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SMALL SMART INTERSTELLAR PROBES

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Humanity is making rapid progress in computers, robotics, nanotechnology and space exploration. Consequently, within 200 years, we will be likely to launch small interstellar probes containing highly advanced computers.Perhaps other civilizations, more advanced than ours, launched intelligent machines long ago to explore parts of our galaxy. One of their tiny probes may have already reached our planet in order to observe or monitor us. Our current scientific search for extraterrestrial intelligence should be expanded by adding a sophisticated search for such a probe. Two SETI "declarations of principles" have been developed to cover the search for radio and laser signals originating many light-years away. Some SETI scientists have assumed that these two declarations also apply to the scenario of discovering a nearby probe but, in fact, the fit is not very good. A separate set of "Procedures Following Detection of An Interstellar Probe" has been drafted.

1. INTRODUCTION

Most scientific searches for extraterrestrial intelligence try to detect a radio or optical signal that originated many light-years from our solar system. The capacity and sophistication of these search efforts have progressed very well in recent years.

Most of the SETI literature seems to assume that this type of search effort is the only possible way to detect extraterrestrial intelligence. Only rarely is attention drawn to any other possible approach. One notable exception, more than a decade ago, was the Freitas and Valdes SETI project that looked for a fairly large alien probe at a Lagrange point [1].

This paper focuses on one promising but neglected search strategy: the scientific search for a small interstellar probe containing a highly intelligent computer. This current paper grows out of earlier efforts to assess the entire array of possible search strategies [2, 3].

2. HUMANITY'S EVENTUAL CAPACITY

As far as we can tell at present, it will soon be perfectly feasible for our civilization to build intelligent machines to explore the galaxy. Within 200 years, perhaps just 40 years, our civilization will likely be able to send lightweight robot probes to nearby stars.

In 1997, this idea moved much closer to the mainstream when NASA enthusiastically endorsed it. The exploration of the concept of interstellar probes was adopted at the Space Science Enterprise Strategic Planning Workshop [4] (in Breckenridge, Colorado, May 1997), which is the penultimate step in the production of the next NASA Space Science Strategic Plan. Then at a news conference on the eve of the Pathfinder space probe landing on Mars in July, top NASA officials Daniel Goldin and Wesley Huntress spoke enthusiastically about a basketball-sized interstellar probe as a 25-year goal for NASA [5]. In October, at a plenary session of the International Astronautical Congress in Turin, NASA Administrator Dan Goldin again spoke enthusiastically about developing an interstellar probe, perhaps "within a decade or two" launching a probe to travel 10,000 AU as a step toward probes that can reach more distant targets. He also pointed out that this fundamental goal for NASA will probably drive rapid development in nanotechnology and advanced computer capabilities.

My estimate that humanity will launch interstellar probes within 200 years is supported by the rapid advances that scientists and engineers are currently making in four fields *viz*:

(1) Computers

Various teams and companies are developing advanced *computer* capacities, looking ahead to the prospect of high-level machine thinking and flexible problem-solving abilities within 200 years. In 1997, the ability of IBM's Deep Blue computer to beat world chess champion Garry Kasparov in a 6-game match gave us a glimpse of what the future may bring.

In order to improve computers themselves, and eventually produce tinier faster computers with huge storage capacities, projects are already focusing on holographic data storage, molecular storage (such as a protein called bacteriorhodopsin), and a renaissance in quantum-computing research [6]. Examining the declining cost of teraflop capability over several decades, Robert Freitas estimated that [7], by the year 2021, "Human-Equivalent Computers will cost a mere $1, which means they'll start showing up in children's toys and magazine inserts".

Dan Goldin has spearheaded NASA's interest in dramatically outdoing computer companies in producing cheaper and faster computer chips, even achieving tenfold increases of memory and decreases of price. NASA realizes that immensely fast and inexpensive computer chips would allow it to trim the weight of space probes and increase their degree of autonomous control, thus reducing the cost dramatically [8].

(2) Robotics

Vigorous efforts have already developed sophisticated *robots* and will continue to improve them [9]. One goal is to develop autonomous vehicles with good intelligence, an effort that involves the fields of robotics, machine vision, machine learn-

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ing, intelligent control and planning.

