ASTROBIOLOGY with *OpenSpace*
Public Program Guide

The Search for life in the Solar System and the Search for Extraterrestrial Intelligence (SETI)
using *OpenSpace*

Rachel L. Smith
North Carolina Museum of Natural Sciences
rachel.smith@naturalsciences.org

September 2019

Introduction: This is a general guide for the astrobiology-themed facilitated program using OpenSpace that we have presented at the NC Museum of Natural Sciences. This is not a script or intended as a comprehensive overview of every site, but rather it is a guide to provide some interesting facts on locations that tie together into an interesting and relatable story of how scientists are searching for life beyond Earth. This program illustrates how we can use OpenSpace to explore real mission targets beyond Earth, and shows how our own planet fits into this narrative. I like to emphasize how exploring space, in particular astrobiology-related research, teaches us more about our own planet, the evolution of life, and our place in the Universe.

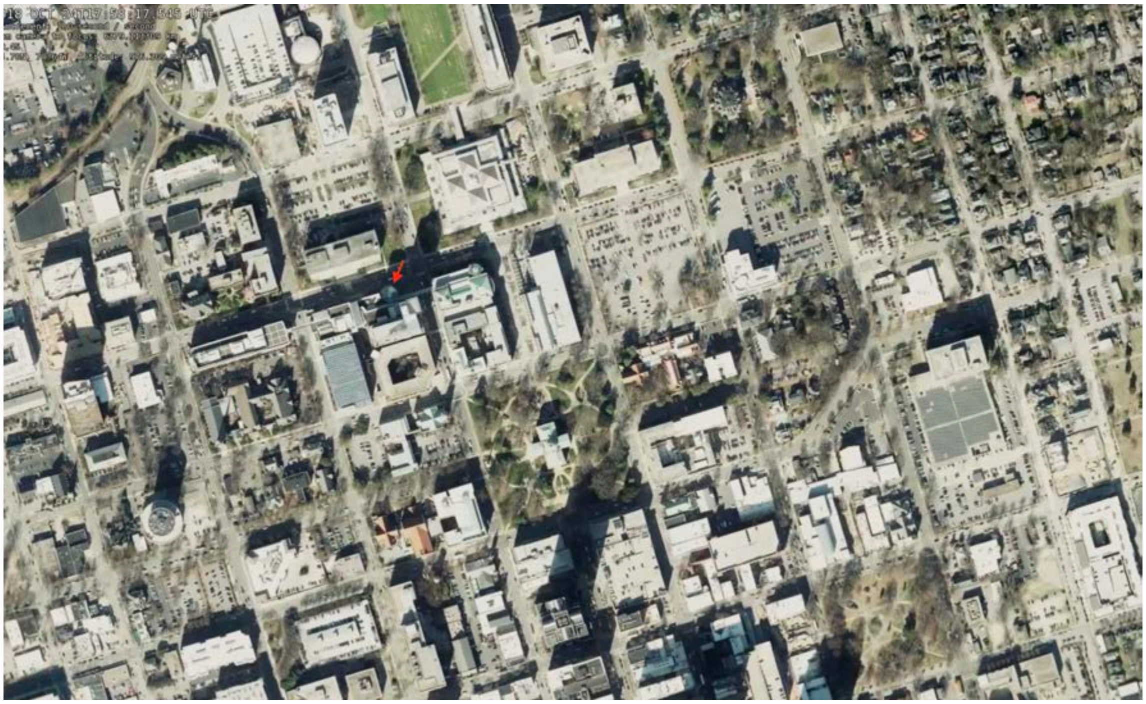
The theme of the first part of the program follows NASA's search for life beyond Earth and "follow the water", i.e. where are the environments where liquid water can exist, and where microbial life survives in "extreme" conditions (termed "extremophiles" or "lovers of the extreme") similar to various locations in the solar system? All life as we know it contains carbon and needs liquid water at some point in its life cycle, so as scientists starting with *what we know*, we consider these two aspects in the search for life. Themes for programs like this can certainly evolve as OpenSpace adds more assets, modules, and functionality, and there are many stories and programs that can currently be created with the software. Any part of this guide can be removed to shorten the program, and for us all of the sites can be done in ~35-40 minutes.

One important note is with OpenSpace we cannot show all regions on Earth that are considered key analogues for searching for life in space, including undersea hydrothermal vents and deep underground mines, both of which are key environments in which extremophiles thrive. However, we can still showcase several sites as examples relevant to current science and NASA missions.

