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A perspective on the astrobiological legacy of Cassini-Huygens

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The Cassini-Huygens mission revealed that the Saturn system is one of the most astrobiologically compelling destinations in the solar system. We uncovered evidence of subsurface oceans of liquid water inside several of Saturn's moons (Mimas, Enceladus, Dione, Titan). These oceans are underlain by cores of low-density hydrated rock, attesting to extensive geochemical interactions (e.g., serpentinization) between water and rock. At Enceladus, we were astounded to learn that a global ocean erupts into space, forming a plume that Cassini was able to sample. The data showed that the plume contains organic materials and ammonia, two key ingredients for life. It was an even bigger surprise when Cassini discovered silica nanoparticles and hydrogen gas coming from Enceladus, which provided evidence for deep hydrothermal activity. The coexistence of H_2 with CO_2 in the plume establishes that there is a source of chemical energy in the ocean of Enceladus, which can support methane-producing organisms like methanogens on Earth. This makes the detection of methane in the plume particularly interesting. At Titan, an Earth-like rather than a truly alien landscape was seen by Huygens, except liquid methane replaces water as a key shaper of geology and climate. Cassini found numerous hydrocarbon lakes and seas peppering Titan's north polar region. These bodies of liquid represent possible abodes for delightfully weird forms of life, which could make use of H_2, acetylene, and more complex organic compounds from the atmosphere. The subsurface liquid water ocean on Titan was once thought to be ammonia-rich (frigid) and isolated from the rocky core, which would diminish its prospects for life. However, Cassini gravity data suggest that the ocean is too dense to be ammonia-rich, and the finding of radiogenic argon in Titan's atmosphere shows that Titan's interior is or was geophysically active. With the close of the Cassini-Huygens chapter of exploration, we look back at all of these accomplishments with indelible admiration, and forward to the paths blazed by this heroic mission for future astrobiological investigations of ocean worlds at Saturn and elsewhere.