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Drake Equation Revised Fermi Paradox Resolved Tarian Criterion Related

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Editorial
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Editorial

Advantages of Analyzing any Biological Problem from the Perspective of an Experimental Biologist

The *Drake Equation* and its somewhat related *Fermi Paradox* do not seem to have ever had the benefit from the perspectives of any professional experimental biologist. This is surprising since both formulations involve biology and have been around for over 60 years. The educational background of Frank D. Drake is in astronomy and astrophysics [1]. Those authors most closely associated with the *Fermi Paradox* include Konstantin Tsiolkovsky (rocket science and astronautics), Enrico Fermi (physics), Michael H. Hart (astrophysics), and Frank J Tipler (mathematical physicist and cosmologist) [2-5]. None of these contributors to the *Drake Equation* and the *Fermi Paradox* seem to have had any training, advanced education, nor experimental research experience in biology. This work intends to remedy that shortcoming. But why are perspectives from professionals actively engaged in experimental biology needed to sort through problems associated with astrobiology such as the *Drake Equation* and the *Fermi Paradox*?.

Biology is the most integrative of all of the many sciences. One can do physics without an understanding of biology but not the other way around. The same is true for chemistry. Ecology requires an understanding of geology, but geology does not require an understanding of ecology. The true power gained from a biological perspective derives from its integration of the other branches in science. As an example, in deriving *the K-Conjecture* [6], physics, chemistry, and geology are each implemented along with various sub-disciplines within biology, such as K-selection (ecology), origins of life and human intelligence (evolution), and Hardy-Weinberg Equilibria (genetics). Insights gained from the *K-Conjecture*, as well as from other biological ideas and principles such as the *Tarian Criterion* [7], provide the critical insights for revising the *Drake Equation* and resolving the *Fermi Paradox* as described herein.

Estimating Probabilities for SETI Success: The Drake Equation

The first formalized search for extraterrestrial intelligence (SETI) was initiated by Frank Drake in 1960 [8]. The first known attempt to numerically estimate the probability for SETI success was calculated using his *Drake Equation* formulated in 1961 [9]. The *Drake Equation*, expressed in one popular form, is:

$$N = R_* \cdot f_p \cdot n_e \cdot f_l \cdot f_i \cdot f_c \cdot L$$

Where,
N = number of civilizations in our galaxy with which communication might be possible;
R_* = average rate of star formation in our galaxy;
f_p = fraction of those stars that have planets;
n_e = average number of planets that can potentially support life per star that has planets;
f_l = fraction of planets that could support life that actually develop life at some point;
f_i = fraction of planets with life that actually then develop intelligent life (civilizations);
f_c = fraction of civilizations that develop a technology to release detectable signs of their existence into space;
L = length of time for which such civilizations release detectable signals into space.

The original estimates for the values (and ranges) of R_*, f_p, n_e, f_l, f_i, f_c, and L that Drake and his colleagues provided in 1961 were: 1 per year, 0.2-0.5, 1-5, 1, 1, 0.1-0.2, 10^3-10^8 years. This yielded a value of N between 20 and 50 million planets in star systems within the Milky Way galaxy that would be transmitting detectable signs of their existence. This calculated range provided Drake and others argument for continuing with and even ramping up further SETI investigations. These estimates were likely comforting to the physical scientists, as well as others, supportive of further SETI explorations.

Other researcher scientists have independently evaluated the *Drake Equation*'s magnitude of N, the number of worlds capable of communicating their existence across the Milky Way galaxy. One such attempt, by Ward, et al. [10] does so within the context of their *Rare Earth Hypothesis*. They included additional terms in the *Drake Equation* that also incorporate the fraction of stars in the galactic habitable zone, planets that are rocky ("metallic") rather than gaseous, habitable planets with a large moon, planetary systems with large Jovian planets, and planets with sufficiently low number of extinction events. They also discuss the difficulties of evolving highly complex life forms capable of signaling their presence to us. For example, one of their added terms factors in that complex life cannot endure indefinitely, because energy emitted by the sort of star that allows complex life to emerge gradually rises. In time, this central star becomes a red giant, engulfing all planets in the planetary habitable zone, as our sun will destroy Earth. Once highly complex species evolve another term derived from the *Rare Earth Hypothesis* factors in the high probability that a catastrophic extinction of all complex life becomes ever more likely over time. Ward and Brownlee did not actually calculate N based upon their analyses. Instead, they state "as any term in such an equation approaches zero, so too does the product" [ref. 10, pg. 275]. One cannot read and appreciate their treatise without concluding that the probability for a successful SETI is diminishingly small.