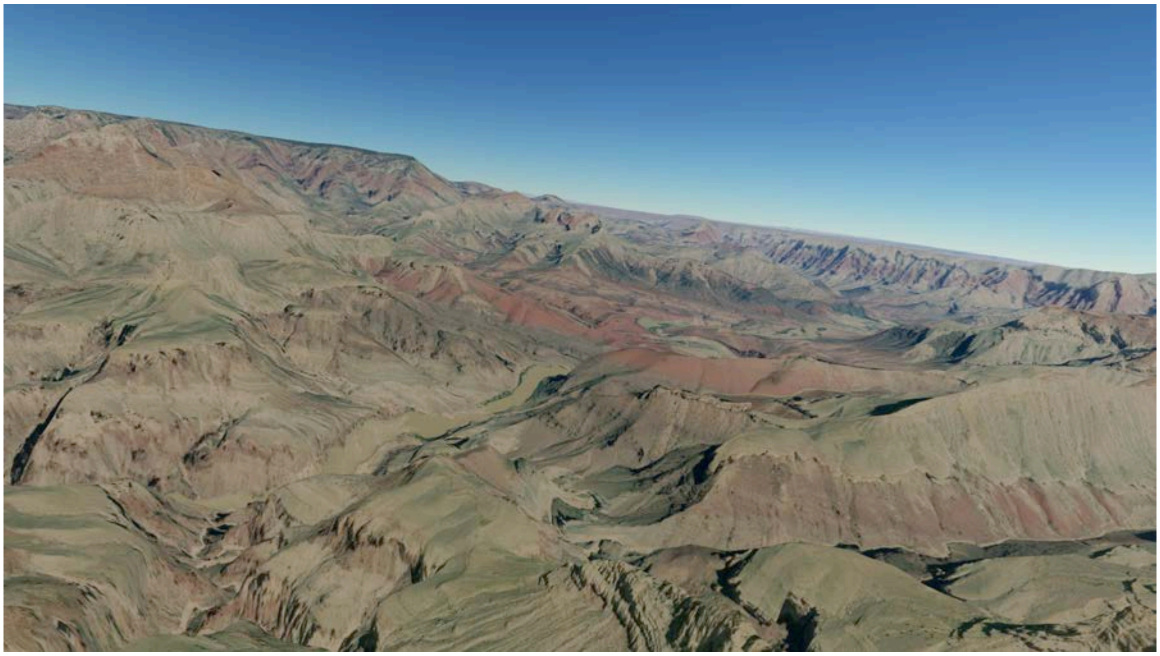
Some general notes and "fun facts" are included for each stop, and with more or less detail included and tailored for the audience or timing. Screenshots from OpenSpace are found within or below each description. A few stops are relatively small and can be hard to find (i.e. Grand Prismatic Spring and Meteor Crater, perhaps), so one way to find them is with Google Maps in satellite view, and then using these maps as a guide for the OpenSpace locations. Also, any location can now be "bookmarked" within OpenSpace for future programs.

Part I: How is Earth an analogue for the search for life in space?

1. **NC Museum of Natural Sciences**: Before launching into astrobiology, I like to start with where we are, which for us has so far been our museum in downtown Raleigh. We can see our Daily Planet theater (Earth globe from the outside) on West Jones Street (noted with red arrow in figure below) with OpenSpace, and from here (or wherever this program is taking place) drive directly to selected locations on Earth.



2. **The Grand Canyon**: Since the program contains various aspects of comparative planetary geology as well as astrobiology, I include a few locations that are both interesting in their own right and can be later compared to other planets; for this program that would be Mars. The first stop is the Grand Canyon, a river valley carved by the Colorado River in the Colorado Plateau. It records the past ~70 million years (exact age is still a subject of debate), and much of the early geological history in North America. The Canyon is 277 miles (446 km) long and 18 miles (29 km) wide. While not the deepest canyon on Earth, it is arguably one of the most spectacular both in visual scale and colorful landscape; compare to <u>Valles Marineris on Mars</u>.



