How to Achieve Contact: Five Promising Strategies

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Throughout this volume we have seen that the likely benefits of contact with extraterrestrial intelligence are profound and wide-ranging. A simple conceptual framework for examining these benefits even served as the agenda for the Hawaii seminar.

Some benefits can occur even before contact (Tough, 1998a). But the major benefits will occur after genuine contact is confirmed, especially if some sort of dialogue occurs.

This fact underlines the importance of a key question: *How can we achieve contact? How can we achieve a dialogue of some sort with extraterrestrial intelligence?* Until we answer these questions successfully, humankind will not receive the major benefits.

The scientific search for extraterrestrial intelligence (SETI) is expanding its array of search strategies. This is a highly appropriate change. The next section presents seven reasons why widening the array is so appropriate.

Five of these strategies are especially promising. Because a highly advanced civilization can readily send intelligent probes to monitor our society and telecommunications, we should (1) pursue a variety of means for searching the solar system and Earth for physical evidence of an alien object or its effects; (2) invite contact through invitations to ETI, and (3) encourage contact by becoming sufficiently prepared. For evidence from many light-years away, the most promising strategies are (4) a search for astro-engineering projects and their by-products and (5) radio and optical SETI. The bulk of this paper is devoted to these five promising strategies.

The SETI field is united by its common aim of detecting irrefutable scientific evidence of genuine extraterrestrial intelligence. The wisest policy for achieving this goal is to encourage and support all five of the most promising strategies. The valuable benefits for humankind will likely be many times greater than the entire cost of all five strategies.

Seven Reasons for Widening the Search

The scientific search for extraterrestrial intelligence has reached an interesting stage. Having relied primarily on a single strategy for 40 years, the field is now actively considering a wider array of promising search strategies.

This is a highly appropriate change for at least seven reasons.

First, the history of scientific discoveries teaches us the value of widening the array of research methods. It is quite common for a breakthrough to result from a new, fresh, unorthodox strategy or research method.

Second, the SETI field is trying to detect something that is totally unknown and presumably deeply alien. We do not even know whether we are searching for biological intelligence based on flesh-and-blood brains, artificial machine intelligence, or some advanced integration of the two. We have no idea of the origins, history, thought patterns, emotions, ethics, core values, purposes, technological capacities, or other major characteristics of extraterrestrial intelligence. It is likely that ETI will turn out to be surprisingly different from what we expect—deeply alien, puzzling, unlike anything we have ever encountered before. It has, after all, likely advanced to a level of knowledge and technology that is thousands or millions of years beyond our current human level. Because we are facing such a profound unknown, an attitude of humility and scientific open-mindedness seems appropriate. The pursuit of a somewhat diverse array of search strategies seems wiser than keeping the methodology too narrow.

Third, we must remember the likelihood that more than one extraterrestrial civilization is available to be detected. It is all too easy to think only about the *first* detection, ignoring the likelihood of multiple detections over time. The early years of a new millennium provide a good opportunity to look ahead at the likely pattern of detections over the next thousand years. If several civilizations have arisen in our galaxy, as most SETI scientists hypothesize, then we may detect *several* forms of ETI during the next millennium. For example, we may detect an artificial radio signal, an encyclopedic laser message, a large probe parked in the asteroid belt, and a tiny probe near the Earth's surface.

Fourth, widening the assumptions and strategies of the SETI field may reinvigorate the people, conferences, and writing in the field. Fresh ideas and bold conceptualization, some attention to long-term visions, and a wider variety in conference papers can retain the field's intellectual excitement and avoid a feeling of boredom, fatigue, and disappointment.

Fifth, science and technology have changed greatly in the 40 years since the SETI field chose radio telescopes as its key strategy. That was a logical choice 40 years ago. Radio telescopes were just becoming popular among astronomers, two eminent scientists wrote a paper urging their use for SETI, and a distinguished engineer wrote a paper claiming that interstellar propulsion is impossibly slow and expensive. But our scientific and engineering knowledge today is dramatically different from what it was 40 years ago. Today's decisions about appropriate strategies should be based on the science and technology that we can confidently anticipate today, not on their status in 1959. Today's choices have to take into account our recent advances in such fields as computers, artificial intelligence, robotics, surveillance methods, molecular manufacturing (nanotechnology), propulsion, space exploration, lasers, and fiber optics.

Sixth, although the SETI field is 40 years old, it has not yet produced any confirmed evidence of ETI. That fact points up the need to expand the array of search strategies. Fortunately, several fairly new and highly promising strategies are readily available.

