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Exo-Astrosociology and the Search for Technosignatures

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The search for extraterrestrial societies on exoplanets, exomoons, and artificial structures has thus far proven unsuccessful. Nevertheless, astrosociology focuses on the human dimension of space exploration, which involves everything humanity discovers in space, and that includes nonhuman sentient life, which is the focus here. At this point in human history, the search itself is the focus by necessity as are all of the methodologies employed to increase the likelihood of such a discovery. Even if the eventual discovery of an extraterrestrial civilization is unlikely, astrosociologists, like astrobiologists and SETI scientists, must assume it is a likely outcome. Therefore, the efforts focusing on finding technosignatures are pursued. The connection between astrobiology and astrosociology lies in the basic idea that because Earth-based humans are actively searching for extraterrestrial life, it is therefore important to study how and why they participate in such activities as well as what would result if their searches discovered a nonhuman society. This essay focuses most heavily on technosignatures although other indications of life, such as biosignatures, are also relevant and thus receive some attention here. Thus, the detection of intelligent, technological life elsewhere in our universe does not fall only into the domains of astrobiology and SETI. There substantial issues that astrosociology, and more specifically the subfield of exo-astrosociology, can best address.

Nomenclature

ARI	=	The Astrosociology Research Institute
ET	=	extraterrestrial
ETI	=	extraterrestrial intelligence
ETIL	=	extraterrestrial intelligent life
ETS	=	extraterrestrial society
METI	=	Messaging to Extraterrestrial Intelligence
NASA	=	National Aeronautics and Space Administration
SETI	=	search for extraterrestrial intelligence
STEM	=	science, technology, engineering, and mathematics
STEAM	=	science, technology, engineering, mathematics, and the arts

I. Introduction: The Difficulty of the Task

EXO-ASTROSOCIOLOGISTS are interested in life elsewhere in the cosmos, just like other scientists and scholars such as SETI researchers and astrobiologists as well as an untold number of those in the public sphere. Those who participate in the search itself continue to face a seemingly daunting task; namely, to detect a nonrelated genesis of life elsewhere in our universe. Paraphrasing Carl Sagan's character Ellie Arroway's statement that was famously articulated in the 1997 movie *Contact*: "the universe is an amazingly big place, so if it's just us, it seems like an awful waste of space."

With this in mind, humanity continues the search. Not surprisingly, though, the most common type of question that arises coincides with the *Fermi Paradox*, which corresponds to the current failure to detect evidence of extraterrestrial biology or technology, asking: Where is everybody? Where are all the nonhuman intelligent species? Relatedly, are *homo sapiens* truly alone? Is life on Earth a fluke or does life exist elsewhere? Is it rare or abundant? These types of questions have probably fascinated pre-humans and certainly modern humans for millennia. Several possibilities can explain this paradox that relate to "The Great Filter Theory" and the Kardashev scale (Webb,

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2015).[2] However, the current failure to discover a second genesis of life does not prove that it does not exist, so the best humanity can do is to keep searching.

As astrobiologists and astronomers continue to discover additional occurrences of various organic molecules, life-friendly chemicals, and supportive compounds in space, is it logical to conclude that countless other geneses of life do not exist? Admittedly, the leap from organic molecules to even microbial life is a huge one. On the other hand, how could the emergence of intelligent life occur on Earth and nowhere else, when our home planet is a relatively small rock in a somewhat strange Solar System with a single star on the outskirts of a typical spiral galaxy? Additionally, if the theory of panspermia is valid, which conjectures that the organic compounds on Earth and thus possibly elsewhere are delivered by colliding comets and asteroids, then the likelihood increases even more. It is, of course, uncertain whether life was delivered intact or less sophisticated organic compounds somehow eventually produced the creation of life.

This examination of efforts to search for extraterrestrial life integrates an astrosociological perspective that adds social, cultural, psychological, and behavioral factors to the more common astrobiological approach. As a social scientist, an astrosociologist to be more precise, it should be expected that I will also combine physical science and social science elements into this discussion. SETI and astrobiology have mostly focused on the physical sciences though the searches are carried out by human beings, so there are serious implications for humanity. Social scientists and humanists have much to offer in the search for extraterrestrial life, which is complementary to the efforts of astronomers, astrobiologists, and other physical and natural space scientists. I will leave the "hard" scientific details to the physical and natural scientists while this discussion focuses mostly on the human dimension, and in this particular case, implications of the extraterrestrial dimension as they relate to humankind. Moreover, space artists have much to offer as well because their works can visualize concepts to make them easier to understand. Two good examples of this include depictions of (1) exoplanets and exomoons and (2) potential ET life based on perceived or imagined environmental conditions.

II. Defining Three Important Fields in Two Branches of Science

A number of different types of people have dedicated their lives to finding evidence for life elsewhere in the Milky Way Galaxy. Humanity has always pondered the question about whether it was alone among the points of light that were visible in the night sky. Therefore, it is not surprising that the search for extraterrestrial life began in earnest among physical and natural scientists in the 1960s once scientific instruments became sophisticated enough. In fact, for most of human history, the idea of the plurality of worlds with intelligent life was hotly debated (Dick, 1982; Vakoch, 2013). In this effort to scientifically search for ET life, the two fields of astrobiology and SETI advanced quite quickly compared to the efforts by social scientists and humanists. Their work sort of sputtered forward through the work of a few pioneering social scientists and humanists until perhaps two decades later (see, for example, Harrison,1997; Finney and Jones,1985). Also, Dick (2000) offers a good breakdown of other social science efforts regarding astrobiology during this early period while Harrison and Connell (2001) and Tough (2000) do the same for SETI.

Thus, the various issues of SETI and astrobiology had become serious among social scientists and more accepted among physical and natural scientists starting in the 1980s and 1990s. Today, the sputter has become more of a trend toward establishing a community of social scientists interested in the search for other intelligent beings in the cosmos. Exo-astrosociology, which represents the effort of ARI to foster this trend, is one offshoot in this positive direction. Finally, Tough (1998) wrote about the consequences after SETI succeeds and he mentioned the term "astrosociology" as a possible new field that would be needed at that historic point. I came across this article six years later and started my development of astrosociology and my new career as an astrosociologist. Furthermore, this essay seeks to establish that important social science contributions must occur *before* SETI or astrobiology can reach a thorough understanding of all elements of both human and extraterrestrial intelligent life. The argument here is that the more effort humanity places toward the search for ETI, the more it will understand itself and the more it

[2] These concepts are not discussed here directly. However, a quick treatment here is warranted. The Great Filter Theory focuses on the problem of the Fermi Paradox and offers possible reasons why intelligent extraterrestrial species have failed to make their presence known to humankind. The Great Filter Theory provides possible points of development at which a technological species may destroy itself or regress to a state in which contact with other species beyond their atmospheres becomes impossible. Possibilities include nuclear war, isolationism, and simply the huge real estate of space. The Kardashev scale refers to the three stages of development of civilizations based on their ability to use increasing amounts of energy. (Humankind has not yet reached the Type I level because it cannot efficiently utilize all of the energy available from the Sun, and thus it is designated as a Type 0 civilization).

will make the search more successful by limiting anthropocentric notions about what to look for and thus expanding the parameters utilized.

A. Astrobiology and SETI

According to NASA, astrobiology, is "the study of the origins, evolution, and future of life in the universe" (NASA Astrobiology Institute). This definition does not specifically state what type of life although the emphasis has been on searching in our Solar System, which means microbial life either alive or fossilized. This has been changing over time, however, so that the emphasis is expanding deeper into outer space. As emphasized here, collaborative efforts between astrobiology and SETI have contributed to this trend.

A major methodology employed is to determine how to detect life elsewhere in our Solar System and beyond. However, because extraterrestrial life remains elusive, an important alternative that can provide useful data is to study life on Earth, especially investigating harsh environments and the various forms of extremophiles; that is, various forms of life that can endure in seemingly not survivable environments such as boiling water, various forms of radiation, within ice, in acidic and alkaline water, without sunlight, and under high pressures. By understanding how life can adapt to extreme ecosystems, astrobiologists are able to literally unearth clues for where extraterrestrial life may reside. Researchers have located extremophiles in a number of extremely harsh ecosystems throughout the world and continue to find new ones. This provides hope for places such as Enceladus, Europa, and Titan.

More specifically, astrobiologists are searching for a second genesis of life, one that sprang up independently from life on Earth (McKay, 2001). This life may be microbial or it may be multicellular, even intelligent, though the current emphasis is Mars. The aim is to prove that humanity is not alone and that other life sprang up independently of life on Earth. Moreover, SETI scientists and astrobiologists work together and they conduct research that can be from either camp. Sometimes it is difficult to place a label as to whether a project is one or the other because it involves elements of both.