3. **Meteor Crater**: This crater is one of the most famous preserved craters on Earth and is located outside of Flagstaff, AZ. It is about 1200 meters in diameter and 170 meters deep, and formed ~50,000 years ago (during the Pleistocene epoch) when a ~50 meter-diameter piece of a nickel-iron asteroid exploded over the region, creating the crater we see today. In the Pleistocene, this region was much cooler and wetter, and such animals as giant sloths and mammoths roamed. This crater was used to train the Apollo astronauts so that they could learn to differentiate impact from volcanic lunar craters. Related to astrobiology, we still do not have a complete story as to how Earth got its

oceans, or how life started on this planet, and water-laden asteroids might have delivered water and/or the ingredients for life to Earth. Further, asteroids could easily deliver these ingredients to other habitable worlds. Asteroids are also not so positive for life in that they are likely at least partially responsible for several extinction events, the most famous of which was that of the dinosaurs ~65 million years ago (related crater is Chicxulub Crater in the Yucatán Peninsula, Mexico).

4. **Grand Prismatic Spring**: This is a vividly colorful thermal hot spring in Yellowstone National Park, and the largest (110-meter diameter; 50-meter depth) hot spring in the US. The colors in the spring are due to mats of extremophile microbes that live and thrive in the ~160-degree F pool. It is hypothesized that such extremophiles (specifically *thermophiles*, or "heat-loving" organisms) could be analogues to potential life in extreme temperatures beyond Earth, possibly in hydrothermal vent systems on Europa.

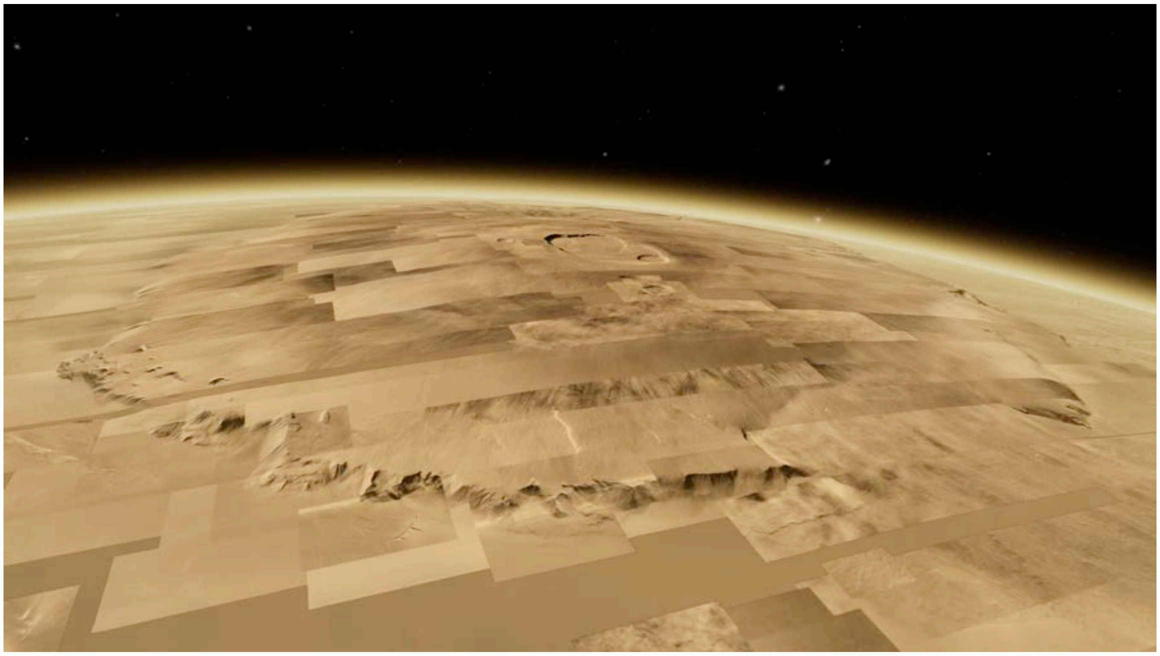
5. **San Francisco Bay Salt Ponds**: These artificial salt pans lie along San Francisco Bay, and are evaporation ponds that are home to *halophiles* – "salt-loving" extremophiles. The 8,000-acre ponds were engineered to harvest salt from the Bay, and the varying colors of the ponds, which can be seen out airplane windows while landing at SFO airport, are produced by the microbes living in the salt. Interestingly, conservation efforts in the Bay area have changed the colors of the pans from vibrant green, blue, and orange hues to more natural tones as some of the pond area is restored back to marshland.

