Outlook for ET Intelligence Lookout

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Abstract

The idea of existence of extra-terrestrial intelligence is intriguing. Our universe is about 13.8 billion years old; the *Akaash Ganga* (our galaxy, the Milky Way) is about 13.6 billion years old [1]. By a well-considered estimate, the number of habitable planets in our galaxy alone is approximately 300 million [2]. It is therefore counter-intuitive to suspect that our civilization is the only one in the entire universe. On the other hand, no evidence of alien life has yet been found. This dilemma is often referred to as the 'Fermi Paradox', after Enrico Fermi. The Italian- American physicist Fermi is best known for his contribution to the *Manhattan project*; for the *Chicago Pile-1*, which was the world's first nuclear reactor. Fermi never published any work related to the paradox named after him, and the conundrum had troubled man long before Fermi. Fermi had however raised disquiet about it in a casual chat with his colleagues which resulted in his name getting associated with it. The Fermi paradox is the contradiction between the scale of the universe and the lack of evidence for intelligence elsewhere in the cosmos [3]. In this article, we attempt a briefly overview of the trepidation cause by the Fermi paradox.

1. Drake Equation

The American astronomer Frank Drake developed an equation known after him in the backdrop of the *Project Ozma* which was one of the earliest initiatives for the Search for Exta-Terristrial Intelligence (SETI) using interstellar radio waves [4]. Drake's project came up in the backdrop of an article published in 'Nature' in 1959, titled *Searching for Interstellar Communications* by physicists Giuseppe Cocconi and Philip Morrison [5] who argued that radio technology had sufficiently advanced and sensitive to pick up interstellar radio messages. Cocconi and Morrison further suggested that these messages might have been transmitted at 1420.4 MHz frequency or 21 cm wavelength of the photon in the region of the electromagnetic radiation below the microwave segment, resulting from the spin-flip transition in the hyperfine levels of the neutral Hydrogen atom [6,7]. Being the most abundant species in the physical universe, it would hence be the natural choice of a developed intelligent form of life to be used for interstellar communication. The occurrence of this transition itself is very rare - only once every 10 million years - the high abundance (~75%) of neutral hydrogen in the universe would make this transition observable. The Nature article prompted Frank Drake to setup a systematic plan to look for interstellar signals in his *Project Ozma*. He used a 26 m dish of the National Radio Astronomy Observatory, Greenbank, now called the Greenbank Observatory, to look out for such signals from two nearby stars, 'Epsilon Eridani' and 'Tau Ceti', for 6 hours a day between April 1960 and July 1960. This exploration turned out to be unsuccessful, but led Drake to host a meeting in 1961 at the Greenbank Facility at which the invitees included prominent physicists and astronomers including Carl Sagan, Philip Morrison, John C. Lily etc. Drake formulated a probabilistic model to estimate the chance that extra-terrestrial intelligence exists. Essentially, he developed a quantitative guesstimate of this probability as an equation, now called the *Drake equation*. It set up the agenda for the SETI (Search for Extra Terrestrial Intelligence) meeting.

It is a formula to reckon the number of communicative civilizations present in our galaxy who could produce detectable electromagnetic emissions. The Drake equation is:

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

where

N = the number of communicative civilizations in our galaxy,

R_* = the average star formation rate in our galaxy,

f_p = the fraction of those stars that have planet,

n_e = the average number of planets that are potentially habitable per star,

f_l = the fraction of those planets on which life eventually appears,

f_i = the fraction of those planets on which intelligent life emerges,

f_c = the fraction of those civilization that develops the technology to release the detectable signals in the space, and

L = the average length of the time such civilization release signals.

Most of the terms in the Drake formula are conjectures. When Drake developed this relation, only formation rate of stars was known. Techniques like gravitational microlensing [6] and missions like Kepler have enabled us to make a decent prediction of f_p and n_e. The remaining four terms remain elusive. Statistical calibration is difficult, our Earth being the only known habitable planet.