(3) Nanotechnology

Manufacturing flawless materials and tiny machines from cheap materials one atom at a time is the ultimate aim of today's *nanotechnology* projects. Nanotechnology, also called molecular engineering, is an extremely active field with many projects based in various organizations around the world [10]. The common theme is clear - the precise control achieved by building with individual atoms and molecules will make it possible to build incredibly cheap and almost flawless objects once we design them [11]. For instance, it will be easy for "universal assemblers" to replicate themselves and to build flawless materials. Machines, probes, and other objects will be much smaller, lighter and cheaper than we are used to imagining.

Drexler anticipates that such developments will occur within 20 or 30 years [12]. Freitas estimates that we will achieve full-scale nanotechnology within 60 years. He foresees that "by the mid-21st century, nanotechnology will make possible many science fiction inventions once relegated to the distant future. Very little lies beyond our grasp" [13].

If it succeeds, nanotechnology will enable us to build small flawless interstellar probes. Discussing this prospect, Edward Belbruno claims that "we could perhaps have this technology ready within the next 20 years if there were a commitment to develop it" [14].

According to a position paper on space and molecular nanotechnology, the theoretical strength-to-density ratio of matter is about 75 times that currently achieved by aerospace aluminum alloys. Nanotechnology will produce spacecraft components made of a flawless diamond-titanium composite and enable us to build tiny interstellar probes for a cost of $1 per kilogram. The same position paper points out that "tiny computers, sensors and actuators, trivially cheap on a per-unit basis, may allow things like smart walls to automatically repair micrometeorite damage" [15].

Even if atom-by-atom nanotechnology never succeeds, other methods of miniaturization and self-replication are being vigorously pursued. One example is MicroElectroMechanical Systems (MEMS) [16].

(4) Space exploration

Within the field of *space exploration*, key projects are already moving toward smaller, lighter, cheaper, more autonomous spacecraft [17]. In addition, serious theoretical work is focusing on various propulsion possibilities for interstellar probes, including antimatter propulsion, nuclear pulses, solar-electric propulsion, solar sails and several sorts of beam propulsion [18]. Looking to the long-term future, NASA has a Breakthrough Propulsion Physics Program [19]. Salvatore Santoli has described in detail a possible short-range vehicle weighing only 80 g [20]. Already, even without new physics or unexpected new technologies, we can identify technological solutions to the problem of interstellar propulsion [21].

Just before the 1996 bioastronomy symposium in Capri, 50 experts met in Turin to examine "realistic near-term scientific space missions to the outer solar system and beyond" [22]. This symposium was organized by the Interstellar Space Exploration Committee of the International Academy of Astronautics. Papers discussed a wide range of potential propulsion systems, problems and possible solutions.

2.1 Interstellar Probes

Progress in computers, robotics, nanotechnology and space exploration will presumably continue during the foreseeable future. As a result, within 200 years, humanity will be able to build cheap, small, lightweight probes to explore nearby stars.

An interstellar probe might be smaller, lighter and cheaper than a magnum of champagne or even a hockey puck. Because of the likely advances in computing and nanotechnology, each probe will probably carry a computer that is intelligent enough to study its surroundings, make decisions throughout the trip, guide the probe to a particularly promising planet, study whatever it finds and eventually use local resources to send accumulated observations back home. Presumably the probe will be capable of diagnosing and repairing any damage that it sustains during the trip. Nanotechnology literature suggests several ways in which this might be achieved.

Several ingenious possibilities for slowing down a tiny probe as it approaches its destination have been discussed extensively in the literature, most notably by Robert Forward [23]. The particular solutions for slowing down the probe depend, of course, on the particular method of propulsion that is being used.

"But what about the antenna?" is a common question whenever small probes are discussed. The probe will be intelligent enough to operate from its home base without instructions, so no antenna will be needed for that purpose. In addition, as computers become smarter, they may themselves become the major players in space exploration. That is, our present-day concept of sending reports back to us here at home may change into the concept of the probe as an intelligent self-contained scientist/explorer/diplomat that does not send a report anywhere, at least not until its mission is completed. When it is time to send messages back home, there are at least four possibilities.

(1) The probe might deploy an extremely thin antenna that it carried with it.

(2) According to the nanotechnology literature, the probe's tiny universal assemblers could manufacture an antenna from materials found on an asteroid or other uninhabited body.

(3) If the probe found a local civilization and achieved a cooperative relationship, they might send the message together, using local equipment.

(4) Humanity's preferred means of interstellar communication 200 years from now may no longer be radio. It may be a new method that does not require an antenna.

All in all, it seems unlikely that antenna difficulties will turn out to be the major stumbling block to sending successful interstellar probes 200 years from now. It is helpful to imagine oneself for a moment in the world of 200 years from now, one filled with technologies and capacities and knowledge that we can only dream of. Within this context, the problem of an antenna suddenly seems manageable.