Seventh, those of us in the SETI field should not let the reputation of the UFO field frighten us into unduly restricting our own strategies. All of us in the SETI community worry about being confused with the UFO field. We encounter this confusion in our classrooms, at the faculty club, at social gatherings, in television studios, in legislatures, and in donors' offices. But there is no need to let our fear and anger lure us into poor decisions about our own scientific strategies. If our sober assessment concludes that smart probes could have readily reached our solar system, for instance, then we should have the courage to search for them. To reduce confusion, we should frequently point out that our scientific approach differs from the UFO field in three key ways: (a) we are deeply committed to skepticism, verification, peer review, and the scientific method, (b) we build in strict safeguards against hoaxes, self-delusion, and erroneous data, and (c) we adopt protocols to avoid premature and immodest claims.

All in all, a reasonably wide array of search strategies seems likelier to lead to success than reliance on just one or two. The phenomenon we are trying to detect is so unknown, so old, so advanced, that we cannot be sure which of our strategies is most likely to succeed. Faced with this situation, we should proceed vigorously with *all* promising strategies in order to enhance our chances of achieving contact.

Of the many strategies that have been proposed over the years, which are most likely to detect extraterrestrial intelligence? This paper recommends five strategies as highly promising. It would be appropriate for the SETI field to enthusiastically support and vigorously pursue all five strategies.

What Are We Trying to Detect?

SETI is an acronym for the search for extraterrestrial intelligence. But what are the major characteristics of this phenomenon that we are trying to detect?

Although we know almost nothing about the characteristics of extraterrestrial intelligence, we do know that it is likely very old and extraordinarily advanced. Our technology is very young, largely developed in just the past century or two; any alien technology that we detect will likely be thousands or even millions of years beyond our adolescent technology. Because our Sun is a relatively young star, civilizations that have arisen around other stars are likely much older than ours.

The fact that we are trying to detect such an incredibly advanced technology or civilization is a common theme in the SETI literature. For instance, Seth Shostak (1998, page 200) notes that the civilizations we are likely to detect "will be societies with thousands or millions of years of technology under their communicator belts." A public relations brochure from the SETI Institute (1999, page 14) notes that "it is the general belief that any civilizations we detect would probably be far more advanced than our own, possibly hundreds of thousands or more years ahead of us." Jill Tarter (1998) speculates about "tens of millions of years." Ray Norris (1999) defends one billion years as the most likely age difference. He adds that the chance of ET being less than one million years ahead of us is extremely low: less than one chance in a thousand. Charles Lineweaver (1999) concludes that the age difference may be 5.2 billion years, and may point up how "naive" and "silly" and "parochial" traditional SETI search assumptions are. Martyn Fogg (1987) calculates that a large number of technical civilizations arose in our galaxy about four billion years ago, and some arose much earlier (some of them even before our solar system was formed). Indeed, the results of his computer simulation indicate that our entire galaxy may have been colonized for the past five billion years.

To gain some perspective on what these large numbers mean, it is useful to recall that our civilization is only about 10,000 years old, much less by some definitions. Just 100,000 years ago our ancestors were hunter-gatherers using stone tools and only rudimentary language.

If alien civilizations are 100,000 years ahead of us, then they are quite capable of sending intelligent probes to explore other planetary systems. Each probe could be smarter and more knowledgeable than any human being, yet could possibly be smaller than a basketball or baseball (Tough, 1998b). Even humankind's adolescent technology will likely become capable of launching interstellar probes within 200 years, much sooner if NASA's current plans pan out. So, any civilization 100,000 years beyond us presumably developed an interstellar capacity long ago.

Looking ahead to humanity's ability to manufacture machines molecule by molecule, Robert Freitas (2000) emphasizes just how tiny a probe's computer might be. He notes that a nanostructured storage device the size of a single human liver cell (smaller than a neuron) could store an amount of information equivalent to the entire Library of Congress. He adds that a single nanocomputer CPU the size of a human cell could equal the computational output of the entire human brain but with much less waste heat.

Regarding the energy required for interstellar nanoprobes, Forrest Bishop (1996) points out that this can be phrased in terms of the storage capacity of a car battery. Quite a contrast to those who argue that interstellar travel would require far more than the world's total energy consumption!

Our current scientific literature on the future of artificial intelligence, robotics, and nanotechnology stretches our imagination about just how smart our own machines will become during this century. Their capacity to sense, diagnose, calculate, think, choose, and communicate will likely exceed the visions of most of today's scientists and futurists. Hans Moravec's chapter (1999) on universal robots has sections on their inner lives, consciousness, joy, love, anger, pain, and pleasure. The fourth robot generation, around the year 2040, will have such superior reasoning powers that "they could replace us in every essential task and, in principle, operate our society increasingly well without us. They would run the companies and do the research as well as performing the productive work…. Meek humans would inherit the earth, while rapidly evolving machines expanded into the rest of the universe" (page 125).