6. **Alaskan Glaciers**: Any ice sheets could be chosen to showcase *psychrophiles* – "ice-loving" extremophiles that live in permanent frozen regions, such as Greenland, Antarctica, and other regions with ice sheets and glaciers. I chose the Alaskan glaciers since they are visually striking with their blue ice floes. Microbes that can survive inside ice, often well below zero-degrees C, are potential analogues for possible life on icy moons (like Europa) and planets.

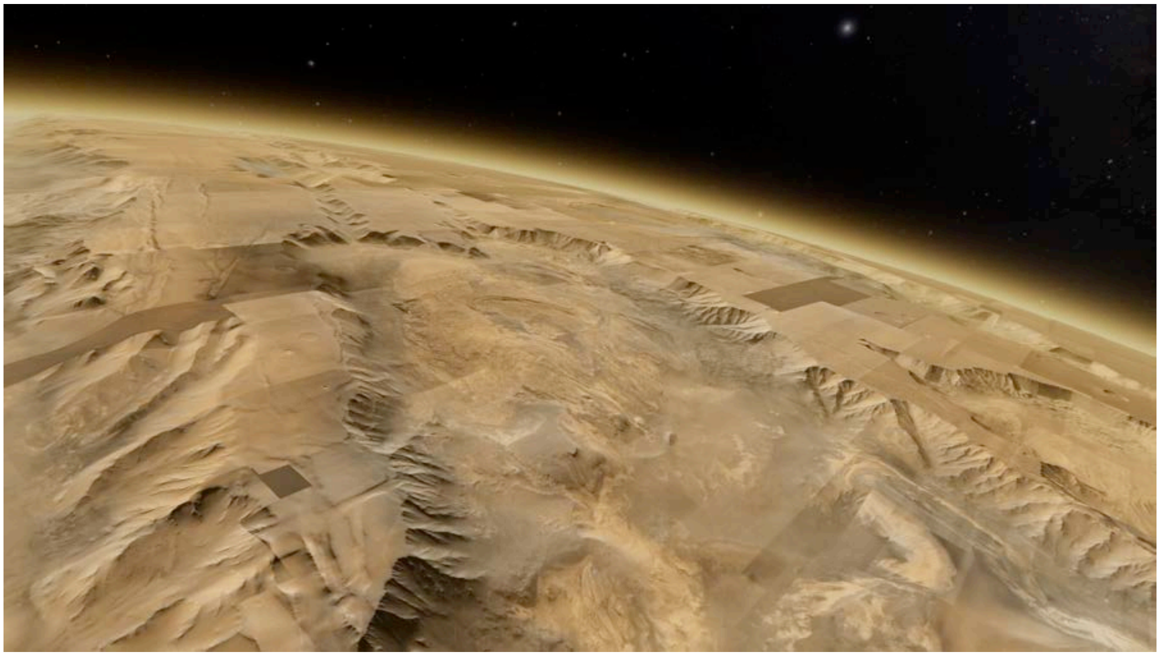
7**. Telescopes on Mauna Kea, Big Island, Hawaii**. I like to end on Earth with Mauna Kea, a spectacular mountain (and the tallest on Earth when measured from its oceanic base) of 13 working observatories for ground-based astronomy, including the Keck and Infrared Telescope Facility telescopes which I currently use for my research. This mountain is widely considered in the astronomy community to be the best site on Earth for ground-based observations, being both high (nearly 14,000 feet; ~4200 meters) and dry, and with the most "good weather" days. Mauna Kea is a shield volcano and can be directly compared to Olympus Mons – a dormant shield volcano on Mars (comparative planetology). With OpenSpace you can also see the observatories and cinder cones (reddish mounts that resemble anthills from above) on the summit of Mauna Kea.

Journey to MARS – this planet is the site of currently most of the robotic missions in the solar system, and where scientists are searching for signs of past and possibly current life. Water flowed in Mars' past, and it may have had an ocean in its northern hemisphere. Water may even be flowing intermittently on the surface today.