In another paper [24], Freitas examined 14 physical, economic, and logical objections that have been raised over the years to the idea of interstellar probes. He concluded that "close examination reveals that each objection is either incorrect, unfounded, or, in some cases, actually a good argument in favour of probes".

2.2 The Speed of Change

This section on humanity's eventual capacity has outlined several likely achievements of the next 200 years. Some readers will feel skeptical about such achievements, of course, but it is also easy to imagine how skeptical the people of 1800 would have felt if they had heard about today's technology.

It is also useful to keep in mind the extraordinary rate of technological change that we can expect over the next 200 years. Even the most realistic mainstream projections sound like science fiction at first. Indeed, Arthur C. Clarke's well-known Third Law may not be much of an exaggeration: "any sufficiently advanced technology is indistinguishable from magic" [25].

Our actual technological capacities 200 years from now may be far beyond most of today's conceptions. All in all, it seems highly probable that humanity will have the capacity to send small, smart, inexpensive probes to nearby stars within the next 200 years.

3. THE CAPACITY OF OTHER CIVILIZATIONS

If human civilization will soon have the capacity to send interstellar probes, it follows logically that older civilizations in our galaxy are also likely to have achieved that capacity long ago. Since our Sun is a relatively young star and our civilization is only a few thousand years old, most civilizations in our galaxy are likely to be much older than we are. There is a good possibility that some of these older civilizations have developed technology thousands of years ahead of ours.

Manufacturing small smart probes is probably easy for them. One of their options is to produce only a few probes designed to use the asteroids and other resources of a nearby planetary system as the raw material for building copies of themselves. Nanotechnology literature indicates that this plan may be quite feasible. These second-generation probes could then continue travelling toward various stars. In short, exploration of the entire galaxy could occur quite inexpensively through several waves of self-replicating probes, sometimes called von Neumann machines. In this way, according to one estimate, "the exploration of the Galaxy would cost about 3 billion dollars, about one-tenth the cost of the Apollo program" [26].

4. THE MOTIVATION OF OTHER CIVILIZATIONS

In addition to their *capacity* to send probes to nearby stars, might some civilizations also have the *motivation* to do so? What might motivate a highly advanced civilization to manufacture and send probes? One can think of at least four possible purposes.

(1) Scientific research to satisfy their curiosity about the universe is probably one major purpose. They want to learn all they can about the stars, planets, life-forms and cultures in their own galaxy. To accomplish this, a civilization might send a probe to every relevant star within 300 light-years, especially if one of the star's planets has an atmosphere containing oxygen, ozone, carbon dioxide, methane, or water vapour. A probe could be very patient, of course. It could wait thousands of years for life or culture to develop, or even millions of years if it is self-repairing.

(2) For any civilization, security might be a second purpose. Surveillance probes could ensure that no civilization becomes a danger to any other civilization in the galaxy.

(3) As a third purpose, a highly advanced civilization might want to make contact with other civilizations, initiate a brisk dialogue with them, give them specific knowledge or an entire galactic encyclopedia, help them in other ways, preach to them, explore possible collaboration, or invite them to become a new member of a galactic federation.

(4) One can imagine a fourth purpose for sending interstellar probes containing encyclopedic knowledge. If a civilization is feeling vulnerable to extinction despite its extraordinary capacities, it may send out many probes to ensure that a record of its culture, values and philosophy will survive.

5. RADIO OR PROBES?

For achieving these four purposes, a highly advanced civilization is much more likely to send a small probe than broadcast a radio signal.

Radio broadcasting is totally useless for the first two purposes, i.e. exploration and surveillance.

For the third purpose (dialogue), an intelligent probe is capable of a much livelier dialogue than distant radio or laser signals that travel many years in each direction, although the dialogue will begin later because of the probe's slower travel time. If it detects another civilization, perhaps the advanced civilization will use two strategies simultaneously. It will carry on a radio dialogue (even though responses take years) while the probe is travelling to the other civilization. The probe will then take over the dialogue, with responses taking just minutes or hours. If the advanced civilization is worried about being attacked, it might use only a probe (no radio) because a probe need not reveal the location of its home civilization, whereas the home source of a radio or optical signal can be readily known.