The acronym "SETI" stands for the search for extraterrestrial intelligence. Unlike past conjectures about other life in the universe, SETI represented a new approach starting in the late 1950s in which twentieth century scientific investigation was actually applied toward finding extraterrestrial intelligence.

> The search for extraterrestrial intelligence (SETI) began as a scientific exploration with the publication of the first refereed paper in 1959 [Cocconi and Morrison,1959], and the first observational project in 1960 at the National Radio Astronomy Observatory [Drake,1960]. Speculations about whether intelligent life on Earth represents the only form of sentience in the cosmos can be traced back to the early Greek and Chinese philosophers. Though admittedly some of these speculations seem quite unreasoned given the cosmology of the 21st century, they illustrate the abiding human curiosity about our place in the universe. Are we alone? (Harp et al., 2012).

Thus, it is clear that this last question has driven humanity to speculate about ET life and to utilize scientific investigative techniques to replace this speculation and folklore to the extent possible over time.

Before the 1960s, an organized approach to thinking about the possibility of extraterrestrial societies did not exist as we know it today even among physical and natural scientists. Frank Drake changed this when he formulated his equation, which set in motion more coherent thinking among interested scientists.

> Since 1961, SETI's intellectual framework has been centered on a probabilistic argument, the now-famous Drake equation:
>
> $$N = R_* * f_p\, n_e * f_l * f_i * f_c * L$$
>
> where N is the number of civilizations in the Milky Way whose electromagnetic emissions are detectable; R_* is the average rate of star formation in our galaxy; f_p is the fraction of those stars with planetary systems; n_e is the number of planets, per solar system, with an environment suitable for life; f_l is the fraction of these planets that actually develop life; f_i is the fraction of life-bearing planets that develop intelligent life; f_c is the fraction of civilizations that develop a technology that releases detectable signs of their existence into space; and L is the length of time such civilizations release detectable signals into space (Cabrol, 2016:662).

Not all of the factors are astronomical or biological. Also, this equation is useful for both SETI and astrobiology. In fact, this equation or any of the improvements presented over the years cannot yield reasonable estimates. However, the final three variables are relevant to social scientists, which provides them with much to ponder.

Many attempts to provide a result for variable *N* have been calculated by many researchers. For example, in their abstract, Frank and Sullivan III (2016:1) state that they have utilized Drake equation variables to calculate a lower limit on the evolution of extraterrestrial intelligent life:

> We find that as long as the probability that a habitable zone planet develops a technological species is larger than $\sim 10^{-24}$, humanity is not the only time technological intelligence has evolved. This constraint has important scientific and philosophical consequences.

Others have offered reformulations of the Drake equation (e.g., Seager, 2016) or have commented about its uselessness (e.g., Sutter, 2018). In any case, however, while this "equation" is far from perfect with a combination of probabilistic and speculative factors, it provided a new way to think about how to estimate the number of communicative extraterrestrial societies (Cabrol, 2016). The term *N* as the overall total and the final two terms f_c and *L* relate to exo-astrosociological variables that considerably complicate the biological considerations, especially as long-term forces, because the existence of civilizations or ETSs involve social-scientific forces (i.e., astrosocial phenomena) (Pass, 2010). This is a good example how both branches of science complement one another and why formal collaboration results in improved investigative strategies.

Projects utilizing human technology to search for extraterrestrial technology traditionally target extraterrestrial radio signals, although other methods such as looking for other types of technologies constructed by advanced civilizations are becoming more common. Scharf (2018) provides a list of possible technosignatures to seek that includes laser-painting, radiation of various kinds, mirrors, neutrino beams, stellar activity manipulation, ultra-relativistic particles, bomb detonations, and different types of artifacts – some of which are akin to trash dumped into space. Traditionally, SETI research has focused on passive listening techniques such as trying to detect radio signals emanating from extraterrestrial societies. However, researchers have employed active SETI techniques as well and this technique seems to be an increasingly popular course of action. Sending radio messages outward into space is not a new approach, as active SETI or METI have occurred as deliberate actions with the plaques on Pioneer 10 and 11 spacecraft launched in 1972 and 1973 as well the Golden Record placed aboard Voyagers 1 and 2 and launched in 1977 (Gertz, 2016). The Golden Record also included an "album cover" with images about humanity. These examples indicate that NASA was not opposed to sending messages early on.

Cabrol (2016:667) argues that it is important to broaden our anthropocentric biases to think more like ETIs: "*To find ET, we must expand our minds beyond a deeply rooted Earth-centric perspective and reevaluate concepts that are taken for granted* [emphasis in original]. She also makes the important point that interdisciplinary cooperation could result in making SETI more successful. In Figure 3, Cabrol explains as the following:

> Connectivity network between disciplines showing the bridges and research avenues that link together space, planetary, and life sciences, geosciences, astrobiology, and cognitive and mathematical sciences. This representation is an expanded version of the Drake equation. It integrates all the historical factors now broken down in measurable terms and expanded to include the search for life we do not know using universal markers, and the disciplines, fields, and methods that will allow us to quantify them (Cabrol, 2016:670).

We must expand our minds even more to include ideas as to how the social sciences and humanities would expand this connectivity network so that social, cultural, and behavioral considerations would be included. The addition of sociocultural and psychological factors could help expand the Drake equation much more. Others, such as Harrison (1997), have in fact made this same argument and worked with SETI and astrobiology researchers in the past. Thus, the problem is not unfamiliarity with social scientific concepts, it is the relative scarcity of including social scientists in the process. It is something that both sides need to work on.

Logically, scientists interested in the search for extraterrestrial life tend to be optimistic since proving a negative is difficult, and it also keeps them motivated to keep searching. Nevertheless, pessimism does exist among some researchers as the search continues without success. The Breakthrough Project, which has provided a new initiative and funding for SETI, completed a survey of 692 in 2017 stars without successfully detecting any signs of extraterrestrial life and, rather than giving up, they concluded that they will need to improve their technology and keep searching (Enriquez et al., 2017). In 2018, they added additional telescopes located in South Africa (Wall, 2018) and aim to search one million stars.

B. Exo-Astrosociology

The subfield of exo-astrosociology is defined as the study of extraterrestrially-related forms of *astrosocial phenomena* (i.e., social, cultural, and behavioral patterns related to extraterrestrial life in outer space). This subfield of astrosociology, which is relatively new compared to its parent field, focuses on the human dimension of space exploration as it relates to the search for extraterrestrial life that is conducted by humanity, which includes how the very search for extraterrestrial life itself impacts humanity in a myriad of ways (Pass, 2015). It also involves how ongoing failure and potential eventual success affects societies, cultures, social groups, subcultures, and individuals.

Social patterns are the trends of people that are reflected in larger movements, which in this case is the search for extraterrestrial life. The concept of "culture" is also important to understand. From a sociological perspective (Pass, 2005:8), culture is defined as:

> …consisting of nearly everything in a society that humans create or think. It reflects the worldview of members of a given society in abstract and tangible forms, providing a sense of belonging and allowing for shared meaning. Culture consists of three dimensions: (1) ideas (including values – abstract standards that define ideal principles), (2) norms (society's informal and formal rules or expectations), and (3) material culture (Bierstedt, 1970).

"Material culture consists of what humans produce in society, such as radio telescopes" or rockets (Pass, 2005). In contrast, a subculture is "the culture of a particular social group consisting of norms and values that differ from the dominant culture. It is literally a culture within the dominant culture" (Pass, 2005). A society and even a geographical region within it are not monolithic, so extreme differences of cherished or sacred ideas may exist. Different worldviews affect the future of space exploration just as space exploration affects worldviews (Harrison, 2007). As related to ET societies, differences of opinion exist between those who wish to search for ET life and those who do not. Behavioral patterns in the context of defining astrosociology refers to how similar psychological factors affect people's conduct in ways that result in larger trends.

The focus, then, is on issues related to the study of the potential existence of extraterrestrial life (and perhaps later the actual study of such life). In contrast to exo-astrosociology, then, astrosociology investigates a much broader array of space topics involving the human dimension. Additionally, both astrosociology and exo-astrosociology are multidisciplinary in their approach, which include the social and behavioral sciences, the humanities, and the arts.