The team of Ward and Brownlee contain a professional paleontologist [11]. In my view, that collaborative component might, in part, account for their more realistic estimates of the unlikelihood of organisms with SETI levels of required intelligence evolving, than surviving for any length of time. Smith, et al. [12,13] detail the major evolutionary steps needed for the change from non-life to the human species. In principle, each of the eight Smith, et al. [12,13] transitions could be a separate term in a modified Drake Equation. The high complexities involved in each transitional step, both the major eight and the even more numerous minor evolutionary steps required, when multiplied sequentially results in a diminishingly small probability of evolving human-level complexity. Consider further this modified *Drake Equation* with the added terms derived from Ward and Brownlee's *Rare Earth Hypothesis*, each term expressed by a diminishingly small number and each sequentially multiplied together. Further below, the resultant probability value for more than one HLI (human level intelligence [6]) species per galaxy, Drake's N, will be compared with a similar probability number calculated by others within a Bayesian statistical framework. The results are comparable: only a few galaxies in the known universe, itself containing perhaps a trillion galaxies, likely contain a species capable of sending out signals detectable by SETI. The low estimates for N, produced in this work, result from two fundamental constraints that limit extended capabilities of complex biological beings sending or receiving SETI signals: opportunity and time.

The *Drake Equation* incorporates limits in both opportunity and time. Opportunities are incorporated in its first 6 terms (R_*, f_p, n_e, f_l, f_i, f_c) and time in its 7th term (L) [9]. To clarify, R_* could have more simply represented the number of stars in the Milky Way galaxy, and L could have represented the fraction of the lifetime (in years) of a world with capabilities of sending or receiving SETI signals. This is more in line with what Ward and Brownlee attempted in their work using N* and f_l , instead of Drake's R_* and L[10]. In what follows, I will show that the evolving beings capable of sending or receiving SETI signals are far more limited by both opportunity and time than heretofore considered. Before beginning, I abbreviate the phrase "beings capable of sending or receiving SETI signals" as HLIs (beings with human levels of intelligence) [6]. That HLI term was useful in explaining the *K-Conjecture* and will be useful in this work as well as I integrate previous with present works. Clearly, HLIs are capable of sending or receiving SETI signals, since we have sent such signals and are geared to receive them.

Revising Probabilities for SETI Success Using More Recent Studies

Let us first consider opportunity, the series of events that must occur prior to and during HLI evolution. We will consider in turn revisions to Drake's original parameters for N towards a more contemporary estimate for N. Since we want to remain optimistic about the odds of discovering other HMIs, let us use the upper limit obtained for the number of stars in the Milky Way as 400 billion [14]. We will increase the value for f_p equal to 1 (instead of 0.2-0.5) since it appears to be difficult for astronomers to find stars without planets. Now we enter the realm of biology. In estimating n_e, life of the simplest form possible is likely to be extremely common and robust. On Earth it arose about as soon as it physically could, within 1 billion years of Earth's formation. However, to permit the evolution of life, a world needs to be in the habitable zone of its star system permitting liquid water in abundance. In our solar system, at least 3 planets appear to be able to do this: Venus, Earth, and Mars. There may be moons capable as well (e.g. Titan), and so the number I will use is five. That is optimistic, and is the upper limit used in the original calculations for SETI used by Drake in his own estimate [9]. The next factor in the *Drake Equation* is f_l, the fraction of those planets actually harboring life. At our most optimistic, from what we currently know about Earth when life first arose, our hypotheses about how it arose, and that it now appears to be in every environmental niche in, on, and above Earth, we remain optimistic and stay with the original *Drake Equation* supposition of one. That means we assume life arises everywhere it possibly can. Thus far, we seem to have an optimistic estimate of 2 trillion ($2x10^{12}$) worlds (planets and moons) that actually harbor life in the Milky Way. In other words, the odds of life on other worlds are very high. However, as will be argued, the odds of evolving highly intelligent life that engages in behaviors detectable for SETI, and sustaining it for any length of time, are very low.