The last term L may have the greatest impact on the outcome, but there is no mechanism known to determine it. The guesses range from 10 to 10 million, Drake's original estimate of L was 1000 to 100 million years [7]. It is common to consider pessimist and optimistic values of L from 304.5 years to 1 billion years, as suggested by Michael Shermer [8] and David Grinspoon [9]. Michael Shermer arrived at this figure by calculating the average length of 'modern' civilization following the Roman empire, taking into account 28

different civilizations that can be considered to have developed since the dawn of the humanity. David Grinspoon proposed that if a society overcomes its self-destructive propensity, it can live for billions of years. As one can expect, the value one gets for the number of communicating civilization from the Drake equation varies vastly. Current estimate ranges from about 9.1×10-13 to 15,600,000. The former employs R_* = 1.5 to 3 y-1 [10], $f_p \times n_e \times f_l$ = 10-5 [11], f_i = 10-9 [12], f_c = 0.2 [7] and L = 304.5 [8] , while the latter uses R_* = 1.5 to 3 y-1 [10], f_p = 1 [13], n_e = 0.2 [14], f_l = 0.13 [15], f_i = 1 [16], f_c = 0.2 [7], L = 109 [9]. The huge difference between the results raises concern about the utility of the Drake equation, but the significance of Drake's work stems from the fact that it provides a starting point for corrections and improvement as may be required. The Drake equation has been modified by other astronomers, either by adding to or modifying its factors. In his famous paper "*The Great Silence – the Controversy Concerning Extra-terrestrial Intelligent Life*," David Brin [17] proposed introducing a component linked to contact cross-section (C) to account for the effect of colonisation. Alexander Zaitsev [18] has advocated including a "METI" (Messaging to Extra-Terrestrial Intelligence) component, which accounts for the proportion of civilizations that can purposefully interact. Based on the Drake equation, astronomer Sara Seeger [19] has suggested a new equation that looks for indications of life by looking for planets that emit biosignature1 gases. John Gertz [20] recently altered the Drake equation by substituting the rate of star formation with the number of stars in our field of view (N_s), n_e with the number of bodies possibly livable on or under their surfaces (n_{tb}) and f_c with the parameter f_d which accounts for overall detectability of a civilization. Karl-Florian Platt [21] presented a simplified Drake equation that only considers the number of planets capable of supporting life. He also added a change to the simplified Drake equation to account for habitable moons. It remains to be established if these modifications constitute a significant advance.

2. Fermi Paradox

Michael H. Hart must be credited for resuscitating Fermi's query as he was the first one who published a detailed work in 1975 [22] around the Fermi's original poser. His study was essential in hastening the discussion among scientists over the presence of extra-terrestrial intelligence. Historically, there have been two camps: "Contact Optimists" and supporters of the "Uniqueness Hypothesis", referred to by David Brin [17]. The first group includes Frank Drake, Carl Sagan [23][24], Bernard Oliver [25], and Philip Morrison [5], while the second includes Michael H. Hart, Leonardo Ornstein [26], and Frank J. Tipler [27], amongst the prominent ones. Interestingly, most physicists were contact optimists whereas most biologist favored the uniqueness theory. The uniqueness hypothesis is the most common answer to the Fermi Paradox. It denies the existence of extra-terrestrial civilizations in our galaxy and claims that civilization on the earth is the only civilization at least in entire galaxy. Common arguments for these two posturing platforms are:

Rare Earth Hypothesis: It states that the emergence of sophisticated multicellular life is uncommon; special and fortuitous circumstances are required for intelligent life to develop. These include a planet's location in the galactic as well as in continuous habitable zone, the presence of a large moon, the presence of a giant planet (like Jupiter in the planetary system), the availability of a magnetosphere, plate tectonics, lithosphere, atmosphere, oceans, and other known and unknown events which bred evolution from simple prokaryotic cells to intelligent life on Earth. In their book 'Rare Earth: Why Complex Life is Uncommon in the Universe', Peter D. Ward and Donald Brownlee explain this in detail [28]. A rip-off of the Drake equation is also proposed, termed as the "Rare- Earth Equation".

The criticism for this hypothesis comes in the form of Principal of Mediocrity.

