Interstellar Probes[1]

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Introduction

Much of the stimulating discussion of interstellar communication assumes the use of radio waves for communication. The arguments in favor of the use of radio waves are sound except in a certain case where interstellar probes merit consideration. In this contribution to the discussion of inter-stellar communication, the case for the use of probes will receive emphasis.

After contact has been made with another civilization, radio is in all cases suitable, and probably optimal, for communication, unless the physics of the future circumvents the serious time delays suffered by electromagnetic waves.

In the precontact phase it is better to consider the situation as a function of d, the distance to the nearest superior community. If d is small, search by radio will in time succeed. At a certain larger value of d, radio search has serious handicaps, and wider attention should be given to the discussion of probes. If d is larger still, further considerations enter as will be seen below, and finally if the nearest superior community is extragalactic, the situation changes again. Table 7.1 summarizes the distinction between the various cases and incorporates values of d characteristic of each case.

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1 The material of this chapter is based on a talk I gave at Green Bank in March 1960 after reading Cocconi and Morrison's stimulating paper in *Nature* 184 (1959), 844, and papers by Su-Shu Huang. Further details connected with the idea of dividing the problem into cases in accordance with the distance to the nearest neighbor, with the consequence that longevity is connected with distance and with the use of a probe will be found in *Nature* 186 (1960), 670 and also in A. G. W. Cameron, *Interstellar Communication.* Benjamin, New York, 1963, p. 232 and 243.

Table 7.1

	I	II	III	IV
d, light-years	10	100	1,000	Extragalactic
Search	Radio	Probe	?	Radio
Communicate	Radio	Radio	?	One way only

The term *superior community* is a key one in this discussion and we must first understand what is meant by it. By superior is not implied any moral or ethical superiority. A community is superior when it is able to communicate by radio waves, fire rockets into the upper atmosphere and into surrounding space, let off atom bombs, and in general do all the technical things we can do and have been able to do for some time. It might be argued that it is conceivable that a civilization has radio communication but does not know about nuclear reactions. It is conceivable but not likely. Perhaps a civilization has radio and is unable to launch rockets, as indeed was our situation for some 50 yr. or more. However, note that the time interval is quite brief, and we can assume that a community, as it learns about physics, passes through the abilities mentioned in fairly rapid sequence. It might take them 100 yr. or even a little longer. It is possible that a community might live on a very heavy planet where gravity is so strong that it is very difficult indeed to launch a rocket. Or there may be a planet where all the uranium has sunk out of easy reach; perhaps it was covered by lava that was not rich in heavy elements and therefore it is probable that nuclear fission will elude them for a long time. However, we shall assume that, apart from some fuzziness due to time, everyone knows whether a community is ahead of ours or not, and we can call that a superior community. It can further be argued that there may be communities that are superior to ours that are not interested in launching rockets. It is true that there might be a planet somewhere which is inhabited by very wise men who sit there and think and are very knowledgeable but are quite clear in their minds that they do not wish to communicate with anyone else. This situation is quite possible, and they may know a lot more physics than we do. They may know how to set off atom bombs but may not in fact have done it. Or, they may know the full theory of satellites, just as Newton did, but have decided not to build one. Well, if such a community exists and there is no reason why one should not exist, then they are not the ones with whom we will be dealing. So we can exclude them. They are not among the communities that we are discussing, although they may very well exist.

Case I, Abundant Life

In this discussion we shall split the whole range of possibilities of communicating with other superior communities in the galaxy into three cases. First we shall deal with what we can call the Ozma case. Project Ozma, as you will recall, consisted of turning a radio telescope on two relatively nearby stars Tau Ceti and Epsilon Eridani, which are 10 or 11 light-years away. After a short period of listening with no meaningful message having been received, the project was terminated. No one has repeated the project or suggested a better one. It seems that it is a good thing to do if the nearest stars that we think are likely to be inhabited are in fact inhabited. By a habitable star we mean one which has a zone around it in which the temperature is moderate: it is not boiling, which would sterilize life, and it is not frozen, which would slow life down considerably. In addition to these considerations, stable circular planetary orbits must be possible. Circular planetary orbits would not be possible, for example, around a double star, where a planet could not travel in a circle but would travel in a more complicated orbit depriving it of the billions of years of stable conditions that are probably necessary for life to evolve. So if we eliminate double stars, and stars that are too cool (meaning that the habitable zone for the planet would have to be so close to the star that its thickness would be so small that the probability of there being a planet there would be small), and stars that are too hot (it seems likely that the very hot stars don't have planets), we are left with stars that we can call "likely stars." The fraction of stars that cannot positively be eliminated as above is about 10 percent in the neighborhood of the sun. Of the likely stars, only a fraction will in fact have life, and an even smaller fraction will have a superior community, which has developed from that life.

As we move out from the sun, Epsilon Eridani is the tenth star we meet, but it is the first likely star, since other nearer well-known stars such as Sirius and Proxima Centauri were rejected on various grounds. If the first star we get to that seems to us to be not completely ruled out proves to possess a superior community, would not that be very surprising indeed? Would it mean that every likely star has a superior community? It certainly would imply, barring a fantastic coincidence, that the universe was heavily populated with superior communities, not only heavily populated with life, but with communities that were able to send us radio communication that Project Ozma might have picked up. Thus we can conclude Project Ozma is a worthy but extraordinarily optimistic project to engage in. Project Ozma is the correct experiment to perform if the universe is really crawling with life.