In a conference paper delivered by Harrison (2005) in an astrosociology session that I chaired, he provided some early advice (as I had only founded the field of astrosociology approximately one year earlier):

> Disciplinary biases that define some areas as "hot" are likely to discourage some sociologists from entering the field. Be prepared for "the giggle factor." Unless they carefully explain their work, sociologists whose activities can be linked to "little green men" risk ridicule and professional censure. For all intents and purposes, you will have no peer group. Although much has been published on life on other worlds, very little of this has been published by professional sociologists and their allies. Thus, expect a spotty and tangential literature base.

He also wrote about how the pseudosciences such as crop circles, UFOs, and alien abductions might have placed a greater burden on the development of astrosociology in its infancy. He was correct. However, things have improved markedly, especially with the explosion of the social media, which allowed this field to move forward more rapidly than would have been the case without it. It also allowed astrobiologists and SETI scientists to appreciate what the social sciences, humanities, and the arts could offer their own efforts to not only locate microorganisms and ETIs, but also to better understand the latter should they discover them. They can also assist them to better predict how human groups, cultures, subcultures, and individuals would potentially react to such a discovery. Additionally, I believe they could also appreciate how an ongoing and complex set of analyses would keep exo-astrosociologists and others extremely busy long after that initial point.

Exo-astrosociologists could also assist non-social-scientists to move beyond anthropocentric and ethnocentric preconceptions about how ETIs may behave and what their priorities might be (Harrison, 2005). How ET beings would respond to the knowledge that humanity exists with all of its quirks that include altruistic and harmful behaviors would very likely be quite foreign to them including the human ways of thinking or assessing events. Social scientists and humanists, including linguistic scholars, can assist in ways that expand traditional approaches in SETI and astrobiology.

C. Three Fields, One Purpose

The major objectives of astrobiology, SETI, and exo-astrosociology that link them together involve designing and implementing methodologies for finding extraterrestrial life, providing thought experiments as to what extraterrestrial cultures may be like; and theorizing about how the discovery, and lack of one on an extended basis, affects humanity at multiple levels of social analysis. In a sense, while they have historically remained rather separated from one another, they have never been apart in terms of the various questions that they seek to answer, especially one astrobiology began to flourish.

A new trend is emerging between astrobiology and SETI in relation to exo-astrosociology. Although astrosociology is a multidisciplinary social *science* field, it is normally excluded from the STEM and even the STEAM disciplines, the latter of which include the arts, because the "S" in the acronym traditionally has referred to only to the physical and natural sciences (Pass and Harrison, 2016). The arts have seemingly attained a more relevant position than the social sciences to some degree. In all honesty, astrosociology has always included the space arts as part of its purview and social scientists have always investigated the impact of the arts. Additionally, astrobiologists and SETI researchers have always speculated about various aspects of astrosocial phenomena, and exo-astrosociology exists to bring social-scientific precision to assist in this endeavor.

The one structural reality that separates exo-astrosociology – and astrosociology generally – from the other two fields relates to the fact that this field is from the other branch of science. The physical and natural science disciplines have more in common in some ways because their cultures are similar and their histories have been more intertwined. On the other hand, exo-astrosociology is based on the human sciences, and since humans conduct both astrobiological and SETI research, the human dimension ties them all together in a sense. Exo-astrosociology's purview includes how astrobiologists and SETI researchers do their work and related issues, but it also involves more social science specific concerns such as what extraterrestrial societies look like and how humans of various types will respond to the news that humanity is not alone should that day occur.

Like astrosociology, astrobiology and SETI are multidisciplinary fields. As exo-astrosociology is not merely a subfield of sociology, the other two fields are not simply a branch of biology or astronomy. The quest to discover extraterrestrial life demands the collaboration of several fields and disciplines. Cross-collaboration between the two branches (cultures) of science remains a vital step in the search for extraterrestrial life that is slowly happening. Thus, a major difference between exo-astrosociology and the other two fields is the fact that the latter two involve a great many researchers while the former is in its infancy with regard to the study of potential extraterrestrial life. In fact, this essay is the first major announcement about the creation of exo-astrosociology. The most important, and distressing, characteristic of this early stage is the small number of individuals pursuing the search for extraterrestrial life from a social-scientific perspective.

Regardless of their differences, however, these three fields have much in common as well, and collaboration among them all will yield the greatest body of knowledge possible. Including the social sciences, humanities, and arts will result in a more holistic approach that will produce the most expansive ideas possible. All three fields provide unique contributions to the search for ET life that cannot be duplicated by any one of them alone (Pass, 2018). The ultimate goal among the three fields is a true realization of convergence (Pass and Harrison, 2016). The future establishment of such an innovative reality would no doubt catapult the search for ET life greatly into new directions unfathomable by today's research efforts.

One purpose exists for all three fields, then, which is to discover extraterrestrial life, study its primitive ecosystem or social order (depending on whether nonintelligent or intelligent life is detected), and understand how such a discovery affects various parts of human societies and individuals. Of course, while no life is found, the unifying goal is to keep searching. That in itself is interesting to exo-astrosociologists because it includes the reasons why astrobiology and SETI are gaining in popularity among both scientists and the public. While ET life resides light years away, what humans do to find it remains an important area of study.

III. Biosignatures and Technosignatures

Before moving forward, two additional vital definitions require attention. Biosignatures and technosignatures represent the two categories of detection methodologies for searching for extraterrestrial life. Nevertheless, both approaches seek to discover ET life by searching for biological variables and technological variables. Therefore, the two overlap in many ways and are complementary to one another.

A. Biosignatures

First, a *biosignature* (or biomarker) is defined (as summarized by *Wikipedia*) as the following, which is easier to articulate than to actually prove:

> any substance – such as an element, isotope, molecule, or phenomenon – that provides scientific evidence of past or present life. Measurable attributes of life include its complex physical and chemical structures and also its utilization of free energy and the production of biomass and wastes.

The markers that may indicate alien life of any type is not a conclusive outcome. This makes it important to distinguish between two types of biosignatures. A "definitive biosignature can be interpreted without question as having been produced by life" while a potential biosignature is a "phenomenon that may have been produced by life, but for which alternative abiotic origins may also be positive" (AFL-SSG, 2006:10). At the current period of the search for the evidence of biological life, the best that we can accomplish is the detection of the potential type of biosignature. The same may be true of attempting to distinguish biology from chemistry even on Mars, for example.

Biosignature gases include methane, oxygen, nitrogen, ozone, and carbon dioxide. Water in its gaseous, liquid, or frozen form is also a major biosignature, although life may exist even without the presence of water as may be the case on Saturn's moon Titan (McKay, 2016). Unlike biosignatures in our Solar System that we can more easily investigate directly via material culture (e.g., orbiter, lander, rover), the search for biosignatures in the atmospheres of exoplanets and exomoons is more indirect. For example, even detecting water vapor or oxygen in the atmosphere of an exoplanet does not guarantee that life is present (He et al., 2018). In our Solar System, in contrast, it is possible to discover, and even run tests for, organic molecules and it is also possible to find living microorganisms or fossils of past life.

A circumstellar habitable zone, or habitable zone, or "Goldilocks Zone" has been defined early on as conditions in which a planet's distance from its star and the heat its star generates results in the presence of liquid water on the surface of said planet. Thus, when considering the most likely prerequisite for life elsewhere in the cosmos, liquid water is the key constituent that defines the habitable zone. This definition is based on a single data point. Humanity is only aware of life on a single planet, namely Earth, and thus speculation about extraterrestrial life is dependent on what is known here. However, surprising findings in our own Solar System and discoveries on Earth itself have resulted in the realization that the traditional definition of the habitable zone is too limited.

Over time, planetary scientists have needed to rethink about the definition of the habitable zone for two major reasons that relate to the hardiness of life and variety of ecosystems.

> That shift happened in two parts, fueled by discoveries in broadly different fields. First came the idea that life could live in colder, darker, stranger places than biologists could have dreamed. Second came the idea that the most basic conditions for survival – chiefly the presence of liquid water – could turn up in unexpected places (Smith, 2017).

Water seems to be everywhere in our Solar System, and moons such as Europa and Enceladus seem like prime candidates for possible life. Missions such as the Voyagers, Galileo, and Cassini demonstrated that even moons were dynamic and sunlight was not the only contributor to this dynamism, as even the tidal pull of gas giants could create ecosystems for possible life (Smith, 2017). Additionally, extremophiles found in harsh terrestrial ecosystems have made scientists realize that life is much more resilient and adaptable than first imagined. Thus, it became clear that life could exist, and even thrive, in places beyond the traditionally-defined habitable zone, either closer to the parent star or farther away from it. Thus, astrobiologists have developed new definitions that are still in flux due to new findings that continue to present themselves.

