SOME IMPLICATIONS FOR BOTH LIFE AND CIVILIZATIONS REGARDING INTERIOR WATER OCEAN WORLDS. S.A. Stern[1], [1]Southwest Research Institute, Space Science and Engineering Division, 1050 Walnut Street, Suite 300, Boulder, CO 80302, astern@swri.edu

Our solar system is replete with worlds possessing Interior water oceans. Such worlds are likely to be common in extrasolar planetary systems as well. Here we examine some implications regarding the development of life and intelligent civilizations in Interior Water Ocean Worlds (IWOWs), where their presence is cloaked by massive overlying burdens of rock and/or ice between the ocean abode and the external Universe.

Why Interior Ocean Worlds Can Be More Conducive to Life Than Worlds With Surface Ecosystems: As we now know, in our solar system, Earth is an uncommon type of water ocean world because its oceans are on its exterior. In contrast, an increasing number of worlds in our solar system have been shown through gravitational, magnetic, or geological/geophysical evidence to indicate that they likely contain interior water oceans [1]. As a result, water ocean worlds are now thought to be common in our solar system [2], IWOWs appear to be particularly conducive to, and perhaps at an advantage for the development and maintenance of life. This is so owing to several key advantages of IWOWs over External Water Ocean Worlds (EWOWs) like Earth. These advantages include:

a) *Environmental Independence to Stellar Type, Multiplicity, and Distance from Their Host Planet*. Owing to the depth of typical interior oceans below the planetary surface, and the overlying thermal insulation provided by the planetary lid atop these oceans, the energy balance, temperature, pressure, and toxicity of IWOWs are only weakly coupled to their host star's stellar type, multiplicity, distance, and evolutionary stage. Thus IWOWs can exist in many stellar environments that EWOWs cannot, and are (as evidenced in our system by IWOWs as far from the Sun as the Kuiper Belt) decoupled from the narrow stellar habitable zones that EWOWs require. Similarly, IWOWs are largely or completely insensitive, depending on their depth below the surface, to stellar multiplicity, host planet orbital eccentricity and spin states. Indeed, IWOWs can even remain liquid and therefore be candidate abodes to life on unbound planets that no longer orbit any star at all.

b) *Environmental Stability Against External Threats*. Again owing to the overlying thermal, radiation, and impact insulation provided by the planetary lid atop IWOWs, they are also protected from numerous kinds of existential threats to life. These include impacts, space radiation, surface climate and obliquity cycles, poisonous atmospheres, and deleterious nearby astrophysical events such as novae and supernovae, hazardous stellar flares (e.g., for M star hosts), and even phenomena like the Faint Young Sun.

As a result of these factors, IWOWs require much less of their parent planet, parent star, and the nearby galactic environment to remain viable for life than do EWOWs. For example, IWOWs do not require planetary magnetospheres for radiation protection, nor do they suffer from external threats due to asteroid/comet impacts, supernovae and novae induced insolation catastrophes, and obliquity extremes, and they are also immune to the passage of their host star through giant molecular clouds of high opacity. These factors make IWOWs attractive sites for the potential development and persistence of biology.

On Interior Ocean Worlds Naturally Sequestering Their Intelligent Civilizations From Space Travel and Interstellar Communications: Because ecosystems inside IWOWs are, by definition, isolated from their surface environments by thick shells of ice or rock or both, intelligent life in such abodes cannot communicate or be easily detected using most electromagnetic means. This electromagnetic sequestering naturally inhibits revealing the presence of such ecosystems or civilizations. Further, it could well be that intelligent species living in IWOWs might not know of the external surface of their worlds, much less the Universe around it. And if they do, it is unclear why they would explore, much less inhabit, the alien and likely lethal environment at their planet's surface. Such civilizations would also be at a disadvantage to persist there or to travel off their home worlds into space, compared to residents of EWOWs, since they are likely to be constrained by the need to carry copious water supplies to live on their world's surface or in space.

Conclusions. Interior water ocean worlds are habitable in a wider range of host worlds and stellar and galactic environments than do worlds with exterior water oceans. As a result, interior water ocean worlds may contain life more frequently than exterior water ocean worlds, like Earth. However, for the reasons

discussed above, such intelligent life would be less likely to devlop an awareness of the Universe and space travel, and therefore may be less likely to communicate actively or passively (i.e., via electromagnetic leakage) than intelligent life on external ocean worlds like Earth.

References: [1] Lunine, J.I., (2017) *Acta Astronautica*, 131, 123-130. [2] Sherwood, R., et al. (2017) Proc. Global Space Exploration Conference 2017. GLEX-17,6.4x36541, Beijing, China. [3] Stern, S.A., (2003) *Astrobiology*, 3, 317.