8**. Olympus Mons**: One of the most striking features of Mars, Olympus Mons, is ~624 km (374 miles) in diameter, and ~25 km (16 miles or 72,000 feet) high, about 2.5 times the height of Mount Everest. It is the largest volcano and planetary mountain in the solar system; the largest mountain anywhere in the solar system is on the asteroid Vesta. It is a shield volcano, similar to Mauna Kea in Hawaii and other shield volcanoes on Earth. This stop and the next are more opportunities for comparative planetology, and one can add that the terrestrial planets all formed from the same materials in the solar nebula and we thus see distinct similarities in their composition and surface features. I like to also remind audiences here that all the ingredients for terrestrial planets and for life are in space, and this fact is a key driver for searching for life beyond Earth.

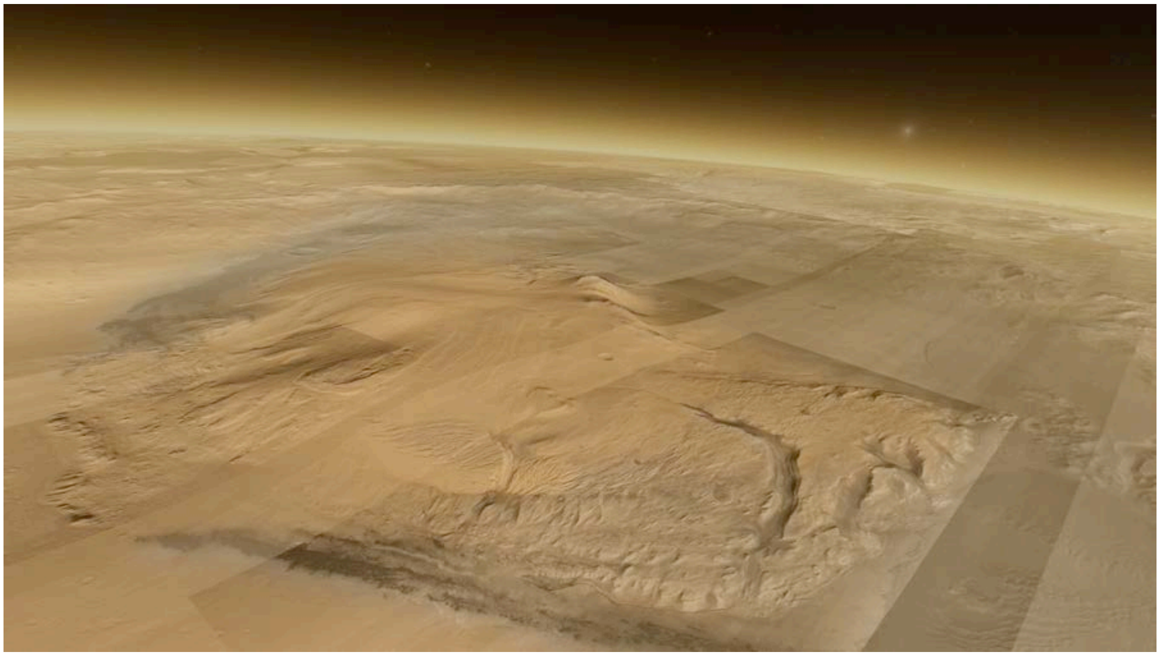


9. **Valles Marineris**: At ~2,500 miles (4,000 km) long, 120 miles (200 km) wide, and ~23,000 feet (7 km) deep, this is one of the largest canyons in the solar system. It extends nearly one-quarter the circumference of Mars, and theories on its formation include volcanism, landslides, and/or asteroid impacts. These processes can be compared to the understanding of the Grand Canyon, a valley carved by the Colorado River (we don't think that Valles Marineris formed from river carving). One can mention



again here that water likely flowed on Mars in the past and may still flow on the surface intermittently as well as underground, which still makes Mars an ideal candidate for searching for past and/or present life.