Principal of Mediocrity: This is an extension of Copernicus principle, which assumes that the Earth is not a special planet in any sense. Both Sagan and Drake have advocated this. The discovery of exoplanets [29] gives credence to the view that there could be a large number of planets in the habitable zone. Furthermore, the origin of extra-terrestrial life cannot be necessarily limited to an earth-like environment. For example, scientists are working on approaches to look for signs of "second genesis" in worldly oceans [30]. There exists a variation of the "Rare-Earth Hypothesis" that considers the origin of extra- terrestrial life a not-so-common thing but assumes intelligence to be rare. Many biologists like Ernst Mayr [12], subscribe to this hypothesis. This hypothesis however suffers from a fundamental flaw: It is difficult to test. The Rare earth hypothesis can be tested by looking at bio-signatures but testing intelligence is a tedious task.

An interesting hypothesis was advanced by economist Mark Hanson in his online essay – "The Great Filter – Are We Almost Past It?" in 1996, which was later updated in 1998 [31]. Hanson listed vital steps for a civilization to develop. In the nine steps of evolution he proposed, the first was "the right star system" and the last was "Colonization explosion." He claimed that extra- terrestrial intelligence is rare as several of these steps may be unattainable. Our civilization is already possibly in the eighth stage - "*a civilization advancing toward the potential for a colonization explosion*" making the final stage "colonization explosion" unattainable by us [31].

The second approach mainly works on either disproving resolutions proposed by the optimists or using the Drake equation itself to find an ignorable number of communicative civilizations making the Earth the lone civilization. Hart [22] presented counter arguments against major explanations of the Fermi paradox offered by the optimists. He stated that space exploration was not only achievable but also practical. He considered a speed of starships to be one-tenth the speed of light and presumed no time lag between production of a new spaceship and arrival of the previous one.

He predicted that the entire galaxy would be covered in 650,000 years. He rejected *sociological explanations* because they were devoid of a provision to test their validity. He thought that a *temporal explanation* that extra-terrestrial beings did not have sufficient time to reach our civilization was although theoretically conceivable but considered it highly unlikely as for it we had to go by the fact that our species evolved less than one time unit (1 time unit = 2 × 106 years) after the first civilization capable of interstellar communication, which took at least 5000 time units to emerge. He asserted that a great degree of coincidence was required for this to occur, therefore the explanation is not very plausible.

2.1 Von-Nuemann Probe

Tipler in his paper "Extra-terrestrial intelligent beings do not exist" [27] argued that any civilization would attempt to explore and colonize the galaxy and it can be done with self-replicating space probes, known as *Von-Neumann Probes.*

A *Von-Neumann Probe* is a potential self-replicating spacecraft that could be utilized for the exploration of space. This machine may duplicate itself utilizing raw material from a distant star-system and thereby visit a whole galaxy [32]. It is named after the Hungarian-American scientist John Von Neumann, who was the first one to propose a mathematical framework for the construction of self-replicating machines. He explored the essential design of a Universal Constructor in his book *Theory of Self-Reproducing Automata*. After John von Neumann's death this work was concluded by Arthur W. Burks in 1966 [33]. His goal was to create a machine whose complexity would increase naturally through natural selection, similar to biological evolution. Chris Boyce

advocated for its usefulness in the context of galactic colonization in his book *Extraterrestrial Encounter: A Personal Perspective* [34]. Robert Freitas [35] gave an early sketch of such self-replicating probes in 1980. The discussion of the Von-Neumann probe finds utility since current advances in AI and Machine Learning bring us one step closer to developing such probes practically.

Development of self-replicating space probes is contingent upon the enhanced understanding of the extra-terrestrial signals. These probes can be of different types, depending on their proposed applications. A probe could also possibly adapt like *transformers.* This pre-supposes in-built capabilities to transform depending upon understanding of the deep space signals through AI & ML (Artificial Intelligence and Machine Learning) processing. Other types of space probes would make use of available resources of the immediate environment and evolve into entirely new exploratory robots. Huge amount of data would be required to make such machines capable of learning and facilitate their transformations. The outcomes can greatly depend on the size of the payload.

