The outer solar system's moons an exciting playground for future astrobiology. Unlike the moons of the inner solar system, moons around Jupiter, Saturn, Uranus, and Neptune exhibit unique features that make them more like dynamic planets than moons. For example, it is believed that Europa (Jupiter), Ganymede (J), Callisto (J), and Enceladus (Saturn) host vast subsurface water oceans that offer a great opportunity for scientific exploration and the search for life beyond Earth. The exploration of these ocean worlds creates important questions for engineers and researchers alike: how do we access and explore these oceans and what kind of technology is required; and what kind of information might be gained by exploring these places.

The actual process of entering these moons' oceans and exploring them is a daunting one. First, the spacecraft and all its instruments must survive the journey to the outer solar system, be able to withstand extreme magnetic fields, and be entirely waterproof. It would need to be able to propulsively land on the surface on the moon due to lack of an atmosphere (except for Saturn's moon Titan). Those are the easy parts. Now, the spacecraft needs a way to bore through 10-100km of solid ice to reach the subsurface ocean. Ways this could possibly be carried out is with a drill or with some kind of melting of the ice (dropping an extremely hot "torpedo" that would cut through the ice until it reaches the ocean below). The spacecraft would then need to traverse down the hole it just created and submerge itself within the ocean. If all this goes smoothly and all the instruments on the craft are healthy, exploration of the ocean can finally begin. That is not to say that useful data cannot be taken throughout this process, however. Being able to descend and land on an alien moon can provide vast amounts of scientific information – this is exactly what the Huygens Probe (of the Cassini mission) did on Saturn's moon Titan. This information would not be terribly difficult to relay back to Earth as the spacecraft is on the moon's surface. Once the craft is below kilometer of icy crust, though, data transmission would be nearly impossible. To relay oceanic data back to Earth, the craft would need to get closer to the surface or transmit directly up the hole it bored to a receiving orbiter. A mission like this is one that would push human ingenuity and creativity to its limits.

Another, much less daunting, mission that could gain valuable information about these icy moons would be a fly-by through their escaping plumes. It is known that Enceladus (and possibly Europa) has plumes of material that vent out of their surface and reach hundreds of kilometers up[1][2]. A fly-by through this material could provide unique data about the contents and composition of the moons. It could look for organic material that may imply the presence of life.

Missions like these ultimately seek to gather useful information about the moon's structure, composition, existence of a subterranean ocean, and what may exist within this ocean. This data would not only help astrobiologists discover if life does or can exist there, but it would also provide valuable information about the formation of the solar system and unique geological data. New technologies would surely be invented to create a spacecraft for this mission and would help pave the way for future space exploration missions as well.

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[1] https://solarsystem.nasa.gov/news/13020/the-moon-with-the-plume/

[2] https://www.space.com/40575-jupiter-moon-europa-plume-galileo-spacecraft.html