Three Versions of the Third Law: Technosignatures and Astrobiology

Astrobiology Science Strategy for the Search for Life in the Universe
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The Lead author and Co-authors represent the following SETI-related organizations whose many members have contributed to, or commented on, this white paper. Since these groups may be unfamiliar to the reader, a brief description and URL's are given below for each organization.

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[1] The Center for SETI Research was one of the original Centers established in 1984 when the 501(c)(3) SETI Institute was founded with a mission is to explore, understand, and explain the origin and nature of life in the universe, and to apply the knowledge gained to inspire and guide present and future generations. We have a passion for discovery, and for sharing knowledge as scientific ambassadors to the public, the press, and the government. https://www.seti.org/aboutus

[2] The Science Advisory Board of the SETI Institute has 13 members from academia, MBARI, USGS, and the Vatican Observatory, and provides scientific guidance to the Board of Trustees. https://www.seti.org/seti-institute/SETI-Institute-science-advisory-board

[3] The Berkeley SETI Research Center serves as the organizational entity for searches for advanced extraterrestrial life at UC Berkeley, including the Search for Extraterrestrial Radio Emissions from Nearby Developed Intelligent Populations (SERENDIP), SETI@Home, Astropulse, public outreach activities, and Breakthrough Listen. http://seti.berkeley.edu

[4] The Breakthrough Listen Initiative has established an Advisory Committee to provide guidance on the scientific and technical aspects of the 10-year, privately funded, observational program to find evidence of ETI. Its 27 members are drawn from academia, observatories, non-profits, and industry from this country as well as China, Australia, the UK and Austria. https://breakthroughinitiatives.org/leaders/1

[5] The Permanent SETI Committee is the current incarnation of a committee established first under the auspices of the International Academy of Astronautics in 1974 to facilitate the global exchange of information about SETI programs. https://iaaseti.org/en/

[6] The International SETI Collaboration was started in 2017 as an ad hoc community, utilizing modern video conferencing tools to enable monthly opportunities for technical information exchange. (No URL available)

Summary
Not knowing exactly what to look for, Astrobiology should embrace, and prioritize, all scientifically plausible and technologically feasible search strategies for both biosignatures and technosignatures. There is no scientific justification for excluding SETI, or any other technosignature modality, from the suite of astrobiological investigations. Arguments based on political sensitivities or apparent access to other funding sources are inappropriate. In this white paper, we argue for a level playing field.

The Third Law
In 1973 Arthur C. Clarke (British engineer turned science fiction author) formulated his three laws [1]

1. When a distinguished but elderly scientist states that something is possible, they are almost certainly right. When they state that something is impossible, they are very probably wrong.
2. The only way of discovering the limits of the possible is to venture a little way past them into the impossible.
3. Any sufficiently advanced technology is indistinguishable from magic.

This third law has dominated dedicated searches for technosignatures ever since, although our research methodology is rigorous, not 'magic'. The search for extraterrestrial intelligence is instead a search for alien technologies that are modifying their environment in ways that can be sensed remotely; e.g., artifacts within our solar system, electromagnetic radiation, great feats of astroengineering, and even industrial pollution.

Some of the 'magic' may be quite difficult to detect, and unrealistic. Karl Schroeder (Canadian futurist and science fiction author) has suggested a second variant of the third law; Any sufficiently advanced technology is indistinguishable from *Natur*e [2]. Great longevity requires sustainability. "In the Great Silence [the failure of decades of SETI projects to detect a signal], we see the future of technology, and it lies in achieving greater and greater efficiencies, until our machines approach the thermodynamic equilibria of their environment, and our economics is replaced by an ecology where nothing is wasted." [3]

Finally, when conceiving the potential perils of superintelligent singletons that are insufficiently boxed or constrained, or given goals that are not well thought out [4], one can imagine that Nick Bostrom (Swedish philosopher and futurist) **might** construct the following version of the third law; Any sufficiently advanced technology is indistinguishable from paper clips. [If such an entity were instructed to make one million paper clips, it would never be 100% sure it had achieved its goal and thus would transform all available matter into paper clips and paper clip manufacturing tools or into whatever its goal specified.]

