HOLD FOR RELEASE
UNTIL PRESENTED
BY WITNESS
September 29, 2015

Statement of

Dr. Jonathan I. Lunine

before the
Committee on Science, Space and Technology
U.S. House of Representatives

Chairman Smith, Ranking Member Johnson and Members of the Committee,
Thank you for the opportunity to present my views on astrobiology and the search for life beyond Earth. These views are my own and come from thirty years of working in the field of planetary science, at various institutions here in the US and abroad.

Two decades ago the discovery of the first planet around another sun-like star was announced. Were I to have testified then in this room on the subject of promising places to search for life in our own solar system, I would have said there were no obvious targets. In 1995 the US had yet to mount a successful Mars mission after the Viking landers and orbiters of the 1970's. The Galileo orbiter was enroute to Jupiter, but with prospects for successful mission marred by a crippled communications antenna. Cassini was more than two years away from launch and nine years from its target, Saturn. The exuberance of the first three decades of planetary exploration had faded and it was not clear what the coming years would bring.

But fast-forward ten years and one sees the exuberance returned. Europa had become a target of keen astrobiological interest after the Galileo orbiter found multiple lines of evidence for a subsurface ocean. Cassini, safely in Saturn orbit, dropped off the European Huygens probe for a successful landing on the giant moon Titan, and then discovered a huge plume of vapor and ice pouring out of the south polar region of Saturn's tiny moon Enceladus. The first geochemical evidence of standing liquid water on ancient Mars—the Mars of billions of years past—was found by a rover called Opportunity.

Fast-forward one more decade to the present-day, and we see the Cassini orbiter directly measuring water, salts and organics in Enceladus' plume. Cassini also is probing with radar the depths and composition of Titan's surface seas of liquid methane and ethane, seas it discovered in 2007. An SUV-sized rover called Curiosity is sniffing the Martian air and tasting the soil; it rolled across an ancient riverbed where water flowed billions of years ago, and is traveling toward Mt. Sharp where the sediments may record two billion years of Martian history. And just this month NASA selected instruments and brought into Phase-A a mission to Europa, a mission that will pave the way for the search for life there.

One of the major results of these last two decades of solar system exploration is the identification of four bodies that may well harbor, or have harbored, life. (By life I am referring to single-celled, microbial life; there is little expectation for anything more complex.) These four suspects possess a particular set of characteristics beyond liquid water that make them, in my view and that of many other scientists, the best leads in the search for life beyond Earth. Let me list for you the specific reasons why:

Mars (figure 1) is the most Earth-like planet in the solar system and has had a rich geological and atmospheric history. In its first billion years Mars had abundant surface liquid water, stabilized and protected by a much denser atmosphere than the tenuous shell of gas we see today. During this time life might have begun, survived for some time on the surface, and then either was extinguished or retreated underground as the atmosphere was lost. The burst of methane detected by the Curiosity rover is intriguing as a possible sign of life, but life is not the only generator of methane: even on the Earth, hot water and carbon dioxide in the presence of the right kind of rock can also make methane. It will require very sensitive measurements of carbon isotopes to determine the origin of the methane.

Europa (figure 2)—the lunar-sized moon of Jupiter-- has a very large salt-water ocean in contact with a rocky core, chemical energy gradients associated with Jupiter's radiation belts, and a prodigious energy budget from tidal heating-- but we know little else about the prospects for life here. Indeed, we do not know whether organic (carbon-hydrogen) molecules exist within the ocean—but we strongly suspect they are there. Equally important, we do not know how far beneath the moon's surface the ocean lies. Knowing that will allow a strategy to be formulated to search for life there.

Titan (figure 3) is larger than the planet Mercury and is the only moon to host a dense atmosphere of nitrogen and methane. The source of the methane—how it is sustained in the atmosphere over billions of years of destruction by ultraviolet rays from the Sun—remains a mystery. But Cassini and its lander Huygens have revealed a "hydrologic cycle" with clouds, rain, gulleys, river valleys and seas. Methane is the working fluid in place of water because the surface temperature is so low. The surface seas –concentrated in the arctic region of Titan--are so vast that they hold hundreds of times more hydrocarbons than do the known oil and gas reserves on planet Earth. And so we cannot avoid asking whether a form of life might have arisen in this exotic, frigid environment. Titan's surface has all the formal requirements for life—abundant organics, liquids, and sources of energy such as sunlight, wind, tides. And yet, that liquid is not water—it is methane. Should we include the seas of Titan in our search for life? As a 2007 National Research Council study[1] asserted: "if life is an intrinsic property of chemical reactivity, life should exist on Titan." Titan is a test for the universality of life as an outcome of cosmic evolution. To quote Stephen Pyne, "What the Galapagos Islands did for the theory of evolution by natural selection, Titan might do for exobiology"[2] It's a wild card, to be sure—but by playing that