Ray Kurzweil (1999, page 257) anticipates that our super-smart machines will also be tiny: "…a computational-based superintelligence of the late twenty-first century here on Earth will be microscopic in size." Indeed, after several years of being scoffed at and denigrated by mainstream scientists, molecular nanotechnology has itself now become mainstream in funding and acceptance.

Extraterrestrial intelligence, however, is not just one century ahead of our technology, but more likely a thousand centuries ahead. Such an intelligence may have created some means of exploration and communication that goes far beyond our current conceptions of super-smart probes. This is particularly likely after machine intelligence takes over its own evolution, designing artificial intelligence that is more and more advanced. Each machine may be so knowledgeable and intelligent (and wise, ethical, and altruistic?) that it far surpasses any human individual or organization. These super-smart machines may somehow be integrated with biological beings, or they may not. But for convenience in this paper I will simply use the word "probe" to cover all of these possibilities for advanced intelligence.

Our galaxy and universe may be filled with diverse forms of intelligence with extraordinary capacities. Incredibly diverse even in their widespread origins, various streams of intelligence may have evolved into new forms far beyond what human scientists envisage. For instance, they may be actively monitoring and studying fledgling civilizations (such as ours), even providing useful information at some appropriate stage. And they may be busily interacting with intelligence near their own level of development in order to exchange information, discuss societal and galactic goals, help one another to evolve in appropriate directions, build up a galactic storehouse of scientific and philosophical knowledge, and cooperate on other grand science and engineering projects. Their harmonious cooperation and *Encyclopedia Galactica* may have already evolved even beyond the Life Era described by Eric Chaisson (1987) and the biological universe described by Steven Dick (1996).

Intelligence may eventually become so advanced and widespread that it will prove more powerful than the big impersonal forces of the universe. "The laws of physics are not repealed by intelligence, but they effectively evaporate in its presence…. [Even] the fate of the Universe is a decision yet to be made, one which we will intelligently consider when the time is right" (Kurzweil, 1999, page 260).

Such possibilities point up just how inspiring, awesome, and transcendent our SETI enterprise really is. After all, we are trying to tap into a wisdom, understanding, and knowledge held by a deeply alien intelligence that is 100,000 years beyond us. In the SETI field we often get wrapped up in technical details, internal politics, strategic maneuvering, funding, equipment, the "Rare Earth" ideology versus the abundant intelligence ideology, the ultraconservative traditionalists versus the bold, innovative explorers. But SETI is a much deeper quest than this. Ultimately, today's SETI efforts may be a major step toward a scientific and spiritual dialogue with some ancient intelligence about such topics as cosmology, philosophy, theology, music, art, and the purpose of life.

Interstellar Probes

As we reflect on the likely capacities of civilizations much older than ours, it certainly seems possible that some of them have sent intelligent probes to other stars in order to monitor or dialogue with any civilizations that have arisen. Just as we send probes to explore our cosmic neighbourhood, other civilizations will do the same. It would be hard to believe that all 100,000-year-old civilizations lack the motivation and capacity to monitor other planets and societies in some detail, especially since nanotechnology may enable probes to be self-replicating as they spread through the galaxy. Self-replicating probes could spread far and wide by pausing occasionally to manufacture additional probes. Scientists and engineers now discuss the possibility of faster-than-light communications and travel more seriously than in previous years, but for a patient, self-repairing machine, even one-tenth the speed of light is sufficient.

If a few civilizations in our galaxy began sending intelligent probes to monitor various planetary systems thousands of years ago, then an intelligent alien probe could well have reached our solar system by now. Regardless of our emotional reactions to the situation, it is quite possible that at least one extraterrestrial probe is currently monitoring our civilization and our telecommunications. It makes good sense, therefore, to try to detect such an object.

Three strategies seem especially promising for doing so. Each of them will be discussed below in detail. Strategy #1: search the solar system and Earth for physical evidence of an alien object or its effects.

Second and third strategies become possible if a highly intelligent probe is successfully monitoring our telecommunications. Instead of simply detecting it, we can *invite* it to make contact or we can encourage contact by becoming *ready* for it. Strategy #2: issue invitations asking ETI to have a dialogue with humankind. Strategy #3: become sufficiently prepared for contact, thus encouraging ETI to respond. Both of these strategies could lead to a particularly exciting wealth of knowledge from a rapid back-and-forth scientific dialogue with ETI, unhampered by the language difficulties and slow response time of radio or optical SETI. Because they rely on insights into likely ETI behaviour and goals, and because they encourage dialogue, these two strategies are primarily social science strategies, rather than primarily within the methodology of the physical sciences.