Even more important for achieving the third purpose, the probe's highly intelligent computer can monitor the local languages, communications media and societal needs before choosing the time, medium, languages and content for its message. The use of local languages avoids any need for decoding and the message can be geared to this civilization's particular level of understanding. A probe can even deliver a message to a civilization that is not searching for a radio or laser signal, perhaps because its technology or interests evolved in some different direction, or that is searching the wrong wavelengths or in the wrong locations. If the civilization is not ready for galactic knowledge or would be harmed by it, the probe can remain silent and undetected.

Supporting the advantages of probes over radio, Robert Freitas Jr. and Francisco Valdes [27] have noted that an intelligent probe can "engage in a true conversation with the indigenous civilization, an almost instantaneous, complex interaction between cultures. Responses to questions and answers are immediate, permitting real-time educational and linguistic exchanges with a precision and rapidity no remote (interstellar) radio signalling system could possibly match. Contact via probes provides a potentially richer, deeper interaction than via interstellar radio links. A probe's onboard memory elements may contain an appreciable fraction of the knowledge and culture of the sending civilization".

Methods of telecommunication can change very rapidly, as we see in our own civilization. Radio and radar may turn out to be short-lived methods that are eventually replaced by other methods beyond our current technology. A civilization whose technology is 5000 years ahead of ours may have abandoned radio communications 4500 years ago. If this sort of communications evolution is common, our SETI efforts to detect deliberate radio transmissions and radio leakage from remote advanced civilizations may not succeed. All the more reason, then, to consider additional innovative search strategies.

6. ADDING A FRESH SEARCH STRATEGY

Summarizing the argument so far, it seems quite likely that some advanced civilizations in our galaxy have both the capacity and the motivation to send probes to many other stars. They may in fact have done this many centuries ago. Even though it contains sensors and an extraordinarily advanced computer, each probe might be smaller, lighter and cheaper than today's bottle of champagne.

Continuing this logical train of thought, it is obviously possible that our solar system is one of the planetary systems that some advanced civilization has chosen to observe. If there are several advanced technological civilizations in our galaxy, as most SETI scientists assume, it seems reasonable that at least one of them has sent a probe to monitor us. Indeed, since their technology is probably thousands of years ahead of ours, it is hard to imagine that not one of them has sent a probe to our solar system. In short, it is quite possible that an intelligent probe has already reached our planet.

Despite great progress in the SETI field in recent years, we must still operate with a high level of uncertainty about the number, characteristics, capacities and purposes of advanced beings in our galaxy. Consequently, at this early stage of development, it would be premature to limit our efforts to just one or two search strategies while neglecting others. The SETI enterprise needs as much diversity as it can get: the breakthrough may come from some unexpected source. Fresh strategies could be highly valuable and worthy of thoughtful consideration.

Expanding our current radio and optical SETI by adding a careful search for an interstellar probe could be very useful. The potential value of adding this supplementary search strategy has been supported by various writers. In his 1960 *Nature* article, for instance, Ronald Bracewell suggested searching the solar system for an interstellar probe containing "a quite elaborate store of information and a complex computer, so that it could not only detect our presence, but could also converse with us" [28]. In a recent paper, he estimates that a probe "might be about the size of a human head" but could conceivably be as small as a virus [29]. Barrow and Tipler stated that a visiting robot containing an extremely advanced computer "would be an intelligent being in its own right, only made of metal rather than flesh and blood" [30]. Michael Papagiannis declared that it is "likely" that other civilizations have already sent one or more space probes to study our planet and "technological evolution" [31]. Paul Davies noted the possibility of finding an alien probe on the ocean floor or earth's surface: such a probe "could then be interrogated directly, as with a modern interactive computer terminal, and a type of dialogue immediately established. Such a device--in effect, an extraterrestrial time capsule--could store vast amounts of important information for us" [32].

With the rapid development of computers, robotics and nanotechnology in the past ten years, we now realize that a probe could be even smarter, smaller and more flexible than we assumed in the mid-1980s. A search for a small nearby object now seems appropriate, whereas all previous scientific searches for alien objects in our solar system have searched for much larger and more distant objects, in the asteroid belt or at a Lagrange point, for instance [33]. Scientific strategies for finding a small, smart, nearby object may be quite different from earlier SETI approaches. For instance, the author's current search strategy makes use of the World Wide Web [34].

7. TWO DECLARATIONS OF PRINCIPLES

A search for a small smart probe could well be added to our current SETI efforts, either trying to detect physical evidence of its presence or inviting it to engage in dialogue. It is also possible that a probe will be discovered inadvertently, perhaps during routine military or security monitoring. A third possibility is that the probe itself will initiate some sort of communication. If any one of these three possibilities occurs, we find ourselves in a scenario quite different from detecting a radio or optical signal from afar.