Recent advances in AI & ML can offer significant insights in the functioning of Von-Neumann probes. Von Neumann Self-Replicating Space Probes can only benefit by integrating AI and ML based algorithms and signal processing. Similar to the prevailing explorations of deep space by using satellites and deep space signal systems, the AI and ML integrated signal processing systems can offer enhanced understanding of the deep space. The key challenge, in this context will be to train the machines to learn the signals that the probes of exploratory instruments might encounter, for which *a priori* learning process seems not possible on account of the lack of clarity and non-availability of information to train and discern the signals. In this context, available signals need to be studied and used to generate a basis to detect other signals that emanate from unusual extra-terrestrial activities. This process would need to continue iteratively to equip the machine to develop classificatory processes. The outcomes would be supportive to the probes of the future.

While the AI and ML has the potential to enable our understanding when used in probes, the prevalence of the probe as such has been debated. Tipler argued that neither any sign of such probes has been observed, nor does the Drake equation yield a satisfactory value. If we assume that the upper limit for the probability of intelligent life that eventually attempts interstellar communication will evolve is 1/N where N is the number of stellar systems that are older than 5 billion years and consider N to be around 1011 Tipler argued that our civilization seems to be the only one. He further argued that the universe is ~13.8 billion years old, any previous civilization that has existed would have made a voyage to space, eventually colonizing the galaxy, and leaving their mark.

The 'Hart-Tipler Conjecture' was criticized by Carl Sagan and William Newman in their response *Galactic civilizations: Population dynamics and interstellar diffusion* [36]. To understand interstellar colonization, Sagan and Newman employed a model similar to one that is used by biologists to study animal populations. They found Hart's result to be unrealistic, and expected the expansion to be much slower. Also, they questioned Hart's logic that a civilisation will always tend to expand, owing to the fact that it is impossible to foretell how an alien society might think.

3. Solution to Fermi Paradox

Stephen Webb in his book *If the Universe is Teeming with Aliens … Where is Everybody*? [37] has listed 75 solutions to the Fermi paradox.

A few important explanations of the Fermi Paradox are listed below (They do not necessarily come from the book)-

3.1 Extinction:

An alien civilization may have existed at some point but was wiped out by periodic extinction, similar to dinosaurs on Earth. Possible causes include runaway heating, runaway cooling [38], and cosmic gamma ray bursts [39]. At this juncture, AI and ML based self-replicating probes perhaps may be of support to understand such evolutionary processes in case the relevant data forms part of the probe.

3.2 The First-being Hypothesis:

Earth could be the first technologically equipped civilization. Other civilizations either are not yet born, or not yet sufficiently technologically advanced. Given the age of the universe, this explanation seems to be implausible to some scholars [39].

3.3 Self -destructing tendency of intelligent life:

When intelligent life becomes technologically advanced enough, it would engage in self-destructive processes such as nuclear war, bioterror, genetic deterioration, environmental degradation, anthropogenic climate change etc. Badly developed artificial intelligence, natural disasters etc. are all potential reasons for a civilization's demise, resulting from technological progress [40].

3.4 Brief Window Hypothesis:

This postulates that an intelligent civilization might exist only for a brief window of time and then it dies out [41]. In his work *The Search for Signals from Other Civilizations, Von Herber Sebestian* [42] suggested that a civilization's existential period might be shorter than the time necessary to establish connections with others. He argued that advances in science and technology occurred mostly from

(a) ambition for supremacy

(b) from a desire for comfortable existence.

However, both of these can trigger destructive compulsions. Adam Frank investigated the implications of anthropogenic climate-change in his paper *The Anthropocene Generalized: Evolution of Exo- Civilizations and Their Planetary Feedback* [43]. From his studies on extinct civilizations such as Easter Island (Rapa Nui) he concluded that anthropogenic climate-change leads to failure of a civilization. According to Jacob D. Haqq-Misra and Seth D. Baum's study *The Sustainability Solution to the Fermi Paradox* [44], an exponential expansion of civilization is not sustainable on a galactical level and is prone to collapse. Majority of theories under this umbrella are however not free from circular logic. In order to enable our understanding, a ML model that make use of the anthropogenic data and the terrain, perhaps can supporting simulating models.