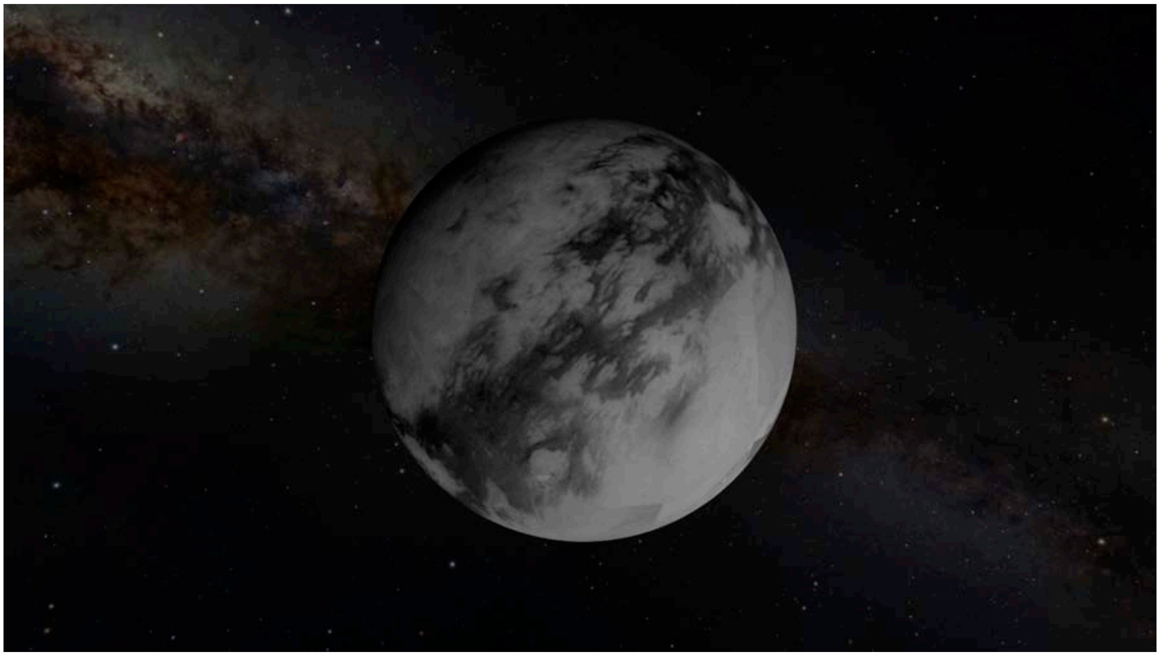
10. **Gale Crater**: This is a supposed dry lakebed, and the landing site for the Curiosity rover which is still actively exploring the chemistry of the region. At the center of Gale Crater is the mountain Aeolis Mons, and there is a nearby outflow channel that likely contained flowing water in Mars' past. It is thought that a lake formed in the crater shortly after its formation. This is an ideal site for searching for past/present life give that water likely existed in this location. A bird's-eye followed by zoomed-in view of the crater are shown below.



Journey to MOONS

11**. Europa**: the smallest of the Galilean moons of Jupiter. This is one of the most intriguing sites for astrobiology since it likely has a global salty liquid water ocean beneath its ~100 km-thick surface of ice. Observations have also shown liquid water geysers spewing from the surface. The ocean is thought be kept liquid from the tidal flexing by Jupiter, and future missions, such as the planned Europa Clipper, will help confirm its presence. If there is indeed liquid water, it is thought that the rock-water interface at its base could be analogous to those interfaces found in Earth's hydrothermal vent systems which provide rich chemical environments for organic chemistry and habitability. Further, a leading hypothesis for the origin of life on Earth several billion years ago (possibly even within the first billion years of Earth's formation) is that it started within rock-water interfaces far below the surface of an early ocean. Another interesting feature of Europa is its crisscrossed surface of bands and ridges that are seen in images from various space missions. These "lineae" may be the result of periodic eruptions of warm ice when the surface crust spreads, also possibly due to tidal flexing from Jupiter.

12. **Titan**: the largest moon of Saturn and the only moon known to have a dense atmosphere. Titan is interesting from an astrobiological standpoint for two main reasons: it has liquid hydrocarbon (methane and ethane) lakes and seas (carbon-rich environments that could possibly harbor life that may not need liquid water, but could potentially survive in liquid methane or ethane), and its thick nitrogen-rich atmosphere is thought to be analogous to that of the primordial Earth, with the exception that there is no water vapor on Titan. Any life existing in Titan's hydrocarbon seas would have to metabolize at (–290 C/94 F), which could hinder complexity and functionality.



While the habitability of Titan is still debated, it is nevertheless an intriguing site for exploration, and was recently selected for the robotic mission, *Dragonfly*, currently scheduled to launch in 2026 and reach Titan in 2034. A theoretical cell membrane made of phospholipids including carbon, hydrogen, oxygen and phosphorous which could survive this extreme environment was also modeled in 2015, lending some theoretical robustness to the idea that life could persist in this harsh environment.