Consequently, it is important to re-examine the two current international SETI declarations of principles to see how well they fit the "nearby probe" scenario. These two declarations, widely discussed in the SETI community over the past 12 years, cover confirmation of authenticity, public announcements, the dissemination of data, and the question of replying to the source of the signal. The first declaration has been widely adopted by individuals, SETI projects and observatories. The second declaration is gradually moving through various steps toward adoption by governments and international governmental organizations.

Because these two declarations never state explicitly the sorts of detection situations to which they apply, and to which they do not, they could create extraordinary confusion and tension if a scientist detects a nearby probe rather than a distant radio signal. This scientist would be forced to choose between two unpleasant options: either follow a principle that is totally inappropriate in this unanticipated situation, or face the risk of "enforcement mechanisms" such as censure and sanctions through "the disciplinary mechanisms of scientific institutions" [35].

In order to avoid this confusion and tension, it is extremely important that the relevant parties make an explicit statement that these two international declarations apply only to the detection of a signal that comes from a distance of many light-years. At its 1997 meeting in Turin, the IAA subcommittee on issues of policy concerning communication with ETI informally accepted this distinction but did not adopt a formal position on the matter. The situation would be vastly improved if the documents themselves, and the concerned parties, stated clearly that they do not apply to any other situations, such as the detection of a small probe or large staffed spacecraft near our planet.

Efforts to develop separate sets of principles or procedures for these other two scenarios have already begun. A draft covering the probe scenario was distributed at the subcommittee meeting in Turin and is presented in the next section of this paper. A draft for the large staffed spacecraft scenario was recently published in the *JBIS* [36]. This "large staffed spacecraft" scenario goes far beyond the scope of this present paper and will not be discussed further.

The first declaration is officially called "Declaration of

Principles Concerning Activities Following Detection of Extraterrestrial Intelligence." It has been widely discussed, and most radio search efforts have agreed to follow it.

This first declaration was designed primarily for a detection scenario involving a distant radio or optical signal that comes from an extraterrestrial civilization many light-years from our solar system. This is the standard SETI detection scenario that everyone thinks of when they think of SETI. Recent progress in computers, robotics, nanotechnology and space exploration, however, now make it obvious that another scenario, too, is a lively possibility i.e. the detection of a small, highly intelligent probe close to Earth. This second scenario is not mentioned in the document, which fails to state whether it is intended to cover it or not.

It is important, consequently, to examine each of the principles in this international protocol to see how well they fit the probe detection scenario. Two of the basic principles fit quite well but the third does not fit at all. The first basic principle emphasizes the importance of verifying that the source is genuinely extraterrestrial before making a public announcement. Vigorous thorough verification is an extremely important principle that fits both scenarios very well. The detailed arrangements and personnel will vary from one scenario to another, of course, but the fundamental principle remains valid. The second basic principle emphasizes the importance of collecting and archiving all possible data and making all of it promptly and freely available to other scientists. This basic principle, too, applies to both scenarios, though again the details will vary depending on whether it is a remote astronomical phenomenon or a nearby probe.

The third principle, however, does not fit the probe detection scenario at all. This third basic principle is simply listed in the first declaration of principles but is spelled out in detail in the second declaration, called "Draft Declaration of Principles Concerning the Sending of Communications to Extraterrestrial Intelligence." This principle basically says, "Don't reply." To be more precise, it instructs that no communication take place until the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) has met, followed by a meeting of the United Nations General Assembly to decide whether to reply and to decide the content of the reply.

Most members of the SETI community would wholeheartedly agree that "the content of such a message should reflect a careful concern for the broad interests and well-being of Humanity." However, many of the specific procedures and arrangements in the second declaration make little sense if a scientist or research team is faced with an immediate message from a nearby intelligent probe. That is not the time to ask the United Nations General Assembly to compose a response: that process would take far too long. Anyone familiar with the usual speed and procedures of COPUOS and the General Assembly would hesitate to ask them to compose a message to ETI within a few hours or days. If a probe initiates a dialogue and then is met by weeks of silence while the United Nations composes a reply, the probe might interpret the lack of an immediate response as uninterested, unfriendly, or even hostile.

Indeed, the whole concept of a single lengthy reply fails to fit the probe scenario at all. Lively quick back-and-forth communication is much more likely. The probe has presumably already monitored our radio and television broadcasts, learned at least one of our languages and learned about our culture and history. It does not need a lengthy reply containing language lessons and an encyclopedia, unlike the radio SETI scenario of sending a reply to a source many light-years from us.