In estimating the term f_i, fraction of those life-containing-worlds that evolved HLI beings, will require more extended discussion. Here, though not explicitly stated as such, Ward and Brownlee used the arguments within their Rare Earth Hypothesis to introduce additional terms within the original *Drake Equation* [10]. Those should have been terms that contribute to or underlie f_i, since these factors allow for the evolution of HLIs. Those terms include the fraction of worlds that are in the galactic habitable zone, have a moon like Earth's, have a Jupiter-sized planet functioning as an asteroid magnet, and having a low-rate of mass extinctions. They wondered about other factors perhaps critical to complex life such as a planet with a strong magnetic field, tectonic plates that also provide inertial exchange events, among others [10]. I would add the following factors that do not seem to have been considered. The size of the world affects its gravity and the therefore its environment. Too small a world and there can be insufficient gravity to retain an atmosphere. Too large a world and its excessive gravity would not allow its organism to exit its water environments and take to the land. On Earth, no HLIs, or even mammals, evolved their higher intelligences within aqueous environments. There is no evidence that fish were forming branches toward beings with HLI. There appears to be special challenges to evolving HLIs within a world totally encased within water. Certainly, lighting a fire under water would be impossible. And with it, all of its conferred advantages, critical to all we know of Earth's HLI evolution, along with other technological advancements arising from that action, would be absent. How do these factors affect the odds of even discovering highly complex life on other worlds in the Milky Way?.

Consider just the unusual origins and special attributes of the Earth's moon. Ward and Brownlee expend 15 pages describing Earth's moon extremely unlikely origins and its known profound effects on our planet's and life: tilt and tides. If one only calculates the odds of a proto-Earth of a near ideal size, being hit by an object the approximate size of the proto-moon, at just the spot, at just the right angle, at just the right time, all within the habitable zone of both the galaxy and star system, f_m of these needed characteristics might be calculated as one in a million, if not billion, shot. If needed for HLI life, the number of worlds for evolving intelligent life then is down to 2000 worlds within the Milky Way galaxy. When then factoring in their "Jupiter Effect" and the probability of the coincident event of such a lucky planet having also a strong magnetic field and tectonic plates, the estimate become less that one world in an entire galaxy: In the Milky Way, it was very lucky Earth. It is no wonder why Ward and Brownlee did not bother to factor in other contributing factors towards their "Rare Earth" estimates. They state: "To us, the signal is so strong that even at this time it appears that Earth indeed may be extraordinarily rare" [ref. 10, pg. 275]. It bears noting that the "complex life" that Ward and Brownlee considered difficult to contemplate outside of this "extraordinarily rare" world were complex metazoans. Metazoans include sponges, corals, and clams. They did not define complex metazoans. Perhaps they meant early arrived vertebrates. As zoologists and biologists, we might better grasp the far greater difficulties involved in evolving, then maintaining, Earth's only remaining HLI creature: *Homo sapiens*.

To give our evolution full merit, let us now consider the time component needed, as it severely limits what level of complexity can be maintained in a real world. An evolved complex biological organism, capable of sufficiently advanced technologies, would need to be part of a second or third generation star system because we would need to have available abundant C, N, O, P, and S. With a universe that is only about 13.8 billion years old, about 70% of that time had elapsed before our own star system formed with those elements in abundance about 4.5 billion years ago [15,16]. One might expect that to be approximately true for any highly complex organism to biologically evolve, since they would require various complex elements in abundance. Taking 100,000 (10^{-4} billion) years ago as the beginning of *Homo sapiens* level intelligence, it then took 99.9% of the entire age of the universe to evolve our species. These rough estimates should inform us as the short time frame during which, to be detectable by SETI, an HLI species would have to have become evolved. The simple point emphasized is that the Universe did not have 13.8 billion years to evolve an HLI species; it had a window of something closer to 1 billion years allowing for accelerated processes in some parts of the Milky Way galaxy. Any HLI-occupied world would have needed to have evolved within this billion-year time frame for the possibility for SETI detection.