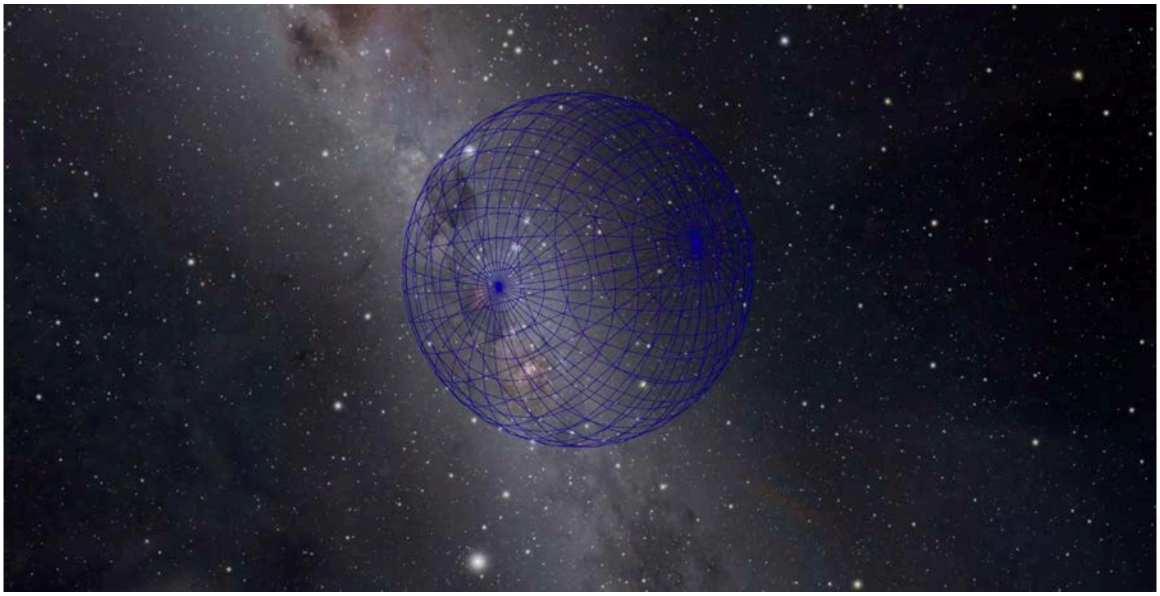
13. **Enceladus**: This moon of Saturn is yet another solar system body that likely has a subsurface water ocean and thus could be habitable for "extreme" life similar to what could be found on Europa. Water geysers and silicates (tiny rock particles) have also been observed spewing from its interior. Enceladus has surface fissures, plains and corrugated terrain that provides additional evidence for an undersurface ocean. As with Europa and other under-ocean environments that have potential rock-water interfaces (substrates for organic chemistry) observing silicate particles was exciting supporting evidence for such an environment on Titan. Below is a screenshot of Enceladus with Saturn in the background.

Part II: SETI, the Search for ExtraTerrestrial Intelligence (SETI). I like to include a short section on SETI since the public is typically interested in the possibility for intelligent life ("aliens") beyond Earth, and SETI provides an opportunity to compare science fiction to the work of real SETI astronomers. If a shorter program time is desired, I suggest shortening some of the stops in Part I. Two datasets related to SETI that are found in OpenSpace are the radiosphere and exoplanets.

14. **Radiosphere**: With OpenSpace we can travel from Earth to the cosmic microwave background in a handful of seconds, rapidly and non-physically traversing the vast