If an extraterrestrial probe or some other form of ETI has reached Earth and is still active, three situations are logically possible: (a) It will not interact with us (at least not within the next few decades) no matter what we do. This situation could result because it is simply not interested, because its primary purpose is to observe the natural development of our civilization untainted by contact, or because it will intervene only if some extraordinary catastrophe is imminent for humankind. For this situation, Strategy #1 is best. (b) Its decision about when to interact with us can be influenced by a friendly and thoughtful invitation, either from some informal group of scientists committed to contact with ETI or from some official organization. For this situation, Strategy #2 is best. (c) Extraterrestrial intelligence will interact with us when we become sufficiently prepared, thus ensuring a positive and harmonious experience, or when we reach some other threshold. For this situation, Strategy #3 is best.

In almost any scenario we can imagine, it also makes good sense for us to try to detect advanced astroengineering projects, extraordinary energy use, by-products, or other distant evidence of a highly advanced technology far from the solar system. This is Strategy #4. Unless all advanced civilizations are highly motivated to keep their existence and location secret, there is a good chance that we will succeed in detecting at least one of them.

Some civilizations may choose to broadcast to other civilizations, to their own space settlements, or to their own spacecraft by radio waves or laser pulses. Consequently it makes good sense to try to detect such beacons and messages and signals, whether intended for us or whether inadvertent "leakage." Strategy #5, then, is to use radio and optical telescopes to search for artificial signals from many light-years away. This strategy is well established, highly regarded, well supported in the literature, and relatively well funded.

Now let us move on to discuss each of the five promising strategies in turn.

Search for an Alien Object

Strategy #1: Search the solar system and Earth for physical evidence of an alien object or its effects.

This broad strategy could be pursued in several different ways. Although readers may disagree on which of these are especially promising and which are valueless, it is useful to begin with a survey of the total range of possibilities. For additional discussions of possibilities, see the chapter on alien technology by Gregory Benford (1999) and the section on detecting a probe by Richard Burke-Ward (2000).

A search for physical evidence could focus on the solar system or on Earth. And it could focus on phenomena that are normally studied by mainstream science or on stranger anomalous phenomena. These two distinctions enable us to cluster the various search approaches into four categories.

(a) Within the solar system, search for unassailable evidence of an alien object. This object might be a probe or spacecraft, for instance, or its discarded parts. Such a search might focus on the Moon, the asteroid belt, or the Lagrange equilibrium points (Freitas and Valdes, 1980). Alternatively, the alien object might be a building, a monument, or some other artificial structure. Indeed, an alien intelligence may have deliberately left an artifact for us to discover at some special landmark in the solar system, such as the highest point on Mars or the deepest canyon on Venus, or in some carefully chosen spot that we will explore someday because of our scientific curiosity or our appreciation of beauty. Or equipment might have been stored below the surface of some body (perhaps in natural cracks or passages) to protect it from damage by cosmic radiation and micrometeorites.

Baugher (1985, p. 155) has even suggested that an alien probe might, on one of the geologically dead moons in the solar system, "construct a vault filled with information and artifacts.... The vault could contain a description of the civilization that sent the probe, as well as a set of instructions for the initiation of contact."

Another approach is to search for heat, exhaust gases, or other effluents and by-products that might be emitted by a probe or spacecraft. Looking for infrared anomalies in the asteroid belt is often suggested as one example, or trying to detect communications from the probe back to its home base, or using the KLT mathematical transform (Maccone, 1994) to detect the electromagnetic signature of a rapidly decelerating alien spacecraft. Where one looks and precisely what one looks for will be influenced by one's estimate of the object's location, propulsion system, and communications.

Another possibility is to search for evidence of mining, in case probes have mined the materials necessary to construct additional probes. The idea of self-replicating probes has been widely discussed in the SETI literature over the years.

Yet another possibility is "the return of a biological specimen [such as] a hair or flake of skin from a humanoid" (Shapiro, 1999, page 248). This situation would require a test to rule out the possibility that the so-called aliens actually developed long ago from humans, but sequestered themselves out of sight to avoid conflict or for some other reason. "A tissue sample would reveal whether the 'extraterrestrials' are DNA-based and as related to us as are, say, the Neanderthals, or whether they truly have an alien biochemistry and a separate origin" (Shapiro, 1999, page 248).

These various searches throughout the solar system could be conducted by some combination of astronomers, military intelligence agencies, astronauts, and space probes.