On the other hand, an exoplanet that falls within a traditional habitable zone does not guarantee that life exists, as many other factors contribute to whether life is possible. Biosignatures in the atmosphere of an exoplanet or exomoon may just reflect a coincidence of chemicals that somehow mimic what we associate with life on Earth. Without enough energy, life could probably not exist, either (McKay, 2016). Therefore, further investigation would be warranted if rudimentary indications of biosignatures in an atmosphere was detected. It is even probable that we may find many negative outcomes before discovering ET life. Many conditions could negate the establishment of ET life even among extremophiles that may attempt to gain a "foothold."

In fact, one of the major problems associated with the detection of biosignatures relates to the difficulty in defining life, even as it exists on Earth (Benner, 2010). This imprecision is a *human* problem associated with imprecise language. We obviously tend to recognize it on Earth, even if we cannot agree on how to define it precisely, but how does this problem manifest itself when searching for ET life on other planets? We are not even certain if the life we know is truly representative of life elsewhere in our universe. Thus, it is important to expand our anthropocentric notion about life so as to be more prepared to recognize "alien" life that is dissimilar.

The Kepler and K2 missions located hundreds of potential exoplanets and the TESS mission is currently operating for the same purpose. If proposed missions such as HabEx, LUVOIR, and the James Webb telescope can find additional exoplanets, especially Earth-like ones, and if they can identify carbon dioxide, methane, water, oxygen or any other biosignatures in both known and yet undiscovered planetary atmospheres thought necessary for ET life, it could indicate the planet is hosting life. Amino acids and vegetation represent higher-order biomarkers to look for.

Biosignatures themselves are not direct evidence of ET life, however. Nevertheless, they do act as indicators of promising targets on rocky worlds. While it is not possible to be certain that any given exoplanet is devoid of life, it is useful to weed out less promising targets for those that seem like better opportunities. It is a required logistical calculation that save time and valuable resources. This is important because astronomers and astrobiologists tend to be quite optimistic about detecting biosignatures that point to the existence of ET life (Seager, 2016).

1. Lessons for the Exo-Astrosociologist

Astrosociologists generally study how space science is conducted and what the results mean for societies, their structures, and their populations. Research associated with the study of biosignatures provides humanity with new visions of itself and where it fits into its universe. Whether religious or not, humans have always sought to explore undiscovered territories, both physical and abstract, and striving to learn as much as possible about where they live on various scales – from their families, to their neighborhoods, to their communities, to their regions, to their nations, to their planet, and to points beyond – continues to drive them.

Searching for biosignatures is the most far-flung example of trying to learn about themselves, but seeking to discover life beyond Earth is, for many, based on the fervent hope that humanity is not alone. Human beings are social creatures who do not want to be alone and isolated. The search for extraterrestrial life is just a more expansive need to feel connected to something bigger than themselves. In this case, they want to find their cosmic neighbors.

Exo-astrosociologists need to look more closely at these types of issues. This is where the social scientist and humanist can provide important insights into the social, cultural, psychological, and behavioral facets of the search. Why is the search important for individual scientists and humanity as a whole? How does science fiction fuel the need to learn more about our universe? Why are some people and subcultures opposed to the proposition of finding extraterrestrial life? The answers to these types of questions, while related to physical and natural space scientists, are not answerable by them due to their scientific scope of knowledge. Social scientists and humanists are trained for this, which is a complementary exploration of sorts. A convergence is required between the two branches (cultures) of science, which is discussed in greater detail below.

B. Technosignatures

The second concept is the *technosignature* (or technomarker). Margot et al. (2018:2) provide a good definition of a technosignature as stated below.

> We define a "technosignature" as any measurable property or effect that provides scientific evidence of past or present technology, by analogy with "biosignatures," which provide evidence of past or present life. The detection of a technosignature such as an extraterrestrial signal with a time-frequency structure that cannot be produced by natural sources would provide compelling evidence of the existence of another civilization.

The search is for signs of ET technology that is not somehow mimicked by nature, something artificial that has been produced by some form of "intelligent" life. Also, biosignatures could be produced by technosignatures, such as what humanity is doing on Earth through its contribution to climate change.

The category of technosignatures most often focused upon are radio signals not produced by natural sources due to the long history of SETI efforts. This strategy continues. However, the current search for technosignatures has expanded from this traditional approach. More sensitive instruments will make it possible for the search for biosignatures to include the capability to also detect some types of technosignatures, especially those chemical markers in exoplanet atmospheres potentially associated with extraterrestrial societies.

Detection of a technosignature is potentially more difficult than that of a biosignature, though the latter could lead investigators to look more closely for the former. Additionally, some chemicals in the atmosphere of an exoplanet, such as carbon dioxide, could be categorized as both a biosignature and technosignature if intelligent life is present. Once telescopes are sensitive enough, technosignatures could be more easily found as well via detection of pollution and greenhouse gases (Lin and Gonzales, 2014).

Artificial structures represent an important type of technosignature. Dyson spheres are an artificial structure or collection of structures that surround a star in order to collect its energy in a much more efficient manner. One possible example of how one might detect one of these monstrosities was exemplified by Star KIC 8462852 (also known as Tabby's Star or Boyajian's Star). It is a large star that lies about 1,500 light-years from Earth. The inconsistent dimming event intervals, which were observed by NASA's Kepler space telescope starting in 2009, seem too substantial and irregular to be caused by an orbiting planet according to many astronomers. Natural causes that best explain the data associated with Tabby's Star probably rule out an artificial structure, but people – including scientists – were excited about the prospect of finding a real technosignature. Other types of artificial technosignatures in space include satellites, space stations, and orbiting spacecraft. Technosignatures may also exist in the form of debris left over from a long-extinct civilization.

After a long period of not funding SETI and thus the search for technosignatures in the form of ETI broadcasted radio waves since 1993, NASA announced its support and held a workshop in Houston from September 26th to 28th, 2018 (Gough, 2018). Perhaps this change of heart by this space agency was due to the expansion of the search beyond radio signals. Jill Tarter, a SETI pioneer, has called for the renaming of SETI to something such as "the search for technosignatures" or signs of technology created by intelligent alien civilizations (Cofield, 2018). She echoes the argument of some others that we cannot define or measure intelligence "and we sure as hell don't know how to detect it remotely" (Cofield, 2018).

"On October 19, [2017], Rob Weryk of the University of Hawaii's Institute for astronomy (IA) discovered a strange celestial object" (Bennett, 2017). 'Oumuamua, the tumbling oblong probable asteroid or comet that passed through our Solar System sparked a discussion among scientists and others in the social media about whether it was a probe out of control from an ET society that flew by to check us out. Its appearance raised speculations about what such a probe would look like and how humanity can best determine its true nature.

The scientific investigations of space scientists interested exo-astrosociologists about 'Oumuamua as the former raced to determine the physical properties of this object because human beings were studying a type of astrosocial phenomenon. Also, of importance were the fervent speculations about its purpose and probing by radio telescopes to determine whether this object from another solar system was some type of ET material culture. This object provided an opportunity to study an object from another solar system and that was significant. Another interesting element to this discovery to exo-astrosociologists is the fact that the International Astronomical Union lacked a nomenclature protocol for an object that was passing through our Solar System never to be seen again. They had to name this object in a hurry before it got away from them.

> And so, a new naming style was born. The IAU Minor Planet Center established a preliminary naming scheme using the designation "I" for interstellar, rather than "C" for comet or "A" for asteroid. A/2017U1 has now been designated 1I/2017U1, and the astronomers who discovered the interstellar visitor using the Pan-STARRS 1 telescope on the volcano Haleakalā in Maui have also give the object a common name: 'Oumuamua" meaning 'scout' or 'messenger' from afar (Bennett, 2017).

While the object was either material culture from an ETIS, a rock with life hitchhiking on it, or simply a rock devoid of life, the human interactions with it among space scientists, the media, the public, and other social categories of people demonstrates the importance of studying the human dimension of space exploration in concert with the so-called "hard" science. Human beings are always involved, which are the subjects of social scientists and humanists.

Through the study of how the impact of human activity has affected Earth's climate at the outset of the Anthropocene, it will be possible to glean ideas about what types of technosignatures to search for in ET atmospheres that should possess similar traces of pollutants and other chemicals (Grinspoon, 2016). Furthermore, the study of climate change on Earth helps both to characterize and find solutions to benefit humanity. Scientists should definitely take advantage of both the terrestrial and extraterrestrial benefits.