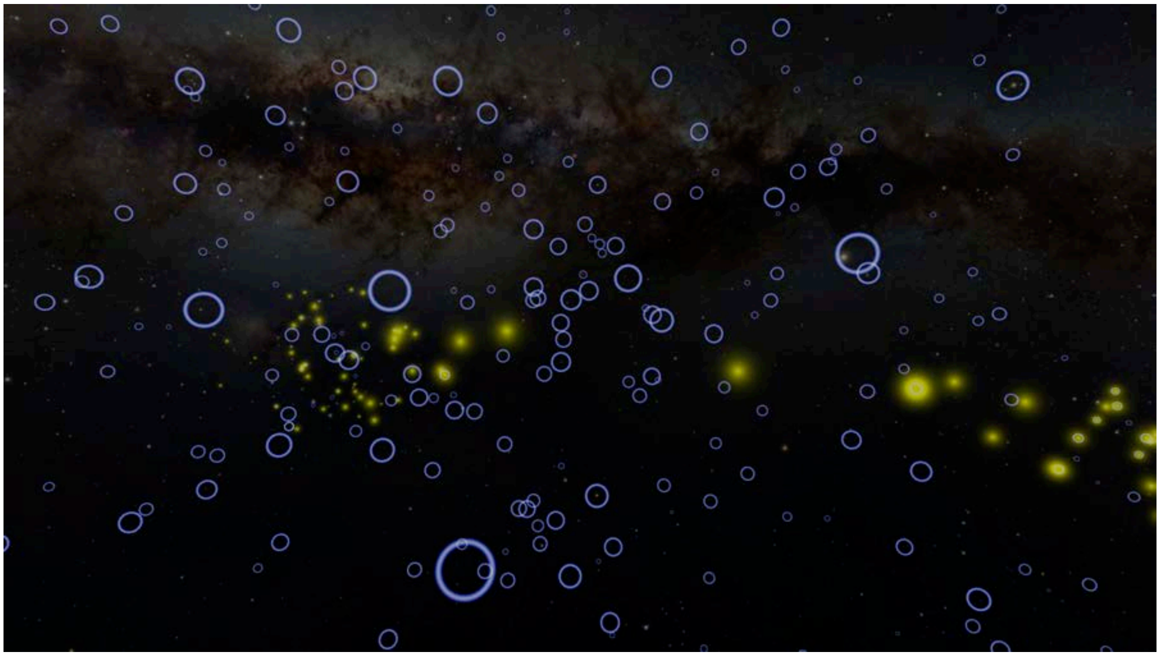
emptiness of space. The edge of Earth's radiosphere – the distance radio signals have thus far traveled from our planet – is ~ 110 light years; i.e. humans have been sending signals out to space for a mere 110 years. This is next to no time at all compared to the age of the Universe. We can turn the radiosphere on shortly after leaving the solar system, and then zoom out to see this distance in context with enormity of the Galaxy and Universe. The take-away from this visual is that we haven't sent signals out to space for long, and so far it seems rather unlikely that there is intelligent life anywhere near Earth, or at least close enough that we could hope to receive a signal within many lifetimes. Even if intelligent life were relatively close to Earth this could still be thousands of light years from us, and therefore it would take an equivalent time to reach them, and then then another equal time frame to return a signal. Further, humans as a civilization are "growing dark" as technology moves from radio and television broadcasting digital platforms. Therefore we might have to intentionally beam signals toward potential areas of civilizations (i.e. where there are "Earth-like" planets) if we hope to ever make our presence known.

As Carl Sagan famously said, "Space is vast, and the stars are far apart", so even if life were out there, we may, likely, never know. Yet, many scientists remain hopeful that we are not alone.



15. **Exoplanets**. Showing the exoplanets in OpenSpace offers the opportunity to talk about the ongoing search for potentially habitable, "Earth-like" worlds, and how we use various datasets to determine these characteristics. Currently, we can really only know if a planet is terrestrial (has a solid surface rather than just a being gaseous) and within the habitable zone of its host star(s), as well as certain basic characteristics of the planet's orbit, but we are still not sure how to define biosignatures – the tell-tale atmospheric molecules for an inhabited world. Further, we are far from having the ability to travel great distances from Earth, as we currently still use chemical rockets.

Even if we could go as fast as the Voyager probes – the fastest spacecraft sent by humans to date – traveling ~one million miles per day, it would take ~70,000 years to reach our closest star system, Proxima Centauri. We clearly need to develop new technologies to take us to the stars. Another point to bring in while visualizing the exoplanets is how we “show” data, i.e. these are two-dimensional visualizations of the positions of the exoplanets, which is all the information we have for objects to which we cannot yet travel. We have many such data sets in OpenSpace (e.g. galaxies, quasars, cosmic microwave background). Until we sent spacecraft to the exoplanets we will have only markers for them in space, as well as artistic renderings or models of their surfaces and atmospheres. This is why we only see the exoplanets as circles.



OpenSpace is funded in part by NASA under award No NNX16AB93A as part of the Science Mission Directorate Science Activation efforts resulting from Cooperative Agreement Notice (CAN) NNH15ZDA004C.

Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration.

OpenSpace is also funded in part by the Knut & Alice Wallenberg Foundation in Sweden and the Swedish e-Science Research Centre.