Both declarations of principles assume that verification and reply are two discrete procedures, perhaps separated by many months. With a probe, however, it may turn out that verification and communication are intertwined, not discrete. Fairly quick back-and-forth communication may be required as part of the verification process. The research team might ask the probe to prove its extraterrestrial origin by giving us new scientific knowledge or some other demonstration of its extraordinary ability. Indeed, back-and-forth communication may be absolutely necessary for verification. The only other option, surely not one that any SETI scientist would encourage, is to capture the probe in order to see where the parts were manufactured.

8. PROCEDURES FOLLOWING DETECTION OF AN INTERSTELLAR PROBE (DRAFT)

This section presents a rough draft of a set of procedures for use following detection of a nearby probe. An earlier version was presented at the 1997 meeting of the IAA subcommittee on issues of policy concerning communications with ETI. Although far from final, this draft gives some sense of the sorts of issues and procedures that might eventually be covered by a final version sometime in the future.

Readers already familiar with the two declarations of principles for radio SETI will find some of the same basic principles in this draft. They will also note how different this draft turns out to be, because the two situations are so different.

Human civilization could benefit greatly from an educative and scientific dialogue with extraterrestrial intelligence. The potential long-term gains from such a dialogue are extraordinarily high and will presumably outweigh any risks or costs. Consequently, the ultimate aim of all stages of interaction with an interstellar probe is to establish an ongoing educative and scientific dialogue of significant long-term benefit to human culture and society.

The following procedures apply to any situation that meets both of the following criteria. Any other situation may require different procedures.

Criterion #1: A small smart interstellar probe has already reached our solar system. It has learned a great deal about us through direct observation and through monitoring our telecommunications and can now read at least one major human language.

Criterion #2: In order to work out the necessary technical details for subsequent communications, the probe sends a message to a SETI researcher.

Why might a probe choose a SETI researcher for this early stage? The probe might choose a SETI researcher if it has noted that major international organizations still have little interest in making contact with other civilizations and are unlikely to treat its initial message with appropriate respect. It might choose a particular SETI researcher if that person invited the probe to make contact, or holds a key post within the SETI community, or has attracted the probe's favorable attention in some other way.

These procedures are divided into four stages:

(1) preparation;

(2) working out the necessary technical arrangements;

(3) confirming or disconfirming authenticity;

(4) a worldwide dialogue.

8.1 Preparation

The researcher should develop a thoughtful set of procedures, guidelines and principles for use following the apparent detection of an interstellar probe. (Throughout these procedures, the word "researcher" means the person who establishes initial contact with the probe, or the leader of the research team that does so.)

All procedures should take into account the first three irrevocable directives spelled out in the "Declaration Toward a Global Ethic" signed by representatives of 14 diverse religions at the 1993 Parliament of the World's Religions [37]. Modified to apply to human-ETI interaction, these three principles can be summarized as follows:

(a) have respect for ETI, and avoid violence;

(b) speak and act truthfully, avoiding lies and deception;

(c) deal honestly and fairly with ETI, avoiding any temptation to exploit the situation for personal greed.

All procedures should also take into account the fundamental principles or metalaws [38] that all intelligent species in the universe may follow, such as a peaceful and friendly welcome, freedom from harm and intrusion and capture, an effort to understand each other, respect for each other's customs and creeds, help when needed, and cooperation in science and technology as well as the arts and social sciences.

Procedures at all stages should give serious consideration to how the probe itself wants to be treated, based on our understanding, empathy and respect [39]. It is inappropriate for us to reject its expectations and requests simply because they differ from our human customs and norms and laws.

The researcher should make the proposed set of procedures widely available on the World Wide Web, through scientific meetings, or in other ways.

In order to improve the proposed procedures, the researcher should solicit criticism and suggestions from relevant colleagues around the world. This could be done through establishing a formal or informal advisory panel for the project, through scientific meetings, through the World Wide Web, and through other formal and informal channels.

8.2 Working Out the Necessary Technical Arrangements

The purpose of this second stage is to establish the technical aspects of communication, to arrange for evidence of authenticity and to explore any security needs. Responsibility for this second stage: lies with the SETI researcher.