In seeking to discover evidence of any of these versions of the third law, astrobiology could succeed. Unfortunately, without knowing the answer in advance, we do not have a foolproof way of deciding what strategies for the detection of technosignatures make the most sense. Therefore, until we have more information, we should employ those strategies that have sufficient sensitivity to produce significant null results or a positive detection.

We have now discovered that there are more planets than stars, at least in the Milky Way Galaxy, and we are seriously studying the life strategies that allow extremophiles to populate almost every environmental niche on this planet. Even though a 2007 NRC report on weird life [5] concluded that biosolvents other than water might be possible, the astrobiology community has continued defining potentially habitable planets, and their habitable zone, in terms of liquid water. That definition is useful because it acknowledges

our limited capability to study other possibilities. We don't know how to find weird life, and we might not recognize it if we did; on Earth or beyond. Some scientific science fiction writers have done a credible job of imagining life forms that were not initially recognized as such; think of Fred Hoyle's Black Cloud [6], or Robert Forward's 'Cheela' living at accelerated speeds on the surface of a neutron star [7], or Arthur C. Clarke's aquatic Europans [8]. These last are something that the astrobiology community is actively planning to seek out in the near future. If they are there, will they be recognizable? Will they be detected by any of the life detection tools we will send; tools that are inevitably going to be based on life as we know it? As the chemosynthetic communities surrounding Earth's black smokers remind us, life on the ocean floor need not all be microscopic, and underwater camera systems and lights will be valuable tools on Europa once we get the capability to deploy them there. In other environments, tools that recognize patterns of technology might be even more valuable.

According to Sagan, Thompson, Carlson, Gurnett, and Hord in their 1993 Nature paper, when the Galileo spacecraft did a flyby of Earth, utilizing all its scientific instruments, "one of the strongest pieces of evidence for life (indeed intelligent life) on Earth was the presence of narrow-band, pulsed, amplitude-modulated radio transmission." [9]**.** And yet this is precisely the type of evidence that the current **2015 NASA Astrobiology Strategy** specifically refuses to acknowledge under the umbrella of astrobiology: "While traditional Search for Extraterrestrial Intelligence (SETI) is not part of astrobiology, and is currently well-funded by private sources, it is reasonable for astrobiology to maintain strong ties to the SETI community." [10]. This is an arbitrary distinction that artificially limits the selection of appropriate tools for astrobiology to employ in the search for life beyond Earth, one that it is not supported scientifically. The science of astrobiology recognizes life as a continuum from microbes to mathematicians. It is time to remove this artificial barrier, and to re-integrate the community of all those who wish to study the origin, evolution, and *distribution* of life in the universe.

A Brief History

Until 1993, when Sen. Bryan (D–Nev.) terminated FY94 funding for NASA's High Resolution Microwave Survey, and SETI became a 4-letter S-word at NASA Headquarters, the disciplines of Exobiology, Bioastronomy, and finally Astrobiology all took a catholic view of life and its co-evolution with its host world. Post-HRMS termination, other small NASA SETI programs were also shut down [11]. The NSF included a prohibition against funding for SETI in its annual, agency-wide, *NSF Guide to Programs*. That language remained in place until actions by Congress caused NSF Director Rita Colwell to remove it in 2000 [12].

Indeed SETI, at least by that name, has always been a political lightning rod, and that has resulted in a checkered history of inclusion in, or exclusion from, the series of astrobiology roadmaps leading up to the current **2015 NASA Astrobiology Strategy**. In the precursor **Astrobiology Roadmaps of 1998, 2003, and 2008**, SETI was addressed (or ignored) under Goal 7, "Determine how to recognize the signatures of life on other worlds ". This Goal and its attendant objectives have evolved over time as astrobiology has matured, technologies have improved, and the political climate has changed. Table 1 is an attempt to summarize the status of observational SETI research in each precursor document.