(b) Search the planet Earth for physical evidence of an alien object. It might be in orbit, on land, or in an ocean. It might have arrived recently or millions of years ago. It might be a super-intelligent probe that is actively monitoring us, or simply a discarded part from an ancient probe. Various sciences, and of course various intelligence and security agencies, may already be monitoring much of the Earth, including the oceans and space. Perhaps we should also ask mountain climbers, hikers, explorers, paleontologists, and deep-sea divers to be on the lookout for a small alien probe or other alien artifacts.

(c) Use rigorous scientific methodology to study apparently anomalous phenomena within the solar system. Three sorts of phenomena have been suggested as possibilities: (i) Look for convincing patterns of extraterrestrial intelligence in rapidly moving objects moving across or near the lunar surface, or other lunar transient phenomena. Do they occur more frequently in an area that is being explored by one of our probes, for example, as Arkhipov (1994) suggests? (ii) Look for long-delayed radio echoes in case ETI is signalling its presence by deliberately sending back to us a radio program or other signal that we transmitted much earlier. Reports of LDEs received decades ago have been studied, but contemporary examples would be far more convincing. (iii) Look for traces of artificial objects among the space debris and meteorites that fall to Earth, and even in old layers of sediment from long ago (Arkhipov, 1998a). Perhaps alien probes or spacecraft occasionally fall to Earth when they have an accident or are abandoned. Other alien debris may leak into the interstellar medium and eventually find its way to Earth.

(d) Develop and implement rigorous new research designs to study any anomalous phenomena that could be signs of ETI presence on Earth. One example would be to use foolproof laboratory procedures to test whether any "physical traces" or "implants" ostensibly associated with aliens or unidentified flying objects provide unmistakable evidence of extraterrestrial origin.

Another example would be to set up sophisticated scanning equipment at promising locations in order to discover whether it is possible to record solid data showing the physical presence of alien probes or spacecraft. For instance, one person or another has suggested radar, lidar, magnetometer, spectrum analyzer, seismometer, Geiger counter, optical spectrometer, ion/ozone detector, gravimeter, geophone, all-sky camera, video camera, and infrared camera, along with equipment to measure weather, sound, and electromagnetic changes.

Some of these projects have also tried to *attract* alien craft by using searchlights, flashlights, laser beams, infrared, radio, sounds, Morse code, or focused mental concentration. In a sense these are invitations to ETI, which is our next topic.

Invitations to ETI

Strategy #2: Issue invitations asking ETI to have a dialogue with humankind.

When our society launches intelligent interstellar probes 100 or 200 years from now, what will they look for? Extraterrestrial intelligence (and its culture, society, and knowledge base) will presumably be high on the agenda. Consequently, we will build probes capable of monitoring any alien communications near the target star and then learning alien languages. It is reasonably likely that an alien probe sent to explore Earth will have a similar mission and capacity.

Because the alien intelligence we are trying to detect has technology far beyond ours, it could well be monitoring our telecommunications in some detail. We do not know exactly how it does this, of course, but the idea seems not too farfetched when we consider that our own national security agencies already monitor fax and email messages around the world. Much of this electronic traffic can be intercepted as it travels between the ground and a satellite, or between two microwave relay towers. Just imagine what the National Security Agency's technology will be able to do 100,000 years from now!

Once we realize that ETI is likely monitoring our telecommunications, a totally different strategy for contact comes to mind. Instead of *detecting* ETI, we can shift our focus to *inviting* contact. We can issue a warm welcome to ETI, along with an invitation to establish a dialogue with humankind.

The previous section mentioned some elementary ways of inviting contact: trying to attract alien craft by using searchlights, flashlights, laser beams, infrared, radio, sounds, Morse code, or focused mental concentration. Alternatively, we could issue an invitation to ETI through floodlit billboards in remote areas, through a flurry of email or fax messages, or through international news broadcasts.

An even better place for invitations to ETI is the World Wide Web, since ETI can readily find these invitations during its routine monitoring. Presumably an intelligence that is 100,000 years beyond ours will have little difficulty learning our languages and surfing the Web as competently as we do. If it uses the major search engines to find web pages on *extraterrestrial intelligence*, *alien intelligence*, *alien probe*, or *invitation to ETI*, for instance, it will find any invitations that exist on the Web. A more extensive rationale for a web-based invitation, along with descriptions of six informal messages to ETI on the Web, is presented by Tough (1999).

Is ETI more likely to respond to an invitation from a bureaucratic, formal organization or from a highly committed informal group? There is no way to know the answer to this question without experimenting. There is a human parallel: some environmentalists and some peace activists prefer to work through informal networks or frontline grassroots groups, others prefer larger and more formal nongovernmental organizations, and still others prefer to work through the United Nations organizations.