1. Lessons for the Exo-Astrosociologist

Unlike with the regard to discoveries associated with the search for biosignatures mostly in our Solar System, which have produced discoveries and insights of tangible value, the research associated with the search for technosignatures is less impressive. The search for biosignatures is still speculative in the sense that a second genesis of life is still elusive. However, trying to locate or hear from an intelligent extraterrestrial society is far more difficult unless a radio signal happens to beam toward the Earth or a verified ET spacecraft flies by us. Detecting technosignatures in other solar systems, especially in the attoamperes of exoplanets or exomoons, or discovering an artificial structure such as a space station or Dyson sphere, is extremely difficult using today's technology.

Nevertheless, the search itself benefits humanity for at least two major reasons. First, the willingness to commit resources to search for technosignatures contributes to the advancement of science and technology in order to get the job done. Second, this activity results in spinoffs and technology transfers that improve the lives of people and often help to solve some of the social problems they face. As mentioned above, humans benefit in both ways that further the search for ET societies and in other ways that involve benefits to humanity itself that go beyond the search for ET societies.

Is there a point in time in which humanity will simply give up? The answer to such a question does not involve extraterrestrials at all. It involves human beings. Governments may cut funding at some point, seeing it as a waste of resources. On the other hand, they may continue to fund the search because they value it for the benefits that flow out of it beyond finding ET societies. Perhaps the questions raised at the beginning of this essay are relevant. Is humanity truly alone in the universe? Perhaps the drive to answer questions such as this propel humanity forward in this search as they reap the benefits that come with scientific and technological advancement.

IV. Collaborations between the Two Branches of Science

This essay focuses most heavily on issues related to detecting *intelligent* extraterrestrials through technologically-based indicators that occur due to the everyday functioning of their societies. Traditionally, the search for extraterrestrial radio signals has served as the most common types of technosignatures. However, biological indicators such as carbon dioxide and oxygen may serve as initial markers for the existence of a technological social order (or microscopic life or inorganic molecules that mimic organic molecules). Historically, astrobiologists focused on biosignatures while SETI researchers focused on technosignatures. However, there is no need to pit technosignatures against biosignatures when the crux of the matter is to discover extraterrestrial life because such a stance places limitations on achieving such a discovery. Similarly, the exclusion of SETI from astrobiology, which has implications for NASA funding and creates other problems, limits the potential fruitfulness of the enterprise; and thus, SETI should be viewed as part of astrobiology. And, indeed, SETI and astrobiology began to converge their research areas formally starting in 2011 (Almár, 2018). The future approach for finding extant or extinct extraterrestrial life should involve a renewed collaboration among all disciplines and fields that possess a stake in the search; and that includes the social and behavioral sciences, the humanities, and the arts.

The human dimension – which is critical to the astrosociological field – is intertwined with the focus on finding extraterrestrial life. A technosignature, by its very definition, implies the establishment of a complex social order created by another intelligent species unrelated to any on Earth. Discovery of such a nonhuman society would cascade across all terrestrial cultures and create an area of astrosociological research that would undoubtedly transform humanity into something different because it would prove once again that humanity is not the center of the universe, but rather a miracle of life on the far outskirts of the cosmic ocean. This rather preliminary investigation through an astrosociological (or social-scientific) lens into the possibility of extraterrestrial societies goes beyond the discovery of a second genesis of nonsentient life, which in itself is vitally important, and looks at what credibly can be done to find a technologically advanced extraterrestrial social order.

While astrosociologists and astrobiologists share many of the same concerns, the former also ask questions that are based on the traditions of the social sciences and humanities. Exo-astrosociologists, astrobiologists, and SETI researchers benefit most when they work together. The social scientist and humanist are almost like missing links in the process. This should not be the case because more can be accomplished through formal collaboration.

Finally, this exercise may seem like an extremely speculative topic. However, the purpose here is to demonstrate once again that the social and behavioral sciences, humanities, and arts are relevant. Moreover, they can shed additional light onto phenomena that traditionally have been studied by astronomers, planetary scientists, and other "hard" science investigators. Only recently have those from the so-called "soft" sciences turned their attention to these fascinating questions; though it must be emphasized that relatively few individuals have done so thus far. One of the main missions of ARI is to improve on this unproductive reality.

V. The Status of the Search for an Extraterrestrial Society

SETI researchers are attempting to detect societies on far-flung exoplanets, exomoons, or artificial structures while astrobiologists are focusing most on the direct detection of microorganisms. Both types of activities are difficult. Even the detection of organic compounds or life-friendly chemicals in non-Earth atmospheres does not guarantee the existence of life itself. On the other hand, locating techosignatures such as radio or laser signals or industrial pollution cannot provide definitive proof of an extraterrestrial social system, either past of present. Still, given the fact that both camps are doing similar things with the same goal of finding ET life, it is not productive to pit astrobiology against SETI as some type of race to find nonhuman life (Tarter et al, 2018). It is best to think of the two fields as complementary, each with very similar goals and each potentially beneficial to the other. In fact, some are beginning to argue that SETI is actually part of astrobiology, which is a turnaround from previous patterns of activity (Wright, 2018).

When searching for extraterrestrial life, both biosignatures and technosignatures can reveal its existence. SETI and astrobiology are similar and thus their scientists should collaborate, and both are worthy of NASA funding. As of yet, however, humanity has discovered no definitive techosignatures, not even a single verified radio transmission. Nevertheless, while many individuals view the efforts of astrobiologists and SETI researchers as worthless or even hopeless, astrosociologists regard the same state of affairs as worthy of study because a dedicated collection of human beings are taking up the initiative despite negatable progress. There are signs that biosignatures on distant planets may indeed exist based on detections of biomolecules in the atmospheres of exoplanets. Additionally, these molecules exist as free-floating molecules in space environments within nebulae and elsewhere (Pass, 2010). In summary, then, the status of the search for an extraterrestrial society is best represented as hopeful despite the absence of indisputable evidence. Beyond this, astrosociologists' interest falls upon the very search for extraterrestrial life even while there is no guarantee of a positive outcome. The process is what is worthy of study.

While searching for markers that reveal an extant social group represents the most sought-after discovery, it is important to keep in mind that a detection of an extinct society – or even a microbial form of extraterrestrial life – would also place humanity in another position in which it is not an exclusive accidental existence. The first discovery of life elsewhere in the universe may even unravel reality into a series of detections, just as the proof of a single distant planetary system led to the discovery of a plethora of other exoplanets. Moving forward has always resulted in unforeseen advancements.

A. "Low-Tech" Signatures

The first impulse is to look for the sophisticated signs of a technological society. However, a good intersection between the two branches of science, a collaboration between the two cultures, is to consider signatures that normally only fall in line with astrobiological inquiries. For example, Dr. Alice Gorman has suggested that because human groups used stone tools as their main technological innovation for the longest time in history, the consideration of social-scientific forms of evidence can be helpful (see Figure 1). While the detection of elements such as siliceous rocks is quite an indirect indication of possible intelligent life, it does provide for the possibility of

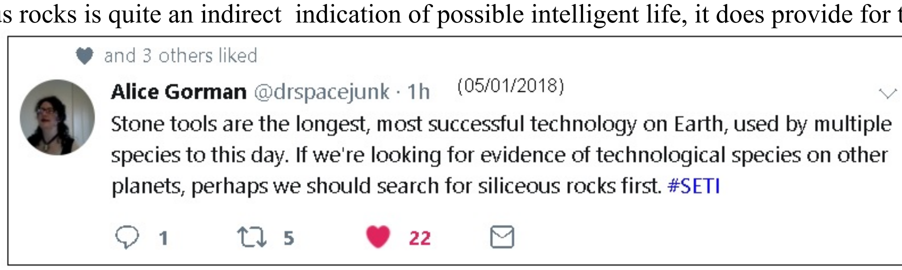

Figure 1. Tweet by Alice Gorman.

intelligent life in the past or present. Whether or not this is a good possibility, this thought exercise demonstrates the importance of thinking outside the box to consider evidence based on traces left behind by biological or even artificial beings interacting in an organized social system. The problem becomes seemingly intractable, however, because how does one detect stone tools or even stone structures on the scale of light years away from Earth? The only practical, though currently insoluble, solution is to send a probe or somehow travel to the location utilizing some type of yet undiscovered technology.

Remnants of nonhuman societies may not be obvious at first inspection. If an ET society is less advanced, not yet able to utilize tools other than those made of stone, then it may be necessary to look for other sorts of biosignatures and technosignatures. Discovery of biosignatures without indications of technosignatures could still lead to finding a preindustrial ET society. However, one must still be careful about false positives in this regard where no society actually exists. At the same time, larger structures are easier to locate. One only needs to think of the pyramids constructed by various ancient societies on Earth.