[1] The Limits of Organic Life in Planetary Systems, National Research Council, National Academies Press, Washington DC, 2007, p. 74.
[2] Pyne, S. Exploration, Space and the Third Great Age of Discovery. Penguin, NY, 2010, p. 206.

card we give ourselves the chance of discovering something profoundly important about the way the universe works.

Enceladus (figure 4) has surprised us. This Saturnian moon is only one-thousandth the volume of neighboring Titan, and yet it sports a plume of material emanating from a series of fractures in its south polar region. Cassini has flown repeatedly through this expanding cloud of icy grains and vapor, and will do so again next October. Thanks to the prodigious capabilities of its chemical sniffers—mass spectrometers—and other instruments, Cassini has found organic molecules, frozen drops of salty water, and tiny grains of silica that hint at a hot hydrothermal system in a deep interior ocean from which the jets that source the plume presumably emanate. Cassini's sensitive measurements of the gravity field of Enceladus reveal the presence of a subsurface south-polar ocean of water, while an infrared device has detected high temperatures in and around the fractures. Make a list of the requirements for terrestrial-type life—liquid water, organics, minerals, energy and chemical gradients—and you find that Enceladus has it all. Conveniently, the evidence is not hidden beneath the surface—it's coming out into space in the plume. Enceladus is quite willing to "spill the beans".

So now that I've introduced the four suspects, how do we actually tease out their secrets regarding life? It's different for each, but the common thread is direct sampling… flying through a plume, rolling around from site to site or floating across a sea, drilling or melting into an icy surface. And there's more complexity to the answer than just "yes" or "no"—we want to know whether any life we may discover had an independent origin from us.

Such evidence need not be—indeed likely will not be—an entire living organism. More likely is that we will detect and measure signatures that set the chemistry in living organisms apart from abiotic chemistry. Key to this is that, in contrast to non-biological processes, life does not make use of the full range of possible organic molecules. "Biology is built from a selected set".[3] And so if we can recognize patterns in the makeup of organic molecules collected from our suspects— for example, a common building-block molecule with a particular number of carbon atoms, a preferred handedness, or isotopic trends—we then have strong evidence of biology at work. These types of tests are practical for measurements made on a spacecraft in an alien environment millions of miles from Earth.[4]

For Mars however, there is almost as much value in finding the remnants of extinct organisms as there is in finding life itself. And so a search for fossils—presumably microfossils—is well worthwhile. As for extant life on Mars, finding sources of methane and measuring the isotopic composition is one practical way to get at possible life deep beneath the surface. Another is to seek well-preserved organic molecules just below the surface, to see if they record the signatures of biology. Curiosity has tentatively detected organics, but the Mars 2020 rover will do the heavy lifting here.

---

[3] Davila, A. and C. McKay Chance and necessity in biochemistry. *Astrobiology* 14, 2014, p. 534.

[4] An Astrobiology Strategy for the Exploration of Mars. National Research Council, National Academy Press, Washington DC, 2007. Boxes 3.1-3.5.

Life might be abundant in the Europan ocean, or it might be absent: Either way, we do not know how to access oceanic samples to make the determination. The Europa mission now in development will provide the essential information needed to decide, among other things, whether ocean water is welling up through the cracks, and how to access it. We must do this mission before making more ambitious plans to search for life on Europa.

For Titan, the search for life should target one of the great methane seas, by dropping a capsule capable of floating across its surface. Here the complication is that we don't know what kind of biochemistry we are looking for, and so a generalized search for patterns in molecular structures and abundances that indicate deviation from the randomness of abiotic chemistry is appropriate.

Enceladus provides us potentially with the most straightforward way to look for life signs, given the evidence that the larger ice grains in the plume are frozen seawater from the deep interior. Merely flying through the plume as Cassini has done multiple times, with modern instrumentation intended to detect life, is sufficient to do the search. It is fair to assume that the basic biochemical building blocks are like those on Earth, since every indication we have from Cassini is that the subsurface ocean would support terrestrial microbes. One might even contemplate returning samples to Earth, though an in-situ exploration seems the right first step given the ease with which it can be done.