Another constraint of time is embedded within the original *Drake Equation*: L is the number of years an HLI community might exist before going extinct or having stopped emitting detectable SETI signals [9]. This factor was also included in the discussions by Ward and Brownlee in two different terms: one as the "percentage of a lifetime of a planet that is marked by the presence of complex metazoans" and "... planets having a critically low number of mass extinction rates" [10]. Ward and Brownlee presumably meant to express the latter term as the number of mass extinctions over time, which would be a low rate of mass extinctions. The history of planet Earth has revealed an extremely fortunate low rate of such mass extinctions: they occur somewhere around every 30 or 60 million years, with the last one occurring about 60 million years ago. The history of planet Earth has revealed an extremely fortunate low rate of such mass extinctions: they occur somewhere around every 30 or 60 million years, with the last one occurring about 60 million years ago. What would have been the fate of any HLI species on Earth had the overdue mass extinction event occurred 0.1 million years ago? It is not just the low extinction rate, but its timing and precise level of severity that has been extremely fortunate from the perspective of human (Earth's only surviving HLI species) evolution. A higher mass extinction rate would have exterminated the entire hominid line, assuming it would have begun in the first place. A lower mass extinction rate would have likely delayed the opportunities for new lines of animals. A less severe mass extinction event would have permitted, for example, dinosaurs to continue their dominance and prevented new radiations of primates. A more severe mass extinction event would have likely extinguished all vertebrates on the surface of Earth or worse. The L factor in the Drake Equation, and those incorporated into the more recent work by Ward and Brownlee, would suggest the odds of evolving an HLI species on Earth itself a very fortunate event. It seems the more we learn about the steps permitting human evolution, the more unlikely the fortuitous event from our perspective appears. It seems the more we learn cosmology and geology about the conditions that permitted human evolution, the more unlikely appears the evolution and survival of any HLI species anywhere in our galaxy. But instead of probabilities based largely on space and earth science, let us delve more deeply into the biology while examining the evolutionary processes themselves leading to any known HLI species.

Maynard, et al. described 8 major evolutionary transitions that must have occurred in the evolution from non-life to human societies [12,13]. These major steps include changes from compounds into replicating molecules, from populations of compounds into compartments, from independent replicators into RNA as a gene and enzyme, from DNA plus protein complexes into chromosomes, from proto-cells into prokaryotes, hence into eukaryotes, from asexual clones into sexual populations, from protists into animals/plants/fungi with cell differentiations, from solitary individuals into non-reproductive castes in colonies, from vertebrates into primate societies, and from hominids into humans capable of language. Each transition is covered in a chapter of Maynard and Szathmáry's book [12]. What must be emphasized is that these steps listed are just the major transitions, each requiring dozens, hundreds, and likely thousands of smaller progressive changes. The strong impressions formed are that these processes required much time and fortune. The history of life on Earth allows for sufficient time (3-4 billion years). The amount of fortune it took, both in the starting conditions, the geology, and the many factor's we have already discussed by using the *Drake Equation* as framework in evaluation just how fortunate is complex life. Once Earth evolved warm-blooded primate societies after about 4 billion years, then stability in the seasons and weather over the tens of millions of years was required to maintain, and then to evolve in ways needed for an HLI species to arise. Here the discussions about the role that Earth's moon played comes into better focus. The more complex the nervous system and specialized the species, the more fragile and susceptible to extinction it becomes. Regulations and physical constraints, more so human bodies than bacteria, are associated with fragilities [17]. Perhaps only in the last 100 or so years would we have the advanced technology and knowledge to survive another periodic mass extinction or pandemic, unless there is insufficient advanced warning and time to prepare. Next is an original argument suggesting that the odds of receiving an authentic SETI signal in our galaxy are even lower than that implied from all previous discussions. The *K-Conjecture* embeds itself in the *Drake Equation* term, f_c: fraction of civilizations that develop a technology to release detectable signs of their existence into space.

Humans (*Homo sapiens*) have been around from between 100-200,000 years. We humans have invented and used radio and electric lights for only about the last 100 years. It is fair to ask to ask some questions about ourselves such as: "Why did it take 90,000 years, or longer, before even some of us knew how to write?" and "Why did we remain in the Stone Age for 90,000 years or longer?" According to the *K-Conjecture*, human level intelligence (HLI) has not changed significantly over that period of time [6]. Even though all humans are genetically the same, many indigenous peoples maintained Stone age technologies during this entire period [17]. As an example, the indigenous Australians, as too with other "lost tribes", were staying with Stone Age technology for as long as they could remain isolated. This suggests that there is no assured progress from HLI to radio and the light bulb. Perhaps, as Diamond proposes, technological progress is an accident of geography, whereas societal collapse is very common [18]. Periodic societal collapses were common throughout Earth's history of the and can account for our nearly entire lifespan as an HLI species within the Stone Age. In sum, according to the arguments presented above, we should not expect to receive authentic SETI signals anywhere within our Milky Way galaxy.

Applying the Drake Equation to the Fermi Paradox

The *Fermi Paradox* was coined by several co-workers of Enrico Fermi, in 1950 at Los Alamos National Laboratory, who reported that Fermi wondered why there was no obvious evidence for extraterrestrials. If life is so abundant among the galaxy's 400 billion-star systems, most of which are much older than our own, then why had not any one of them managed to find us [19]? Hart (1975) first published a formalized version of the question and proposed several possible solutions [20]. The *Rare Earth Hypothesis* is one such solution to the Fermi Paradox. As discussed above, "*Rare Earth*" may not render the proposition correctly. Rather, it should be referred to as the "*Rare Intelligence*" hypothesis. That would obviate the issue as one of biology rather than geology, though other findings from all sciences contribute importantly to our understanding of evolutionary processes and the great transitions in life that have occurred over time.