SETI's unmentionable, post-termination status did not change until the door was cracked open during a 2001 hearing on Life in the Universe, held by the Subcommittee on Space and Aeronautics. In reply to a direct question from the Subcommittee, NASA Associate Administrator Ed Weiler responded, "NASA is no longer prohibited by any congressional language from considering or funding SETI research, so SETI is currently eligible and considered fairly under peer review for NASA opportunities." [13]

Table 1: Treatment of Technosignatures and SETI in Astrobiology Roadmaps/Strategies

Document	Biosign.	Technosign.	SETI	Action
1998 Roadmap	√	—	—	**Goal 7** envisioned only chemical biomarkers or remote biosignatures
2003 Roadmap	√	√	√	**Goal 7** added on "Thus, although technology is probably much more rare than life in the universe, its associated biosignatures perhaps enjoy a much higher "signal-to-noise" ratio. Accordingly, current methods should be further developed and novel methods should be identified for detecting electromagnetic radiation or other diagnostic artifacts that indicate remote technological civilizations."
2008 Roadmap	√	√	√	**Goal 7** was changed to "Determine how to recognize signatures of life on other worlds and on early Earth. Identify biosignatures that can reveal and characterize past or present life in ancient samples from Earth, extraterrestrial samples measured in situ or returned to Earth, and remotely measured planetary atmospheres and surfaces. Identify biosignatures of distant technologies." The **background section for Goal 7** stated "Accordingly, current methods should be further developed and novel methods should be identified for detecting electromagnetic radiation or other diagnostic artifacts that indicate remote technological civilizations." **Objective 7.2** expanded with "Learn how to identify and measure biosignatures that can reveal the existence of life or technology through remote observations."
2015 Strategy	√	√	**X**	**Page 76** "… we should also be aware of the possibility of planets with anomalies that are the result of technological activities. Much attention has focused on which qualities of terrestrial life might be universal, and therefore relevant to the search for biosignatures; similarly, it is worth considering which aspects of technological civilization might be universal, how such qualities should be expected to affect the observable aspects of a planet, and how they might be discernible from other biosignatures." However, on **Page 150** "While traditional Search for Extraterrestrial Intelligence (SETI) is not part of astrobiology, and is currently well-funded by private sources, it is reasonable for astrobiology to maintain strong ties to the SETI community."

√ indicates that this activity was supported by the document
— indicates that the document was silent regarding this activity
X indicates that the document explicitly excluded this activity

While roadmaps and strategic plans are of great importance, it is NASA's funding vehicle, the annual ROSES call for proposals, and the less frequent NAI CAN opportunities that define the playing field of the possible. These have been inconsistent with respect to searches for technosignatures and SETI. Operating under the guidelines of the 2008 Astrobiology Roadmap, Table 2. shows what the opportunity space has been.

Table 2: Treatment of Technosignatures and SETI in NASA ROSES and NAI CAN calls.

Document	Biosign.	Technosign.	SETI	Opportunity
ROSES 2008	√	√	√	C.17 (Astrobiology, Exobiology, Evolutionary Biology) is silent on SETI, but E.3 (Origins of Solar Systems) solicits "… detection and characterization of other planetary systems including those that may harbor intelligent life."
ROSES 2009	√	√	—	E.3 stated that, "the research goals of proposals aimed at identification and characterization of signals and/or properties of extrasolar planets that may harbor intelligent life previously included in this program are covered by the Astrobiology: Exobiology and Evolutionary Biology (Appendix C.17) and Astrobiology Science and Technology Instrument Development (ASTID, Appendix C.19) program elements. While C.17 and C.19 remained silent on SETI.
ROSES 2010 & 2011	√	√	√	C.17 under the program element *Evolution of Advanced Life* now includes "Proposals aimed at identification and characterization of signals and/or properties of extrasolar planets that may harbor intelligent life are also solicited."
ROSES 2012				There was no call for C.17 that year
ROSES 2013	√	√	**X**	C.17 explicitly excluded SETI proposals. "Proposals aimed at identification and characterization of signals and/or properties of extrasolar planets that may harbor intelligent life are not solicited at this time."
ROSES 2014 - 16	√	√	**X**	This same exclusionary language persisted from ROSES 2013 through ROSES 2016, and C.17 was restructured into C.5 (Exobiology).
ROSES 2017	√	√	**X ?**	C.5 is confusing. Under the program element *Evolution of Advanced Life*, the same exclusionary statement persists. But under the element *Biosignatures and Life Elsewhere,* "Additionally, research focused on understanding or characterizing nonradio "technosignatures" from extrasolar planets that may harbor intelligent life are included in this area."