At the beginning of this testimony I gave you a historical perspective of the kind of progress that has been made over the past 20 years. The current pace of missions and flight times makes it highly unlikely life will be detected in the outer solar system in the next decade, but there is an outside chance that Mars 2020 could find such evidence on Mars in that time frame. For the outer solar system I am more sanguine about a 20-year horizon—new missions to Enceladus and Titan could arrive by the early 2030's, and a follow-on to the currently planned Europa mission might be mounted in time to arrive late in that decade. The long flight times in the outer solar system—5 years to Jupiter, 8+ to Saturn—dictate that planning for these missions must begin now if they are to happen in 20 years.

None of this will happen without the will of the nation to conduct an aggressive program of planetary exploration. The US has been the clear leader in this endeavor, but the absence of proactive planning and funding in recent years has built into outer solar system exploration a gap of a decade between the end of Juno and Cassini and the arrival of the Europa mission. Looking at how much we have done and discovered in the past twenty years, I hope that we as a nation decide to pursue with renewed vigor this remarkable and noble endeavor. Should we do so, there will be even more remarkable discoveries to come.

Thank you for this opportunity to speak today.

Figures

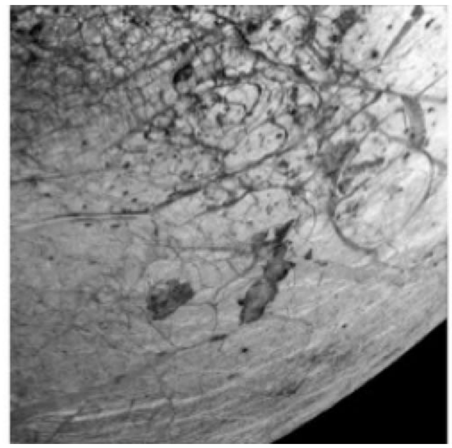

Figure 1 (credit NASA/JPL-Caltech/MSSS)

Figure 2 (credit NASA/JPL)

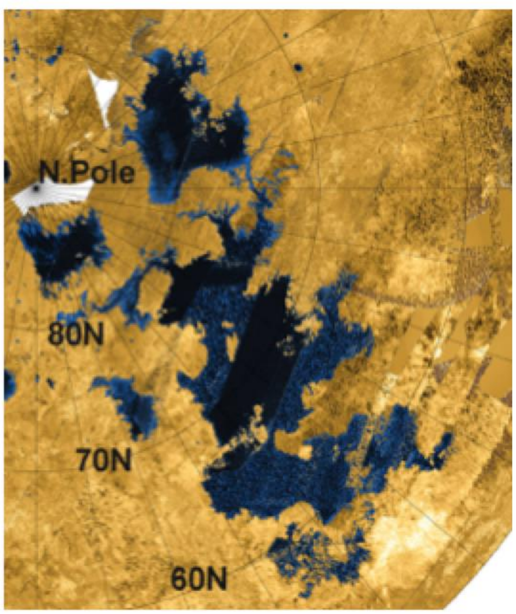

Figure 3 (credit NASA/JPL-Caltech/USGS)

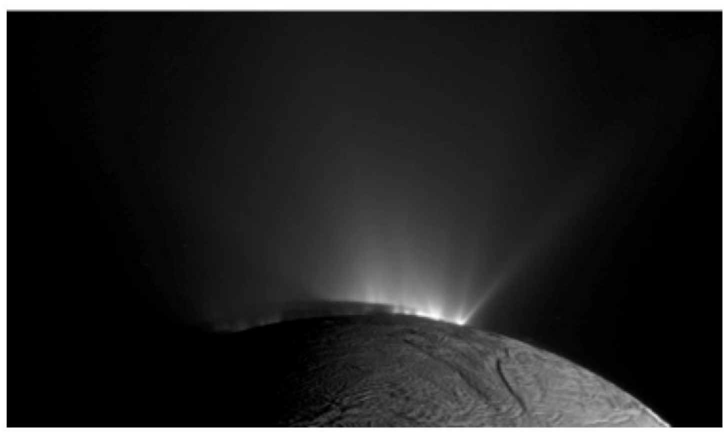

Figure 4 (credit NASA/JPL-Caltech/ Space Science Institute)