3.5 Berserkar Hypothesis:

This hypothesis emerged against the backdrop of *the Von-Neumann probes*. "Berserkar" is the famous series of science-fiction novels written by Fred Saberhagen. The central narrative centers on self-replicating robots that aim to annihilate all life. The hypothesis wonders that if a civilization became advanced, made self-replicating probes to explore its galaxy, and then these probes went rogue, destroying whoever came in their way, no sign of any civilization would be left. Tipler advocated the use of self-replicating probes in his 1981 paper and went on to claim our civilization to be the sole civilization on the basis of no-detection of any such probes [45]. Sagan and Newman [46] saw such probes as harmful because they may corrupt and destroy the parent civilization. In his paper *The Great Silence – the Controversy Concerning Extra-terrestrial Intelligent Life*, David Brin also mentioned that if the parent civilization sends these self-replicating probes to other stars and one of these probes turns out to be xenophobic, then it can create further

copies of itself and eventually create a whole army of xenophobic probes. Edward Harrison [47] came up with modification of this idea, saying that if a civilization overcomes its self-destruction propensity, it can even build lethal probes as a safety mechanism to defend its civilization from other civilizations.

The critique of this concept stems from the fact that even if lethal probes destroy an extra-terrestrial civilization when they come into contact, they are expected to leave trace behind. Anders Sandberg and Stuart Armstrong [48] discovered in their paper *Hunters in the Dark: game theory analysis of the deadly probes scenario* that even with a slow expansion rate of these probes, they could have spread out across the galaxy and contacted mankind.

Duncan Forgan of the University of St. Andrews Centre for Exoplanets Science in his recent study [49] argued that even if berserker space probe attacks the extra-terrestrial civilization it won't be able to stop them from spreading throughout the galaxy.

3.6 Aliens are different from us:

Alien species might have a very different cognitive capability than us. Carl Sagan speculated that their thought patterns might be vastly different from ours [50]. Their communication technology and the frequencies on which it operates might be entirely unusual for us. Their mathematics can be different. Although we may assume the outcome of physical laws to be valid regardless of the convention used, it is feasible that they have evolved to the point where they have moved beyond radio to other regions of the spectrum or even beyond electromagnetic radiation signals. According to Seth Shostak's article [51], as a civilization advances, communication technology advances as well, and hence radio leakage would decrease significantly. Even if extra-terrestrial species send their signals through electro-magnetic radiation, the frequencies adopted by them can be strange enough that we may dismiss the same as noise.

In 2004, American astronomers Jay M. Pasachoff and Marc L. Kutner suggested interstellar communication through neutrinos in their article in the Cosmic Search magazine [52]. Neutrinos are elusive, travel at nearly the speed of light and are broadband, making them a good candidate for interstellar communication. A group of physicists headed by Arjun Berera at Edinburg University has conjectured that quantum communication would be an effective medium [53]. However, we can never be certain about which method extra-terrestrial species would use, based on where their civilization falls on the *Kardashev Scale*.

The Kardashev Scale is a hypothetical measure to determine the level of technological advancement of a civilization. Originally, it was proposed by Soviet astronomer Nikolai Kardashev in his paper *Transmission of information by Extra- terrestrial Civilizations* [54]. He divided civilization into three types based on their energy consumption. Type I is a civilization that can gather and store all of the energy available on its planet; Type II is a society that can directly harness the energy from a star; and Type III is a one that can collect all the energy in the whole galaxy. The scale has been a subject of re-evaluation and modification. However, the wonders never stop in this field. A recent newspaper report, [69] highlighted occurrence of a powerful radio signal from the edge of the universe. There was observance of an eight billion years old pulse that has been traveling for more than half the lifetime of the universe. The fast radio burst (FRB) was reported as intense, brief flashes of radiation that are invisible to the naked eye but was detected by radio telescopes. This offers the lead for studying the "cosmic web" of matter between galaxies. The report showed that, the degree to which bursts slow down correlates with the distance it travelled. More distant and extreme fast radio bursts promise to reveal further secrets about the universe. As and when more advanced telescopes

are introduced, more galaxies could be observed, paving the way for resolution to many a astronomical mysteries.