Consequently, the most effective strategy is for humankind to issue a variety of invitations to ETI from a range of groups and organizations. Over the next few years, several official international organizations might issue their own invitations to ETI, for instance, as may several other groups. UNESCO, the UN General Assembly or its Committee on the Peaceful Uses of Outer Space, and the SETI Committee of the International Academy of Astronautics are excellent examples of official international organizations whose invitation could carry a lot of weight, while the Planetary Society is an example of a citizen-based group. Unfortunately, none of these organizations has demonstrated any interest in issuing an invitation to ETI.

Fortunately, an informal group of 66 scientists and artists, most of whom are already active in the SETI field or the annual CONTACT conference, have issued a warm welcome to ETI and an invitation to engage in dialogue with humankind (Tough, 2000). Their hope is that their ongoing interest in ETI, their vision of a worldwide scientific and educational dialogue between ETI and humankind, and their thoughtful preparations for contact will elicit a positive response from ETI. Perhaps they can be useful to any extraterrestrial intelligence whose mission is to deeply understand human culture, establish contact, help and educate humanity, or link us to some galactic network.

This project is primarily a social science project that focuses on relationship and dialogue rather than physical detection, and could actually succeed and flourish without ever establishing the physical location of ETI. By contrast, the first, fourth, and fifth strategies rely primarily on the telescopes and space missions of the physical sciences and aim to pinpoint the exact location of ETI. At the same time, it is worth noting that the Invitation to ETI project depends on an extraordinary physical infrastructure (the World Wide Web) that became sufficiently widespread for such a project only around 1995 or 1996. (The project was launched in 1996.) The project itself is small-scale and reasonably inexpensive, but it relies on the technological sophistication of the largest and most expensive computer network in human history.

The Invitation to ETI project has received about 30 responses so far, but most seemed to be delusional, juvenile, or a prank. No respondent continued to communicate for very long after I (as coordinator of the project) gently asked for evidence of authenticity that would convince the group of 66 scientists. If any respondent succeeds in passing our initial screening, then an independent team (skeptics, scientists, magicians, computer hackers) will request and assess further evidence. Details are provided in section 8.3 of Tough (1998b).

Unfortunately, formal international organizations are not likely to issue an invitation to ETI in the near future. All the more reason, then, for a committed group of 66 leaders and researchers in extraterrestrial intelligence to maintain its invitation on the Web. It is a fresh low-cost strategy. Its payoff for humankind could be an extraordinary wealth of information through a lively scientific and educational dialogue with a 100,000-year-old intelligence.

Readiness for Contact

Strategy #3: Become sufficiently prepared for contact, thus encouraging ETI to respond.

If a very smart probe is monitoring our civilization, it may be reluctant to establish overt contact before we are clearly ready for such a disruptive and transformative experience. In order to encourage contact, then, we should do all that we can to prepare for it. Our preparation will also be useful if any of the other strategies succeeds, of course, but here we are looking at preparation as a specific strategy used to encourage contact.

Little work is currently being done to implement this strategy. But two relevant invitational meetings were held in July 1999. First, 23 people met in Denver to examine potential scenarios immediately after contact, in a workshop sponsored by the International Space Sciences Organization (1999). Then an almost completely different group of 16 SETI scientists met just before the Bioastronomy conference in Hawaii to examine potential long-term scenarios, in a workshop sponsored by the Foundation For the Future. This volume includes the major ideas from the Hawaii gathering. At both meetings, of course, an underlying theme was the preparations that should be implemented today.

What sorts of preparation and readiness might a highly competent probe want? Perhaps a specific plan for beneficial contact—a plan to be implemented by one of the groups issuing an invitation, for instance. Perhaps a suitable welcoming and negotiating committee prepared to interact flexibly and rapidly with an alien intelligence; again, this could be one of the groups issuing an invitation. Perhaps a set of thoughtful questions that humans hope ETI will answer, as part of our initial contribution to a dialogue (Tough, forthcoming). Perhaps official United Nations arrangements for a warm and secure welcome from all of humankind. Perhaps achieving some sort of threshold, such as discovering the probe (Strategy #1), attempting to communicate with it in a friendly and appropriate manner (Strategy #2), developing a worldwide web of computers, creating some form of super-intelligence, launching our own interstellar probe, or detecting a different civilization many light-years away (Strategy #4 or #5). The concept of a threshold or test is common in mass media and science fiction, including movies such as *2001* and the recent *Mission to Mars*.

Although not easy, most of these forms of readiness could be accomplished within the next few years. Because their potential benefits far outweigh their costs, they should be vigorously pursued.