VI. The Future of the Search for Extraterrestrial Societies

Overall, the search for extraterrestrial life, especially one that represents a second genesis, continues. SETI efforts continue to search for radio signals and other potential techosignatures with a growing variety of methodologies (e.g., trying to detect radio signals but also laser communications) and more precise targeting (e.g., focusing on solar systems with planets in the habitable zone and planets that exhibit biosignatures discovered by astrobiologists when they occur). The Breakthrough Project calls for NASA to get involved again in SETI research, or at least funding it. This change along with other forces could indicate that the future of the search for extraterrestrial societies is perhaps stronger than ever.

Humanity can continue to search for technosignatures utilizing evermore capable telescopes, but this may never be a successful strategy unless some unforeseen breakthrough in human technology occurs.

> We could search for the remnants of technological civilizations from afar. But if we detect nothing through our telescopes, the only way to find out whether long-lived civilizations are technologically primitive is to visit their planets. Astrosociology could become a particularly exciting frontier of exploration as we venture into space (Loeb, 2018).

While sending humans to other star systems remains only a possibility for the distant future, sending probes seems like an approach that could occur much sooner. Expanding our view of possible technomarkers is another way to increase the odds of discovery. The best overall approach to find an extraterrestrial society or remnants of one – within speed limits of our current technology – is to employ as many strategies implementing as many ideas as humanity can devise, which social scientists and humanists can help to improve.

The growing number of astrosociologists and other social scientists and humanists can help to improve the odds of discovering ET societies. The future calls for physical and natural scientists to let them contribute at an unprecedented level. It makes little sense to block out an entire branch of science. The two different cultures can create interactive effects involving one another that will produce new ideas that would be impossible for either branch of science alone.

Thus, a key limitation to space exploration that includes the search for extraterrestrial life involves the relative absence of social scientists, humanists, and artists. While this pattern of exclusion is not unknown, the contributions that are possible tend to fall by the wayside. This is an important reality to consider because astrobiological and SETI actions have astrosociological consequences. While the detection of technosignatures is the obvious focus of SETI, humanity is affected by both the search itself and the implications of a positive outcome.

VII. What Type(s) of Intelligent ET Life Will We Detect?

Life on Earth is diverse today. This fact does not even take into account the huge variety of species of all types that have become extinct ever since the first example of life first emerged out of the primordial ooze. Such diversity on a single planet provides the strongest indicator that the characteristics, the look and function, of life elsewhere is unpredictable. Nevertheless, it is true that the chemicals and law of physics are the same everywhere. Thus, while that does not provide a clear prediction about what extraterrestrial life will look like when we find it, it does provide some ideas about what to search for, as indicated above.

Intelligent life, a type that can construct both material culture and social order, will exhibit or leave behind certain markers that human scientists can look for. In addition, a more advanced extraterrestrial society could conceivably create phenomena that are unknown to humans. Looking for unusual or unknown signatures is something that investigators must consider on an ongoing basis.

There are probably two extremes to answer this question in a very general manner. One potential is that there are intrinsic social laws to the universe, just as physical laws define our universe. Ashkenazi (2017:2) explains below.

> I strongly believe that there are certain social laws, which, while unproven mathematically so far, are as certain and to some degree predictable as natural laws we are familiar with. This is a strong claim, and many social scientists will dispute it vigorously. Nevertheless, …certain social features that human society displays are very likely to be true for any social intelligent species: not the least that "intelligent" and "social" are absolutely contingent.

What these features that resemble human societies are, is, of course, debatable. However, we can make intelligent guesses as to what they might be. For example, technological advancement is almost a certainty for advanced extraterrestrial societies. The idea of a society on an exoplanet also implies some type of organized population and thus social structure and culture. Can science and technology advance without being organized in some way? They cannot advance from generation to generation without communication, as culture is not possible without it. Thus, some type of writing and possibly verbal communication (if the biology allows for it) are needed. However different an extraterrestrial society may be, it is likely to possess recognizable features and produce detectable biosignatures and technosignatures. Is the human drive to explore only ingrained on Earthlings or is it inane in at least most intelligent species? These examples demonstrate the first extreme.

The other extreme views human analogies as fraught with problems (Denning, 2013). While the use of analogs is useful for the physical and natural sciences, such as simulating Mars missions in terrestrial deserts, we know much about Mars but nothing about even one extraterrestrial species. It is similar to what archeologists encounter when attempting to characterize ancient human behavior because, it too, does not exist (Denning, 2013). There is no evidence at all that we can utilize. The only data that exists concerning an intelligent species' behavior is right here on Earth. Furthermore, human behavior is varied and difficult to quantify into laws. What could we really attribute to a totally unknown extraterrestrial species as to their family structures, economies, politics, prejudices and discriminations, religious beliefs, prevalence toward conflict or negotiation (warlike or peace loving), or any number of other traits? Beyond that, how do the other species compare not only with humanity, but with one another? These represent questions that will require social scientists and physical scientists to collaborate in order to achieve the most comprehensive analysis.

Hopefully, the reality is somewhere in between. That is, there exist some similarities if not social or cultural laws that would allow for the possibility of communication. Also, as our technology becomes more sophisticated, perhaps this will become possible or we may discover some currently unknown method of detection that allows us to find an extraterrestrial society.

A. Biological Life, Mechanical Life, Sentient Probes, and/or Hybrids

An extant extraterrestrial society is most likely to be far more advanced that experienced by Earthlings since humanity is still in its infancy, so the question becomes what type of "life" exists there and what type(s) of social order did they construct. On the other hand, even a society such as found on Earth can produce pollution, for example, that humans could detect in the atmosphere of an exoplanet, as already noted. As another example, Lieb and Turner (2012) call for searching for artificial illumination such as what might be found in a city in an extraterrestrial society. Thus, it is not out of the question that humanity may detect an ETS with similar levels of scientific and technological advancement based on a number of technosignatures. It may be that this is a good bet because they, like us, have not yet destroyed themselves. On the other hand, the argument for a more advanced ETS is based on the idea that our universe is well over thirteen billion years old and they have found a way to avoid self-destruction. This would result in an ET species that has had a long period of time to advance itself technologically, scientifically, and biologically among other ways that we cannot even imagine. Although microscopic, Tardigrades (or water bears) demonstrate that life can withstand the conditions of space. What if intelligent beings could accomplish the same resistance to harmful environments?

If a technologically advanced species also has characteristics we associate with extremophiles, this would expand our search parameters quite extensively. There is no reason to believe that an intelligent ET species is as fragile as human beings. Drastic environmental conditions and other factors could push it to evolve into something much more tolerant of circumstances harmful to humans. They could also possibly extend aging or defeat the aging process altogether, which could eventually cause them to spread out beyond their home planet due to extreme population growth and all the problems that result from it.

The forms of life that we might encounter could be diverse, including mechanical life such as robots or ET-based androids, intelligent probes enhanced with sophisticated artificial intelligence, or even some type of hybrid that humanity currently has not even thought of. On the other hand, perhaps only microbes exist. We just do not know so we keep searching. The mystery is intriguing in itself.

B. Reactions to a Discovery by People on Earth

Assessments of the possible reactions to the proof that extraterrestrial life exists have received some attention by social scientists and others. Many of those who have argued for and against the search for ETIL have taken extreme positions although the bulk of humanity probably either does not take a strong position or is simply indifferent. A minority undoubtedly thinks it is a waste of resources that could be used for solving social problems among humans although the funding allocated to space exploration as a whole is extremely modest in all societies.

1. *Prediscovery Ideas*

Prediscovery actions already exist among some scientists and others. The *Declaration of Principles Concerning Activities Following the Detection of Extraterrestrial Intelligence* developed by the SETI Committee of the International Academy of Astronautics in 1989 with assistance of various experts calls for informing the world through all media outlets and other professional meetings that ETIL exists (Acta Astronautica, 1990). It also calls for verification before making any announcement. The idea is that everyone has the right to know and governments do not have the right to hide such a momentous event from the publics of nations. Those who counter this idea fear that the threat of possibly dangerous and technologically advanced "aliens" will come to Earth to exploit humans and their planet or destroy humanity. The stance by the SETI and astrobiology communities obviously favor, not only searching for ETI, but also communicating it to all of humanity in as many ways as possible. Douglas Vakoch (2016), a SETI pioneer, favors sending messages into deep space (active SETI) as does another pioneer Seth Shostak (2013), and Steven Dick concurs adding that it is not possible to prevent nongovernmental entities or individuals from sending messages into space. In fact, Vakoch has founded METI International in order to make messaging ET societies its mission (Scoles, 2016). He also emphasizes, as do we at ARI, that the very search for ET intelligent life benefits humanity as it moves forward. For example, even the increased sophistication of technology implemented to improve the search for ETIL provides benefits beyond those applicable to space exploration. Like with other aspects of space exploration, spinoffs and technology transfers benefit societies and their populations.