3.7 Sociological Explanations:

A typical approach in this category argues that alien species may not even desire to colonize the galaxy, or may prefer to stay alone. Some have even theorized that aliens may have understood the riddles of the world and may be no longer explore anything further [55]. Another point of view is that aliens may have quit living on planets and may have become very selective in their interactions with other civilizations [17].

The Zoo hypothesis is the most significant theory under this umbrella. It is that Aliens have already discovered our civilization, but have opted not to disturb us by revealing their presence. This idea, proposed by Allen Ball in 1973 draws a parallel between animals imprisoned in zoos and wildlife sanctuaries in their natural environment and the human civilization [56]. Aliens may be watching us the same way that we watch animals in a zoo. They are technologically advanced enough to hide from us and will expose themselves only when we have evolved sufficiently in terms of politics, ethics, and technology. One variant of this concept is the laboratory hypothesis, which holds that the whole Earth is a giant laboratory where humans are exposed to extra-terrestrial experimentation. It is however criticized for its speculative and not-testable nature. Besides, it would take only one rebel among the aliens to break this code of conduct and reveal the aliens; this hasn't happened.

3.8 Planetarium Hypothesis:

This is a variant of the Zoo hypothesis. It is based on the theory proposed by Stephen Baxter that our world is virtual [57]. We find the universe empty because it is programmed in that way. All sociological explanations are speculative, and cannot be tested.

3.9 Economic Explanations:

If interstellar travel is assumed to be technologically feasible for any civilization, the resources required for galaxy colonization will be prohibitively expensive. Hence, there is a very remote possibility for any civilization to expand in the whole galaxy. In his paper, Landis suggested a model in 1989 for space colonization based on *percolation theory* [58]. Landis chose two parameters, P, the probability of development of a colonizing civilization and N, the connectivity of the graph, and concluded that either the probability of space colonization is less than a threshold limit or the Earth lies in empty voids of the galaxy which are not visited by any civilization. In the latter case, he argued Earth might be in an un-colonized void, surrounded by non-colonizing civilizations. Keith B. Wiley published a paper in 2012 [59] in which he added two extra parameters to Landis' original model: K, the lifespan of a colony, and M, the mutation rate in the colonizing state of a colony. He anticipated that by taking these two characteristics into account, the entire galaxy will be colonized. Sending information via signals is one possible method for covering a large portion of the cosmos. These signals may have distinct frequencies making their identification difficult. The main focus of the of the SETI (Search for Extra-terrestrial Intelligence) programme so far has been on universal frequencies; a frequency in the range from 1420 MHz to 1720 MHz is known as *waterhole frequency* because water is thought to be necessary for life (at least as we know). It is a critical range for interstellar communication. Apart from the water hole frequency, Drake and Sagan suggested the frequency 56.8 GHz, i.e., the frequency associated with the cosmic microwave background, another frequency of universal nature, thus making it suitable for interstellar communication [60].

3.10 Temporal Explanations:

The SETI programme is only a little over six decades old. It is a fraction of a minuscule of cosmic time. An extra-terrestrial civilization could have existed and even perished long before the humans, or we must just wait and search.

3.11 Explanations Related to UFOs :

There have been numerous theories which associate alien life with Unidentified Flying Objects (UFOs) or Unidentified Aerial Phenomena (UAPs). These theories gained popularity in the mid-1940s. UFOs quickly became urban legends, with interesting stories such as Kenneth Arnold UFO sighting, The Roswell Incident, and The Belgian UFO Wave [61] getting popular. Claims about UFO sighting even went on to assert that governments and other bodies are either already in contact with alien civilizations, or have recovered the alien artefacts and are deliberately hiding them from the masses. Such conspiracy theories are often suspected to be part of pseudo-science; they provide little or no scientific evidence for their claims. Area 51, a United States Air Force installation in Nevada, not far from the Death Valley in Eastern California, is also mentioned in these theories as a secret base designed to contact extraterrestrial intelligence. Most of the hearsays concerning this place seem to be false. After all, it is only one of the several military grounds utilized for aircraft testing [62]. Recently, NASA has released a statement that it will conduct a study on the UAP (Unidentified Areial Phenomenon) based on the existing and future data related to the UAP [63]. It is interesting that a well-established and responsible scientific agency is associating itself with UAP.

