-Probability, High-Consequence risks are part technical, part "psycho-social"
- Quantitative risk-assessment tools are inherently limited
- People judge very low or very high numbers very poorly
- Dominant driver is "distrust of the professional expert, and, by extension, distrust of the process of identifying and dealing with risks"

N. Pidgeon, C. Hood, D. Jones, B. Turner, R. Gibson, 1992. Risk Perception, in *Risk: Analysis, Perception & Management*, ISBN 0 85403 4676. Royal Society

D.M. Kammen, A.I. Schlyakhter, R. Wilson, 1994. What is the risk of the impossible? *Technology: J. of the Franklin Inst.* Vol 331A, pp.97-116.

Successful precedents exist for societal resolution of such risks

How does 10^{-4} compare to other small numbers?

1 in 15. Getting admitted to Yale

1 in 20. Lifetime death from injury

1 in 133. Odds of getting on RuPaul's Drag Race

1 in 606. Lifetime death from vehicular injury

1 in 1615. Yearly death from an injury

1 in 9737. Lifetime death from aircraft accident

1 in 10,000. Max allowable, introducing one Earth organism into a potential habitat

1 in 11,207. Yearly death from assault with a gun

1 in 141,571. Yearly death from falling down stairs

1 in 13,744,732. Yearly death from lightning

1 in 13,983,816. Winning 6-number lottery from pool of 49 numbers

http://www.businessinsider.com/ivy-league-harvard-yale-princeton-acceptance-rates-class-of-2021-2017-3

http://www.iii.org/fact-statistic/mortality-risk

http://wonderopolis.org/wonder/what-are-your-odds-of-winning-the-lottery

Approach demonstrated by particle-physics community

1. Information campaign socializes current state and future options
   - The types of exploration we can now undertake
   - Implications for science and for potential alien life
   - How we manage the risk today

2. Open, inclusive international conversation with wide stakeholder reach allows deterministic policy
   - Scientists + Ethicists + Managers + Citizens
   - Thought leaders from all generations