These scientists have always disagreed with the idea of keeping quiet because it is too late. Human signals of various types such as television broadcasts and especially radar signals have already informed any nearby extraterrestrial societies that Earth is inhabited by intelligent beings and our artificial technosignatures continue to propagate outward deeper into space. However, many others are fearful about what contact with an intelligent ET society could bring about in terms of harm to humanity.

In contrast to the mainstream approach, the argument against even continuing to search for extraterrestrial life centers around a type of fear that "aliens will come to Earth to destroy us" or "to take over our resources and turn us into slaves." Science fiction depicts countless examples of extraterrestrials as bloodthirsty monsters that act more on instinct than intelligence. Theoretical physicist and cosmologist Stephan Hawking famously warned against searching for extraterrestrial societies based on the possibility that a small percentage of them may be hostile and blow up the Earth or do something harmful to humanity (Moskowitz, 2010). He stated that perhaps it is better to keep quiet rather let any aliens know we are here.

> "Such advanced aliens would perhaps become nomads, looking to conquer and colonize whatever planets they could reach,"…[Hawking] said. "Who knows what the limits would be?" And in the 2016 documentary *Stephen Hawking's Favorite Places*, Hawking reiterated his views: "Meeting an advanced civilization could be like Native Americans encountering Columbus. That didn't turn out so well" (Greshko, 2018).

Before his death, however, Hawking supported the Breakthrough Starshot project, which is interestingly a serious "$100-million initiative aiming to send tiny spacecraft to the Alpha Centauri star system, 25 trillion miles away" (Greshko, 2018). He was willing to take the chance that we might have sealed our doom. On the other hand, Michaud (2008) has called for social scientists to inform physical scientists about the possible hazards, as "they badly need input from fields like history, biology, philosophy, and law." He warns that advocacy for METI must be replaced by statistical data.

2. *Postdiscovery Predictions*

Questions about how the discovery of any form of extraterrestrial life would affect humanity have been raised for decades. Some believe that the long-term exposure to science fiction scenarios including depictions of alien monsters should allow most of humanity to take the news of the discovery of ETI life in stride, as a study by Kwon et al. (2017) indicates. However, Shostak (1997) pointed out that the reaction would probably be chaotic as evidenced by the event in which NASA scientists and their colleagues announced the possible discovery of fossilized Martian life located in a meteorite called ALH 84001 in the prestigious Journal *Science*. Part of the chaos was likely caused by the critical debate among scientists as to its authenticity, though the debate goes on (Choi,2016). Interestingly, several scientists claim that positive science came out of this debate, which included the impetus to develop astrobiology (Choi, 2016).

One dimension that frequently attracts attention is religion and how a religiously-based society might organize itself. How would different religious groups react to the discovery of an ET intelligent species and would religious conflict ensue? How would the tensions between religion and science play out in various social settings? The answers to these types of questions are obviously based on conjecture to some extent, but some social-scientific research can provide probabilistic data. A more simplistic position is that atheists and agnostics are more likely to believe in the existence of ET life, so presumably Christians would be less accepting of an actual discovery (Mathews, 2013). However, not all religious groups, or even Christian groups, would likely react similarly and thus it is not advisable to lump them into a single category. In fact, the research associated with these types of religious issues will prove to be quite complex.

For example, McAdamis (2011:351) found that "while even anthropocentric religions have great promise to absorb such evidence, religions that are more detached from a human-centered purpose of the universe [such as doctrines related to a special creation, a unique incarnation, and vicarious redemption] promise to be even more readily adaptable to the potential of life existing beyond Earth. He also called for additional survey research. However, when categorizing religion as a whole, the more religious a person is, the less that person supports space.

> Worship attendance is negatively correlated with nearly all space variables – meaning, greater presence at church may discourage support for space. Traditional understandings of the Bible, running from ancient myths (modernist belief: lower score) to the Word of God (traditionalist belief: higher score), are negatively correlated with knowledge, interest, and funding support…Religious salience or importance – sometimes called *religiosity* – is also negatively correlated with several measures of space support (Ambrosius, 2016:21).

This reality has at least two major impacts related to the search for extraterrestrial life. First, a particular strongly religious person who happens to be in a position to direct policy or make laws may oppose SETI and astrobiology to an extent that searching for ET life is slowed or cancelled (as we saw with NASA and SETI). Second, such a person may be more strongly blindsided by the discover of ET life, especially intelligent life. This may cause some type of backlash that hurts science as a whole due to a turn to isolationism.

On the other hand, the major religions may react quite well to such a discovery, and the individuals within each group may themselves react differently. One cannot place all religious groups in the same category as a practical matter. For example, religions such as Buddhism and the beliefs of several Native American groups have long since accepted the existence of ETIs. Most religions are very likely to adapt to this new reality although probably not to the same extent or in the same ways as they adjust their doctrines.

Individuals may not be as willing to accept ETIs and may even reject scientific evidence as some sort of conspiracy. They may even break off from their current groups and create sects or cults that oppose the scientific proof or deem them as inferior beings. Others may worship them from afar. One thing that is a probable outcome is that various types of groups, institutions, and individuals will react in their own ways and that will contribute to a tidal wave of social and cultural change. If they actually visit Earth – that is, they detect *our* biosignatures and technosignatures and decide to mount an expedition to check us out in person – the impact would be tremendously more chaotic even if they were altruistic in their mindset and various human-based entities thought they were ready for such an event.

Fear can also motivate reactions that may seem to be erratic or irrational. Some individuals may expect an invasion or some other detrimental outcome. They may react irrationally based on their ignorance even if contact lacks serious antagonism. Panic is a possibility though to what extent we cannot measure until it actually occurs. If ET was able to send us some type of a photograph, perhaps our anthropocentric tendencies may reduce our fear if they looked sort of like us or increase it if they appear as totally unlike humanoids. Humans can react in ways that are quite destructive, as evidenced by the Orson Welles' 1938 radio broadcast of "The War of the Worlds."

Another issue relates to how long any negative reaction would last. Would social structures change permanently so that the inability among some categories of people to live their lives without being haunted by the knowledge of other intelligent beings becomes impossible? Much less has caused changes in behavior, cultures and subcultures, and social structures. Would the suicide rate increase among some social categories or groups? In the end, we can make educated guesses based on scientific investigations, but we will not know the extent or the precise patterns that emerge until the discovery is announced to the populations around the world. At that time, the contributions of exo-astrosociologists along with other independent social scientists and humanists will become increasingly valuable to societies partly because accruing evidence will move humankind closer to a remarkable discovery. Exo-astrosociologists need to study the entire scope of how scientists study SETI and astrobiological issues, including why their work is important, utilizing social-scientific applications of the scientific method, which is complementary to those of the physical and natural sciences. A much more holistic approach can be achieved.

Moreover, the discovery of intelligent life other than our own can be viewed as a potential social problem, which may in fact lead to additional related social problems (Pass, 2018). Such an outcome in the search clearly will have significant effects with predictable and unforeseeable characteristics. While the debate about the impact of such a discovery goes on, the one thing that cannot be denied is that social changes will occur and not all of them will be positive for various societies, social groups, subcultures, and individuals. This is just one reason why social scientists and humanists are relevant to space exploration in general and the search for ETI specifically. Moreover, we can better predict how certain groups, whether religious or otherwise, will react if we examine past cultural ideas and actual events (Vakoch, 2000). Similarities of reactions from the past to traumatic and extraordinary events can assist in predicting how different groups may well respond to the confirmed discovery of the existence of an extraterrestrial intelligent species as well as valuable insights into potential reactions to the actual discovery of ET microbial life. It is not difficult to imagine that the confirmation of the existence of ETI would result in a myriad of profound social, cultural, and psychological changes (Vakoch and Lee, 2000) and thus it is important to think about such a possibility as a practical matter. This type of exercise yields positive results in better understanding the human condition even without such a detection.

Finally, it is important to think about how humankind would treat a second genesis of microbial life located somewhere in our solar system, which could be reached by space probes, rovers, and eventually humans (McKay, 2016). Would we protect it? Would we act the same way if past life in the form of fossils were discovered? What if it happens to live in an area with valuable resources that corporations are eager to exploit? While we tend to focus on how humanity would react to not being alone, it is also important to think about how we will impact on the ecosystem of ET life. This latter consideration could well involve social, cultural, economic, military, and political implications (among others) that fall directly in the wheelhouse of exo-astrosociologists.