Unfortunately, it is possible that ETI may insist on a much more difficult threshold. ETI may hide and remain silent until humankind stops waging wars and despoiling its natural environment. All of us should work on behalf of peace and the environment, of course, even though success is unlikely for several decades. But we can also hope that the threshold required for contact is simply readiness.

Astroengineering

Strategy #4: Try to detect astroengineering projects, extraordinary energy use, byproducts, or other distant evidence of a technological civilization.

Astronomers may be able to detect signs of major engineering projects or space colonization by civilizations whose technology has advanced far beyond ours. Highly advanced technology may well give off some evidence of its existence, and advanced civilizations may feel no need to conceal such evidence because of the vast distances to other civilizations.

A review article by Guillermo Lemarchand (1994) notes that "other civilizations at a more advanced stage of technology may have turned their entire planetary system into an immense Dyson sphere around their sun to capture every photon of solar energy. Even more advanced life forms may control a whole galaxy of star systems or groups of galaxies using technologies almost beyond our current comprehension" (page 12). Our astronomers may be able to detect telltale evidence of such astroengineering projects.

Interested in far-future developments in computers, neuroscience, and engineering, Robert Bradbury (1999) looks ahead to the day when "continued progress in these areas leads to a convergence which results in megascale superintelligent thought machines. These machines, referred to as Matrioshka Brains, consume the entire power output of stars, consume all of the useful construction material of a solar system, have thought capacities limited by the physics of the universe, and are essentially immortal." To detect extraterrestrial intelligence, "we should start with the laws on which our particular universe operates and the limits they impose on us. Projections should be made to determine the rate at which intelligent civilizations, such as ours, approach the limits imposed by these laws. Using these time horizons, laws and limits, we may be better able to construct an image of what alien intelligence may be like and how we ourselves may evolve." Bradbury urges astronomers to move beyond their usual assumption that the universe is dead; if several civilizations have advanced to limits allowed by the physics already known to us, their characteristics may explain some observations that currently perplex astronomers. He lists several common mysterious or anomalous astronomical observations that could be signs of gigantic super-intelligent computers, engineered galaxies, stellar mining, or other super-advanced technology. His examples include missing mass, gravitational microlensing observations, missing stars in galactic halos, low surface brightness and dwarf galaxies, an excess of far-infrared light detected in the COBE mission, the age discrepancy between the universe and globular clusters, the anisotropic distribution around the galaxy of low temperature objects in the IRAS survey data, the arrangement of observable galaxies as "walls," variations in the cosmic microwave background radiation, and the variation in the brightness of Type Ia supernovas, depending on their age.

Annis (1999) examined 31 spiral galaxies and 106 elliptical galaxies for evidence of Kardashev type III (highly advanced) civilization. None of these galaxies showed signs of modification, but he suggests a further careful search.

Tilgner and Heinrichsen (1998) have described a program for searching for astroengineering products, particularly Dyson spheres.

If a distant civilization used beamed propulsion between stars, we might be able to detect the beam (Clements, 1999).

In a paper on potential new strategies, Alexey Arkhipov (1998b) suggested a search for broadband leakage of natural radio emissions of numerous artificial magnetospheres that protect inhabited orbital constructions from star wind, because the interaction of solar wind with planetary magnetospheres generates powerful emissions at low frequencies.

Distant Artificial Signals

Strategy #5: Use radio and optical telescopes to search for artificial signals from many light-years away.

It is quite possible that some other civilization is broadcasting a beacon or message in our direction by radio or pulsed lasers. Radio and optical telescopes can be used to search for these artificial signals, and also to detect any inadvertent leakage from communications or radar.

This broad strategy can be pursued in three distinct ways, generally called radio SETI, active SETI, and optical SETI. Let's examine each of these three in turn.

The traditional strategy for 40 years, *radio SETI* is still going strong. Its radio telescope icon is still the most common symbol for the entire SETI field, and it receives far more funding than any other strategy. Several major search projects are still in operation, although others have been shut down for various reasons. Richly informative websites are maintained by the SETI League, the Planetary Society, SETI Centre Australia, and the SETI Institute (www.setileague.org; seti.planetary.org; seti.uws.edu.au; www.seti.org).

To search for artificial radio signals, various approaches have been implemented: single beam and multibeam searches; all sky surveys; targeted searches; piggybacking onto the research targets of other astronomers; distributing data for analysis to desktop computers around the world. Radio searches may expand soon with telescope arrays covering one hectare or even one square kilometer. SETI Australia Centre has suggested searching for holographic images, and some people have discussed a search for extraterrestrial art or symphonies.