This stage begins whenever the SETI researcher receives a communication that claims to be from some nearby form of extraterrestrial intelligence. Communication during this stage will presumably consist of brief, practical, back-and-forth messages. The tone of all human messages should be respectful, cooperative, friendly, enthusiastic and non-adversarial. The probe's intentions should be presumed friendly and altruistic, or at least peaceful and benign, unless its behaviour clearly indicates otherwise. Unusual or bizarre behaviour should not automatically be considered hostile. However, if any message from ETI at any stage indicates some serious threat to human health or peace, the appropriate authorities should be notified.

The eventual goal of these procedures is to establish an educative and scientific dialogue between humankind and ETI. At an early stage, therefore, arrangements must be made for confirmation of authenticity and for security.

The eventual worldwide dialogue will be much more useful if scientists, politicians, religious leaders, business leaders, academics, teachers, reporters, international officials and the general public take the probe's words very seriously. In order to achieve this, it will be necessary to verify that the probe's origins are truly extraterrestrial; otherwise most people will not pay much attention to the probe's words because each year many messages in our society claim to be of extraterrestrial origin. At this early stage, therefore, both the probe and the researcher share the responsibility for choosing the most convincing possible evidence of authenticity.

Security is also important so that a successful dialogue between the probe and humankind can continue for many years. Consequently, it is important to discuss how to maintain the safety and integrity of later communications. The probe should be asked whether it is able to thwart all possible attempts to undermine or sabotage these communications and whether it is able to protect itself against all possible forms of human attack. If the answer to either question is no, then appropriate security arrangements must be negotiated to protect the communications, the probe and the researcher.

8.3 Confirming or Disconfirming Authenticity

The purpose of this third stage is to confirm whether the intelligence responsible for the messages is truly of extraterrestrial origin. Are the messages actually coming from an interstellar probe that has reached our planet, or from some other source?

Responsibility for this third stage: this lies with a team chosen by the researcher in consultation with the research project's advisory panel, and perhaps also in consultation with an established skeptical or scientific organization or a major university. The complexity and formality of the process used to establish the team will depend on the nature of the proposed evidence, as will the scale of the confirmation process itself. If two or three quite different types of evidence are proposed, then two or three teams might be established simultaneously.

The team members should be experts in the fields that are required by the data. This principle is extremely important since the team's expertise must be credible. Team members should be chosen only for their expertise. Political and other criteria should not be considered except that the members must come from at least three or four countries. The SETI researcher will be a full-fledged member of the team, but will not chair it nor vote.

The expertise required by the team will depend on the types of evidence that the probe provides. Until that stage is completed, it is not possible to know what types of expertise are required and who should be appointed to the team. In addition to particular fields of expertise, the team might also include one or two general disconfirmation experts, such as an established skeptic or debunker, a magician, or a computer hacker. Again, the particular choices will depend on the nature of the evidence. The team might also include a non-voting observer to monitor and critique the team's research procedures, and to report independently at the end of the process.

The team's behaviour should be respectful rather than hostile or unfriendly. Especially if the data are highly unusual in some way, the team should examine the data creatively, flexibly and with an open mind.

At the same time, the team must be extremely careful, cautious and skeptical. They must operate within generally acceptable scientific principles and procedures. The team should confirm authenticity only if the data leave virtually no doubt that the probe is of extraterrestrial origin. If in doubt, the team should respectfully request further data from the probe or should announce disconfirmation.

Before a candidate message is confirmed, the researcher and the confirmation team should try to avoid media attention concerning the candidate message. The confirmation team may decide that it requires a total news blackout on its procedures and interim results in order to conduct their work successfully. If any media attention does develop, the researcher and the confirmation team should state that a scientific effort to confirm or disconfirm authenticity is in progress, should emphasize the importance of assuming at this stage that the message is not authentic and should try to keep media attention to a minimum. Any significant announcement or press release should be sent to the most relevant scientific organizations or posted on the World Wide Web within seven days of its release to the media.

All potentially relevant data from this third stage should be carefully preserved and archived to the greatest extent feasible and practicable. After confirmation, the data should be made accessible to relevant researchers around the world.

8.4 A Worldwide Dialogue

Once authenticity has clearly been confirmed, the purpose of this fourth stage is a dialogue between humankind and the probe. This dialogue should reflect a careful concern for the broad interests and well-being of humanity.

Ideally this dialogue should be a two-way conversation between two partners, but it may turn out to be quite one-sided, in either direction, if that is the probe's preference.

In order to promote the well-being of humanity, the contents of the entire dialogue should be made accessible around the world to the greatest extent feasible and practicable. Dissemination must not be restricted to just a few nations or special groups. State authority may be necessary to provide security but should not exercise any sort of control or censorship over the dialogue. Care should be taken to ensure that the entire dialogue is preserved for the benefit of future generations.