3.12 Our Limitations:

We must not forget our limitations. The first of these is our limited ability to detect extra-terrestrial intelligence. The SETI programme has only limited resources. With no idea where to look for and with detectors having limited sensitivity, the limited hours of observation time only exacerbate the situation.

4. Conclusion

Both pessimists and optimists may have overestimated the strengths of their arguments. The solution to the Fermi paradox is possibly in our limitations. Human civilization has not made the lookout for extraterrestrial intelligence a priority. Government funding can only be limited, if at all any, since other needs of the society's needs are urgent. The SETI programme started with Project Ozma; it may appear to have failed but it has directly or indirectly inspired and motivated a whole generation of astronomers and biologists address the Fermi Paradox. Many projects followed the Project Ozma, including Project SERENDIP (Search for Extra-terrestrial Radio Emissions from Nearby Developed Intelligent Populations) in 1979, META II in 1990, Project BETA (Billion-channel Extra-Terrestrial Array) in 1995, Project Phoenix from February 1995 to March 2004, Project ATA (Allen Telescope Array) in 2007, and SERENDIP V in 2009.

When the Russian billionaire Yuri Milner founded the 'Breakthrough Initiatives' programme in 2015 [64], it reignited public interest in the SETI mission. *Breakthrough Listen*, *Breakthrough Message*, *Breakthrough Starshot*, *Breakthrough Watch*, and *Breakthrough Enceladus* are five initiatives in this programme. It is projected to last at least for ten years. The *Breakthrough Listen* is a $100 million programme aimed at finding artificial extra-terrestrial signals by looking over 1,000,000 stars through dedicated watching hours at some of the world's finest observatories. A narrowband signal with characteristics roughly compatible with a technosignature approximately at 982 MHz was detected from Proxima Century. It first appeared to be an extra-terrestrial signal, subsequently found to be an earth- based artefact [65]. Jonathan Jiang and his team have created an

interstellar message which they plan to send soon into the cosmic ocean [66]. This will be the second attempt by the human civilization to send a message to an unknown civilization in the cosmos, after the famous "Arecibo Message," which was sent in 1973. Possibility of employing quantum communication is also being explored [53]. Further, in a recent discovery, scientists studying the environment of the exoplanet K2-18 b with the James Webb Space Telescope recently found a high level of the chemical dimethyl sulfide or some similar compound in its atmosphere. As all the detectable dimethyl sulfide in Earth's atmosphere is produced by microbes, it is often considered as a biosignature. But it will be too early to jump to conclusions, as it has been found that under Earth-like laboratory simulations dimethyl sulfide can be produced through non-living organisms as well, making it a non-reliable candidate for biosignature. Its tough measurement also leaves the possibility of its detection being an instrument artefact [70].

Although there is a long way to go, it seems hard to be pessimistic. NASA's ATLAS telescope recently identified "3I/ATLAS," a comet-like interstellar object from outside our solar system that is scheduled to approach the sun around October 29, travelling close to Venus, Mars, and Jupiter on its way. While most astronomers consider it a comet, physicist Avi Loeb believes it may have been sent by an extraterrestrial civilization rather than a natural phenomenon. In support of the idea, he suggested that because of its retrograde orbital plane, the chances of it travelling close to the sun near Earth are only 0.2% if it is regarded a random event. Its huge diameter of 12 miles adds to his concerns. Although his views did not resonate with many in his own community, events like these raise this discourse time and again [71]. The rays of hope emerge from the recent advancements in computing powers enabled AI and ML systems that have the capacity to process substantially huge signals. This would facilitate various scenario analysis and simulations. In addition, AI and ML driven self-replicating space probes that are trained to understand extra-terrestrial signals and ability to transform may pave the way for setting newer horizons in understanding the extra-terrestrial intelligence.

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