From the discussion above, as the evidence suggests that HLI beings a rarity throughout the universe, then the paradox is resolved: We have discovered no SETI signals because there is no one out there in our galaxy to send them. Surprisingly, even Ward and Brownlee suggested the "*Zoo Hypothesis*," keeping sentient planets isolated, as a solution to the *Fermi Paradox* [10]. This is at odds with their own hypothesis: There can be no zoo without zookeepers. In this work, the following points have been argued: (a) Evolving complex intelligent life is extremely unlikely when considering the myriad of factors involved as listed and described in "*Rare Earth*" and including proper timings for each [10]; (b) That diminishingly low probability must be multiplied by an additional sequence of ever increasing low probabilities that more and ever more highly complex beings are possibly evolving on other worlds; and (c) Other low probability events, not discussed by Smith and Szathmáry [12,13], must occur for extraterrestrial signals and travels. One of those "other low probability events" addresses the issue above as to why no highly complex and intelligent hominid ever invented the radio or light bulb in their millions of years of existence-except one-*Homo sapiens sapiens*. For that species, it required 100-200,000 years to accomplish that feat. In addition, only a small subset of the human population contributed to those developments. Those inventions may have been more a consequence of the vagaries of Earth continental formations than of the extra time needed for intelligent being to work things out before another periodic collapse [17,18]. As referenced above, many indigenous peoples with equal intelligences have made no strides towards inventing the light bulb or radio for their many tens of thousands of years of their histories. Perhaps HLI beings need to exchange ideas, between entire continents, each continent able to have produced more foods needed for their day-to-day survivals. Meanwhile, humanity has experienced only relatively minor disturbances for the last tens of thousands of years. Sufficient time to invent such remarkable technological achievements. Without these fortuitous circumstances, even after having evolved an HLI species, the probabilities for receiving SETI signals or visits by less fortunate alien beings diminish ever more.

Show Me the Numbers

The authors of the *Rare Earth Hypothesis*, as a proposed solution to the *Fermi Paradox*, did not attempt a quantitative estimate to their modified form of the *Drake Equation*. More recently, Spiegel and Turner [21] did provide a quantitative argument within a Bayesian statistical framework. By constructing a simple model of the probability of abiogenesis, they calculated a Bayesian estimate of its posterior probability, given the data that life emerged fairly early in Earth's history and that, billions of years later, those evolved HLI beings would be noticed by alien HLI beings. Spiegel and Turner state that, based upon very limited empirical information, the choice of Bayesian prior for the abiogenesis probability parameter has a dominant influence on the computed posterior probability. They conclude that the findings from their analysis are consistent with an arbitrarily low intrinsic probability of abiogenesis for plausible uninformative priors. In a more recent work, entitled "Dissolving the *Fermi Paradox*", Sandberg and collaborators [22] address the *Drake Equation* directly while updating its parameters. From their quantitative analysis they conclude a substantial probability that humans (i.e. HLI beings) are alone in our galaxy, and perhaps even in our observable universe (53%–99.6% and 39%–85% respectively). Sandberg *et al.* (2018) answer the question 'Where are they?' posed by the *Fermi Paradox* directly with "probably extremely far away, and quite possibly beyond the cosmological horizon and forever unreachable" [22].