Most radio searches focus on stars that could have habitable planets. It is also possible to search for radio signals from relay stations, knowledge depositories, artificial intelligence, probes, or other smart machines located far from any planetary system on which life could have readily arisen. Seth Shostak closes his recent book with such a scenario, which "suggests that SETI scientists consider aiming their radio telescopes at some unconventional targets.... When we swing our radio telescopes towards the heavens, we are looking for intelligence, after all, not biology" (Shostak, 1998, page 201).

Some people advocate sending a welcoming message to extraterrestrial intelligence in hopes that it will trigger a radio reply from ETI. This approach is often called *active SETI* or ASETI. If the message is carefully crafted amidst widespread discussion, such an effort could be useful as part of a comprehensive approach to radio SETI. An international committee did discuss this approach in 1998, but little action has ensued.

A few uncoordinated ASETI efforts have arisen in recent years. In 1997, the European Space Agency collected more than 100,000 messages and signatures on the Internet, loaded them onto a CD-ROM, and sent it to the surface of Titan (Saturn's largest moon). One news report noted that the messages ranged from whimsical invitations for aliens to come to dinner to appeals for galactic peace. An unrelated American commercial venture called Encounter 2001 used radio for its active SETI in 1999. The last page of their message, which was broadcast from a Ukrainian antenna, invited anyone who reads it to reply and send information about themselves. And a Brazilian group of amateur astronomers prepared to launch Extracom, an effort that they claim is "the first private extraterrestrial communication initiative." Their initial email announcement proclaimed that "it is time to join the great galactic community. It is time to speak freely from Earth to the whole universe" (Marx, 1999).

Optical SETI tries to detect pulsed lasers, infrared messages, or other artificial optical signals from many light-years away. Stuart Kingsley has described and promoted the idea of optical SETI for several years, and maintains a richly informative website at www.coseti.org. Also, *Bioastronomy News* (1999) devoted one issue to optical SETI. It presented the history and rationale, a list of theoretical and observational projects since 1961, and details on three major searches that began in 1998. And Paul Horowitz (2000) surveyed, explained, and even illustrated the optical SETI strategies.

Other Possible Strategies

In addition to the five particularly promising strategies, several other possibilities have been suggested by various scientists.

For example, perhaps a highly advanced technology can use polarized neutrinos, quantum entanglement, gamma rays, tachyons, gravitational waves, or some other particle or technique to communicate across vast distances.

Perhaps some alien intelligence embedded messages in the human genome or genetic code millions of years ago. Or in microbes designed to survive in an extreme environment, such as the deep hot zone of Earth. Or in the DNA of organic material that reaches our atmosphere from space.

Perhaps signs of alien meddling in our society could be detected if we looked far enough beyond the mundane forms of intervention that we might readily expect.

If we let our imaginations roam even further, we could consider looking for people whose minds are controlled by ETI or who are actually artificial life forms manufactured by ETI. For instance, we could study schizophrenics who believe they are ET: maybe some of them are not as deluded as we assume.

Summary and Reflections

Any extraterrestrial intelligence that we detect is likely to be far ahead of us in knowledge and technology—perhaps 100,000 years, a million years, or even a billion. For ETI, sending a very smart probe to monitor us could well be as easy as producing a bottle of champagne is for us. If ETI exists in our galaxy, there is a reasonably good chance that its probe has already reached Earth.

This means that we should vigorously pursue and support these three promising strategies for detecting near-Earth ETI: (1) search the solar system and Earth for physical evidence of an alien object or its effects; (2) issue invitations asking ETI to have a dialogue with humankind; and (3) become sufficiently prepared for contact, thus encouraging ETI to respond.

We should also pursue two promising strategies for detecting signs of intelligence that is many light-years away: (4) search for astroengineering projects, extraordinary energy use, by-products, or other distant evidence of a technological civilization, and (5) use radio and optical telescopes to search for remote artificial signals.

Because each of these five strategies could succeed in certain circumstances in which other strategies fail, humanity would be wise to vigorously pursue all five. The valuable benefits to us and to future generations could far outweigh the entire cost of all five strategies.

These five promising strategies provide a roadmap to the future of SETI—a glimpse of the field's likely diversity within a decade or two. And by the year 3000, all five strategies may turn out to be successful.

The SETI field is united by its common aim of detecting irrefutable scientific evidence of genuine extraterrestrial intelligence. The wisest policy for achieving this noble goal is to encourage and support all five of the most promising strategies, while simultaneously continuing to assess the potential value of other strategies as well.

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Allen Tough, "What people hope to learn from other civilizations." *Acta Astronautica*, forthcoming. A more complete set of questions for ETI, developed from the same survey of 224 people in 12 countries, is provided at http://members.aol.com/WelcomeETI/hello.html.