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AN HISTORIC CHOICE OF NUMBER: THE PLANETARY PROTECTION REQUIREMENT FOR EXPLORING OCEAN WORLDS

Abstract

Robotic exploration of our solar system's ocean worlds – especially icy moons of Jupiter and Saturn with vast interior oceans – is imminent. Within decades, our probes may encounter alien microbial life. In Earth's analogues - seafloor hydrothermal vents and cryosphere - life abounds. This makes the risk of "forward contamination" real. How ready are we? What are humanity's obligations? Today's governing requirement is a single value: limiting to 10e-4 the probability of a viable Earth organism entering a liquid water reservoir. By international treaty, this forward-contamination requirement constrains NASA, JAXA, ESA, and private companies. It strongly drives concepts, procedures, technologies, and costs. But where did this value come from? Is it correct? The requirement originated in the US for Viking, and reflects 1940s capability for sterilizing hospital equipment. Furthermore, it originally pertained to a series of missions but is now applied per mission. The 10-4 value may still be appropriate for the missions we now contemplate, but it may be technically or socio-culturally outdated, or both. Without a new, explicit conversation among an international cross-section of stakeholders, mission plans are at risk. Many changes since Viking justify revisiting the requirement's rationale: 1) improved technology for bio-assays; 2) expanded definition of self-replicating organisms; 3) recognition that diverse environments can be habitable; 4) understanding of multi-cellular community behavior; 5) expanded astrobiology target list; and 6) evolved sociological and international context for setting technology policy. We describe the current requirement's source, how it was deemed appropriate, and its verifiability. We summarize progress in biology of extremophiles, scenarios for the origin of life, self-replication of non-life macromolecules, evolution in changing environments, and how microbial communities sustain habitability. All these factors affect how we might quantify the probability of survival and replication in a given alien environment. We summarize how policies are developed for low-probability, high-consequence risks, including compensation of cognitive limitations about probabilities and how perceptions of risk are acculturated. We consider the application of the risk of contaminating another world: an irreversible event affecting subsequent generations, albeit without physical hazard. We assess how decision responsibility might be distributed, and the ethical basis for developing forward-contamination requirements. As with other techno-ethical decisions, we must weigh consequences, compare ethical values, and accept uncertainty based on the comparison. We describe how enlightened understanding and evolving consensus could flow into governing policy.