Various media should be used to disseminate knowledge and ideas from the probe and to collect questions and other responses from a wide range of people. These media might include television, radio, the World Wide Web, file transfer protocol, newspapers, magazines, books, scientific meetings, academic research journals, textbooks, and courses for students and adults. With the possible exception of views that promote violence or oppression or intolerance, no human views or ideologies should be excluded from the dialogue.

Responsibility for this stage: would lie with a small flexible committee of appropriate experts to oversee the dialogue and encourage participation around the world. The committee should not be larger than 20 members and, ideally, be even smaller. The expertise of the members should be in fields that are relevant to the process of this dialogue, such as education, adult learning, journalism, television, and the World Wide Web. The members of this committee should be chosen only for their competence in supervising the dialogue. Political and other criteria should not be considered except that the members must come from at least five nations. Although the committee will operate independently from all other organizations, it may form alliances or agreements with particular organizations if that will enhance the success of the dialogue. Eight months after the committee is appointed, its work and composition might be reviewed, along with the most productive institutional arrangements for its continuing work, if such a review would likely be highly beneficial to the dialogue.

The selection of this committee should be completed less than seven days after the announcement of the probe's authenticity. If Unesco, the IAA SETI Committee, IAU Commission 51, the United Nations secretariat, the United Nations University, the UNU Millennium Project, or a global news organization meets both of the following criteria, that organization should within seven days choose the committee members in cooperation with the SETI researcher and the research project's advisory panel.

Criterion #1: the organization has already studied the situation and has prepared itself to choose a competent committee within seven days of confirmation. Ideally the organization has already cooperated with the researcher and advisory panel in developing a draft list of members, and has already approached several potential members, thus ensuring successful completion of the selection process within seven days.

Criterion #2: the organization guarantees that it will immediately provide, or immediately obtain from other sources, a level of no-strings funding and resources that will enable the committee to function rapidly and effectively for the next 12 months.

If more than one organization meets both criteria, the organization that meets them best should proceed with the task. If none of the seven listed organizations meet both criteria, the committee will be chosen by the researcher in consultation with the research project's advisory panel.

A few major universities might be invited to establish centers to study the new extraterrestrial knowledge. Such centers would be designed to play a key role in understanding the implications of the extraterrestrial messages for our physical sciences, social sciences, philosophy, and other fields within those universities. Additional questions for the probe might arise from their work.

8.5 Two Important Notes About These Procedures

(1) Because the characteristics of extraterrestrial intelligence are totally unknown to us at this stage, we cannot be certain that these procedures and guidelines will fit the actual situation that emerges. In particular, it may turn out that we do not have nearly as much responsibility and choice as these procedures suggest. An extremely smart and knowledgeable probe may have its own ideas about how to prove its authenticity and how to move toward a dialogue with us.

(2) These procedures focus on achieving an educative and scientific dialogue. Additional goals are also possible, of course, that go far beyond the scope of these procedures. Depending on the situation, humankind may want to establish a diplomatic, political, commercial, or other cooperative relationship with the probe or with its home civilization. For such purposes, presumably the United Nations and other appropriate worldwide organizations will assume leadership and responsibility on behalf of humankind.

9. CONCLUDING REMARKS

Recent progress in computers, robotics, nanotechnology and space exploration indicates that humanity will be able to launch small smart interstellar probes within 200 years, perhaps much sooner. Other civilizations that are even more advanced have probably already sent such probes to explore parts of the galaxy. At least one of these probes may already have reached our solar system.

If we detect a nearby probe someday, how well do the two international SETI declarations of principles fit this situation, since they were primarily designed to apply to a radio signal from many light-years away? A detailed examination of the two documents indicates that two of the basic principles fit very well but a third principle ("Don't communicate except through the United Nations") fits very poorly.

Consequently, to enhance clarity and to avoid any future confusion, it is important for the parties to both declarations to make the following explicit statements:

(a) both declarations apply only to the detection of a signal that originates many light-years from Earth;

(b) neither declaration should be applied to any other situation, such as the detection of a nearby probe.

Both of these explicit statements should also be incorporated into the declarations themselves as soon as possible.

An entirely separate set of procedures, such as the draft presented here, should be developed for use if a small smart interstellar probe is detected near our planet. Thoughtful procedures will maximize humanity's long-term benefits from this extraordinary opportunity.

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