VIII. Conclusion

This exercise cannot provide any answers about the characteristics of technological ET social systems. However, this type of discussion can open our eyes beyond the familiar, beyond what we experience on Earth. While the physical laws apply throughout our universe, how these laws work themselves out in very different environments and ecosystems will likely result in a combination of characteristics that are both oddly familiar and truly alien. After all, evolution is based on a series of trials and errors, including those that involve artificial biological and technological enhancements. On Earth, why did **Homo sapiens** come to threaten its own ecosystems rather than chimpanzees or gorillas? As has been stated many times before, if the dinosaurs had not become extinct, they may well have become the dominant intelligent species. Even on our home planet, things could have gone a number of different ways that would not have favored humankind.

The search for extraterrestrial life is relevant to astrosociologists (and thus all social scientists and humanists) for a number of reasons. Exo-astrosociology is relevant because humans are organizing themselves to search for ET life, which is itself a social movement that falls under the purview of sociology and other disciplines. The *human* search for *nonhuman* life elsewhere in the cosmos continues humanity's quest to discover whether or not the Earth is special for some reason; which, by the way, has never been proven to be the case. It also reflects humanity's expansion of its exploration of outer space. "Space aliens" are not the only topic of importance during the conduct of space exploration, as the disciplines of astronomy, cosmology, and the planetary sciences demonstrate. NASA, for example, dropped its pursuit of attempting to discover ETI (i.e., SETI) in 1993 due to Congress defunding it in favor of searching for microbial life in our own solar system (i.e., astrobiology) (Lemonick, 2011). Only recently have discussions become serious about merging the two fields into a search for all forms of ET life. In the meanwhile, SETI was carried out by private organizations, most prominently by the SETI Institute in Mountain View, CA.[3] Now, the possibility exists that a private/government relationship will form that is similar to NASA's Commercial Partners programs associated with rocket development and Moon exploration.

It has become clear that the search for extraterrestrial life, a second genesis of microbial life or, even better, an intelligent species, holds a special place in attempting to understand how humans fit into the overall scheme of the structure of the cosmos. Are we here by accident, by some cosmic design, or for some other unfathomable reason? The general public continues to believe that extraterrestrial intelligent life exists (Main, 2015), so there is an impetus for the scientific communities in both branches of science to continue the search. A contrasting sentiment would not cause most scientists to stop the search probably unless funding dried up, but the number of people involved in SETI and astrobiology demonstrates that these efforts are important to humanity.

In the end, the search for extraterrestrial intelligent life represents an exercise, not in futility despite the ongoing absence of proof, but in the hope that we are not alone. But additionally, in the meanwhile, humanity gains knowledge about the cosmos and learns more about its place in it. Our search for life is intrinsically linked to other forms of exploration. For example, the discovery of exoplanets allows us to compare our Solar System and cosmic bodies with those of others, and we also search for biosignatures and technosignatures while we compare our atmosphere with those the other atmospheres. Exploration of space is a multifold approach to understanding how we compare with other parts of our universe. Beyond the natural and physical sciences, this approach also possesses profound social and cultural (exo-astrosociological) implications for humanity.

When searching for a second genesis of life elsewhere in the universe, it makes little sense to exclude an entire branch of science that includes the social and behavioral sciences, the humanities, and the arts. On the contrary, the

[3] See the SETI Institute's website for additional information: https://seti.org/

most logical approach is to include all perspectives and the scientific investigations by all disciplines and fields. This discussion demonstrates that while the physical and natural space sciences have much to offer, the human sciences do as well. A holistic approach demands that all scientists and scholars with scientific input to offer require inclusion for the best level of understanding of any topic, including the search for intelligent extraterrestrial life.

Loeb (2018) points out that the future of human spaceflight in the search for ET life can be fruitful and the social sciences have something to offer even though travel time will likely take hundreds of thousands of years to reach the nearest exoplanet:

> Over the billions of years available to our technological civilization to explore the Milky Way, we could compile a sociological census of billions of exoplanets. And even if we find mostly faith-based alien cultures instead of advanced infrastructure that would accelerate our own technological development, it would be fascinating to explore the diversity of galactic interpretations of the concept of God.

Finding faith-based cultures – or any type of culture – falls under the purview of sociologists, anthropologists, psychologists, and archeologists to name a few disciplines, so understanding non-biological phenomena from Earth or at the source of investigation requires input from social scientists. Exo-astrosociologists can make significant contributions long before humanity explore space beyond our Solar System in ways discussed here as well as others currently unforeseeable. For example, Colombano (2018:3) who works at NASA's Ames Research Center recommends that we should "(e)ngage sociologists in speculation about what kinds of societies we might expect from the above ["hard" scientific and technological] developments, and whether and how they might choose to communicate." This type of recommendation from a non-social scientist is helpful toward expanding the inclusion level of all scientists. Thus, because exo-astrosociology is a multidisciplinary field, this type of recommendation should be expanded to include the entire "other" branch of science. Although social scientists and humanists have already made important contributions, it has not been enough as their voices are overshadowed by physical and natural scientists. Therefore, the next step is to increase the level of input from social/behavioral scientists and humanists to a reasonable extent so they are both acknowledged – and more importantly – taken seriously.

For example, space archeologists can assist in important ways (Gorman and O'Leary, 2013).[4] An interesting question involves whether the first confirmed detection of a technosignature turns out to be the leftover technology of a dead civilization or an indication of an active nonhuman society. In other words, are the extraterrestrials dead or extant? Are they actively transmitting messages or is the signal coming from a beacon that has outlasted the living inhabitants? Each scenario provides its own series of interesting inquiries. If the extraterrestrial society has destroyed itself and left behind various types of their material culture, then space archeology is the best approach to locate evidence of remaining clues of their past existence, or for that matter, any type of evidence of its material culture. If the ET society still thrives, then space archeology is helpful along with the other social sciences to study their culture, both in terms of their ideas and their physical constructions.

It is arguable that proof of extraterrestrial biology will come from the discovery of biosignatures before that of technosignatures due to efforts taking place in our Solar System, but anything is possible. Perhaps material culture from an ET society will come flying to us. In any such scenario, this would be a coup for astrobiologists and other physical and natural space scientists, but it will also possess extreme importance for exo-astrosociologists as well because the implications for human societies and subcultures, not to mention individuals, will be profound. So much follow-up would be necessary after such a watershed event among all the scientific disciplines, and therefore the social and behavioral sciences, humanities, and arts need to be included in the mainstream of the search for ET life today, which is a concept that is gaining greater traction among those involved in the search.

The subfield of exo-astrosociology can add several contributions based on a focus on the human dimension of the search for extraterrestrial societies. It is important to imagine how nonhuman societies would organize themselves, what values, mores, and norms characterize their societies and cultures. Perhaps one outcome of this line of thinking could be a new way to envision a better future for humanity. We are learning more and more about ourselves as we continue our investigation into the cosmos.

Even if humanity never locates an ET society, the human dimension of space exploration itself is worthy of continuance. We may never discover intelligence beyond our own planet, but the search will undoubtedly uncover fascinating wonders of other types nevertheless. And, as we venture outward into our galaxy, and we begin to evolve independently in various exotic ecosystems, the future extraterrestrials may well have started their adventures on Earth. The idea of isolating ourselves on a single planet seems to be really bad idea – especially in the long run. For these ideas and many more, putting an end to the related searches for biosignatures and technosignatures via

[4] "Space archaeology is the study of 'the material culture relevant to space exploration that is found on earth and in outer space (i.e. exoatmospheric material) and that is clearly the result of human behaviour' (Darrin and O'Leary, 2009:5; O'Leary, 2009c; see also Staski, 2009:19)" (Gorman and O'Leary, 2013:409).

astrobiology and SETI, and adding the analyses of exo-astrosociology seems like a good way to avoid the extinction of our species. Based on current trends, humanity will venture outward into space and therefore the search for ET life will continue. It is not beyond belief that more than one example of a second genesis may well result from our continued search.

Humankind has already sent out its own technosignatures in the form of material culture away from planet Earth aboard Pioneer and Voyager spacecraft that include messages from humanity. Is it out of the question that a more advanced ET society could not do the same for a longer distance with the additional time they had at their disposal? Should we not be on the lookout for ET intelligent space probes? Is that not what we would send if we had the capability? Technosignatures may not be found only on exoplanets, but also flying through space! Our technologies for imaging other solar systems continues to advance making the detection of biosignatures distinguishable fairly soon on a number of exoplanets, but we still have a long series of developments to go until we can actually discern technosignatures directly. If we are lucky, they will come to us!

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