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Consistent with the SETI-friendly **2008 Astrobiology Roadmap**, the **NAI CAN-5** issued that year stated "The [2008] Roadmap lays out Astrobiology investigations in a continuum from the study of the

biogenic compounds during solar system formation through the detection of technologies indicating extraterrestrial intelligent life, with particular attention to the effects of interstellar and interplanetary phenomena on life on Earth—its origins, evolution, and the extent of global changes and destruction that have been caused by Earth-impacting objects." An NAI Team whose proposal contained a SETI component was in fact selected that year.

As the concept of the Anthropocene has gained credence, it has become more firmly established that the search for technosignatures is a legitimate approach to satisfying **Goal 7**, and scientifically what has been called SETI is one such technique. A 2016 paper by N. Cabrol [14] invited suggestions from a multi-disciplinary audience for innovative new ways to detect intelligent life-as-we-don't-yet-know-it. White papers responding to that invitation have been reviewed and will form the basis for a workshop in March 2018, the results of which will be shared with the Space Studies Board Astrobiology Science Strategy for the Search for Life in the Universe Committee. The Advisory Committee for the Breakthrough Listen SETI effort has also established a subcommittee to consider 'other methods' of detecting ETI. SETI is expanding its toolkit.

Conclusion

It is time that we end this scientific schizophrenia. It is of course reasonable for a funding agency to elect not to fund any given proposal, but it is unscientific to exclude clearly related proposals from consideration. Historical politics or a perceived (but unverified) funding status from other sources should not enter into an estimation of the scientific value of an approach. All versions of 'The Third Law' (seemingly "magical" technology, husbanded nature, and machine-driven monotony) may suggest research directions that are radically different. One or more of those may move the field of Astrobiology forward in unexpected, and productive, ways.

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[1] Clarke, Arthur C. (1973). Profiles of the Future: An Inquiry into the Limits of the Possible. Popular Library. *ISBN 9780330236195*.

[2] http://www.kschroeder.com/weblog/the-deepening-paradox (accessed 12/16/17)

[3] ibid

[4] Nick Bostrom (2014). Superintelligence: Paths, Dangers, Strategies. Oxford University Press. *ISBN 978-0199678112*

[5] National Research Council. 2007. *The Limits of Organic Life in Planetary Systems*. Washington, DC: The National Academies Press. https://doi.org/10.17226/11919.

[6] Fred Hoyle (1957). The Black Cloud. William Heinemann Ltd. ISBN 0-451-11432-9

[7] Robert Forward (1980). Dragon's Egg: Cheela Book 1. Ballantine Books *ISBN* 0345286464

[8] Arthur C. Clarke (1982). 2010: Odyssey Two. Granada Publishing Ltd. ISBN 0-345-31282-1

[9] Sagan, Thompson, Carlson, Gurnett & Hord (1993). A search for life on Earth from the Galileo spacecraft. *Nature* 1993, **365**, 715-721

[10] NASA Astrobiology Strategy 2015, page 150.

[11] Private communication in memo from John Rummel to Mary Voytek "SETI in Astrobiology" Feb 2017

[12] Reproduction of letter from Office of NSF Director to Office of Lamar Smith dated April 24, 2000.

[13] As down loaded 1/5/18 from http://commdocs.house.gov/committees/science/hsy73839.000/hsy73839_0f.htm page 132.

[14] Cabrol, N.A. (2016). Alien Mindscapes – A Perspective on the Search for Extraterrestrial Intelligence. *Astrobiology* 2016, **16**, 1-16.