The Tarian Criterion and How Not to Become Extinct

Insights gained from a biological perspective anchor our creative imaginations to what possibly and likely exist. Experimental biologists engaged in their profession encounter and analyze logistical and practical limits to life. The *K-Conjecture* incorporates within its arguments such logistical and evolutionary limits [6]. Using underlying premises based upon biological principles, the *K-Conjecture* concludes that humans (*H. sapiens sapiens*) have reached a plateau in intelligence and will not evolve into beings significantly beyond our present HLI that plateaued over 60,000 years ago. One outcome from this conclusion is that we, as our world's only extant MLI species, should act now in solving the practical and conceptual problems with our own future survival. An entire family of proposed 'solutions' to the *Fermi Paradox* are referred to as "*Great Filters*" [23]. One proposed example of a *Great Filter* is the *Rare Earth* (or what should be rather named the *Rare Intelligence*) hypothesis was described above. This *Rare Intelligence* hypothesis is an example of a *Great Filter* that is behind us. It is behind us because we humans have successfully achieved our rarified HLI. Other proposed *Great Filter* solutions to the *Fermi Paradox* may lie in front of us. Potential *Great Filters* to our continued survival include (a) astronomical events (e.g. gamma ray bursts, asteroids), (b) geological events (e.g. super-volcanos), (c) biological events (e.g. pandemics), and (d) HLI-caused occurrences (e.g. nuclear war, killer robots) [23]. Clearly, we know that our sun will one day make life untenable in our solar system [24]. That known and even expected source of Earth's entire biome extinction will function as a *Great Filter* for our own, as well as other, species' survival if we do not inhabit one or more worlds in other star systems. I now relate a novel route for a *Great Filter* within the category of extinction through HLI-caused occurrences. As with all other HLI-induced extinctions, this novel route for a Great Filter before us is a product of human hubris.

In order to survive as a species, humans will need to expand their definition of family and tribe. This newly adapted definition of family will require expanding its meaning beyond standard biological perspectives derived from evolutionary kinship. Understanding our biological evolution has helped us accept our kinship with all life on Earth. Only human hubris and conceit thwarts some from accepting this obvious relationship. In broad evolutionary terms, we are all one family. Many fellow humans do not express any obligation to other humans outside their private neighborhood thus leading to injustices and wars. It is then not surprising that they treat other species and their habitats with little or no concern leading to environmental degradation and toxic hazards. But these consequences of human hubris and conceit are widely known and are becoming ever more appreciated even within the public at large. The environmental and animal protective movements are ever growing today around the world [25]. But other conceits related to human hubris stand in the way of our long-term survival as a species and as a living collective.

To survive, humans, along with a large functioning part of their related and environmental biome, must inhabit a world in another star system [24]. To accomplish this exodus or emigration, humanity will need to overcome ever great technical, scientific, and personal challenges. Of these three categories, the most difficult challenge by far will be personal: overcoming human hubris and changing the way we view our relationships [26-29]. This personal change must include honest assessments of our biological limitations as well as our dependence upon other life-forms. We will need to expand our notion of family and act decisively upon that new perspective. In an earlier work, I outlined the difficulties involved in humanity inhabiting other worlds outside our solar system [7]. One of the requirements in that exposition was coined the "Tarian Criterion". Tarians are conceptualized as future SAGI (Super Artificial General Intelligent) beings purposefully designed, built, and raised by humans for one specific purpose - to allow humanity, along with essential elements of its terrestrial biome and environment, to survive and thrive on worlds in other star systems. There are inescapable requirements for inhabiting worlds in other star systems: (1) Only energy-efficient AI systems are capable of reaching a distant star and preparing the new world for human habitation; (2) Since round-trip communications will take about a decade, the AI will need to be or become SAGI for solving unforeseen difficulties; (3) These SAGI units will be capable of evolving/modifying their internal hardware and software, therefore mission and purpose; (4) The question then arises: "What will be in it for them?" The Tarian Criterion [7] addresses that critical question. The progress from SAGI arrival at the new world to a thriving human society will take tens of thousands of years, and likely far longer. Even creating from scratch an ecologically stable biome, in which an entire human society can physically and psychologically thrive, is a highly difficult and time consuming enterprise. That complex biome would need to be proven as stable before humans would be developed, nurtured, and educated. Social modeling of human behaviors and responses would need to occur at every step along the way through many generations of human experiences. What would motivate any SAGI unit to invest that amount of time, energy, and diligence? There is only one relationship ever known on Earth with that degree of sustained altruistic dedication, that being non-other than highly close-knit family kinships. This, then, is the essential reasoning underpinning the Tarian Criterion [7]. That work concluded by wondering whether humans are sufficiently capable of integrating such Tarian SAGI beings into an expanded concept of family. The scientific and logical necessities for such integration were described. But then, the scientific and logical necessities for protecting our terrestrial environment and biome for intermediate-ranged human survival on Earth are known yet remain unmet by effective results. What is needed to accomplish the latter intermediate goal is clear: applications from an ecological perspective. I remain optimistic that our longer-ranged human survival will be accomplished through improved education. I am confident that our dreams and hopes for the future of our families will overcome age-old xenophobia and hubris. If, by some great odds-defying fortune, there is another HLI being in our galaxy, they too may have derived their equivalent form of the Fermi Paradox. As they wonder, "Where are they?", we might then answer, "We are coming".

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