The Basic Graph

From the known star density as a function of position in the galaxy one can work out the number of stars within a sphere of given radius centered on the earth. At first this number increases as the cube of the radius. When the sphere bursts through the top and bottom of the galactic disk, the rate of increase of volume occupied by stars slackens off, but on the other hand, the increasing density of stars towards the galactic center compensates. Finally, at a radius of about 100,000 light-years, all the 10^{11}stars of the galaxy are enclosed in the sphere. The number N_L of likely stars within a given radius rises from I at a radius of 10 light-years to 10^{10} at 100,000 light-years. This quantity is shown in Fig. 7.1. The curve can't be claimed to be very accurate, but it can hardly be very wrong either. It is well within a factor of ten and maybe a factor of three.

To survey the situation as a function of the density of life, we now construct the graph of Fig. 7.2, in which the quantity d, the distance to the nearest superior community, is our indicator of the range of possible situations. If Project Ozma had succeeded, we would have d = 10, and life would be abundant. if d = 100,000 light-years (which is about the diameter of the galaxy), it means that superior communities in our galaxy are vanishingly rare. We will discuss d = 100 and d = 1,000 in turn, after first establishing some quantitative facts.

Let N_c be the number of superior communities in the galaxy. Although we do not know this number, a moment's thought will reveal that we can draw a graph of N_c versus d because each in its way is connected with the density of superior communities and, therefore, there must be a relation between them, which is shown in Fig. 7.2. Of course, the relation is statistical: perhaps N_c = 1 and d = 12.

Figure 7.1 The number of likely stars N_L within a sphere of radius R.
[NOT SHOWN]

Figure 7.2 The total number of superior communities in the galaxy *Nc* and the average lifetime *A*, as they depend on the distance d to the nearest superior community.
[NOT SHOWN]

Accidents of clustering must certainly occur, and will have important impacts on the chances of contact, helping where there is crowding, and hindering where there is not. The graph in Fig. 7.2 is based on the expected distance to the nearest neighbor when the stars are uniformly, but randomly, distributed in space, but it has to be admitted that galactic structure superimposes features that have not been taken into account. Such uncertainties in d seem unimportant compared with the uncertainty in Nc which, for all we know now, can have any value from 0 to 10^{10} So it seems that the graph in Fig. 7.2, rough though it may be, can command your assent.

As a numerical example, let us examine the case where the number of superior communities $N_c = 10^7$, and clearly this means that out of 10^{10} likely stars, the frequency of occurrence, p, of superior communities is only one in a thousand ($p = 10^{-3}$). Reading off from Fig. 7.2 we see that d = 100 light-years. As a check, let us refer to Fig. 7.1, where it is seen that for the number of likely stars within a radius of 100 light-years we have N_L = 1,000. As a second example, we find that when d = 1,000 light-years, $N_c = 10^4$, $N_c = 10^6$, and $p = 10^{-6}$

Case II, Less Abundance

If one in a thousand of the likely stars is the home of a superior community, presumably very many more are the site' of life of some kind. Therefore, even this case represents rather common existence of life, and the corresponding distance to the nearest superior community, as read off from Fig. 7.2, namely d = 100 light-years, may be felt to be an underestimate. However, as we are examining a number of representative cases in turn, let us consider how to go about making contact when we have to face the likelihood that only one of the thousand nearest likely stars has a superior community.

It is often supposed that the more advanced community will take the initiative and can be counted on to be beaming a powerful radio signal in our direction. Even so, and even if we were listening, there is only one chance in a thousand that we would be listening in their direction.

In the case of the two stars mentioned previously, we knew where to point our telescopes, but now when we go through the full list, we find about 1,000 stars that we could choose from. The problem becomes more complex when we go to the transmitting end to transmit to this other community which is trying to communicate with us, because they also have 1,000 choices of where to point their telescopes, not the same ones, but they are also surrounded by 1,000 possible stars which to them seem not eliminated as possible habitats for life. They cannot tell by telescopic inspection whether the earth is inhabited-they have to make a guess. They really will not know the micro circumstances. For instance, if they had been looking at the earth with the best telescope they had a couple of thousand years ago, it would have looked essentially the same then as it does now, as seen from that distance. And yet, it wouldn't have been worth their while sending radio waves, in fact, even 100 years ago, because there was no one here who could pick up radio. Mind you, there is always the chance that radio is not the final answer and that we still have not qualified scientifically for entering the galactic communications network because we still have not discovered the next thing that waits downstream for us in physics, and it may be that everything in interplanetary communication hinges on this next discovery. We may be a little overconfident in thinking that we now have the necessary tools, as we do not know what the future holds for us in physics.

Thus we are faced with a situation in which they have 1,000 choices to make, and we have 1,000 choices to make so there is only a one in a million chance that we will be listening to them while they are transmitting at us. Now that is pretty tricky. Professor Morrison has an interesting calculation on how they would apportion their time. He says that they might transmit for a whole day in the direction of the earth and then for a whole day in the direction of one of the other choices and so on and so on and so on, and after some years, they would come back and give us another whole day. Now you see what a fragile plan this is. He credits them with enough wisdom that, having transmitted to us for a whole day, when a time had elapsed equal to the time taken for the message to go to the earth and come back, they would turn their big ear back on us and listen to our reply. But suppose that we are a little slow in decoding the message and do not reply immediately, but hold out for a day or two; they might have hung up by the time our message gets back, and if our reply has to take 100 yr. to get there, and they just happened to have put the receiver down at the moment our reply came in, it would be very disappointing, but to be expected of such a risky technique for making contact.

In addition to the one in a million factor, which is geometrical, there is the problem that we do not know how to choose which wavelength to listen to. An excellent suggestion was that we should use the 21-cm line because in the general range of wavelengths which seems suitable for interplanetary communication, it is the one wavelength which stands out as being chosen by nature to do its own broadcasting; hydrogen atoms which are a most frequent constituent of the universe give out faint radiation on that wavelength. So they know very well that if we have any scientists here, we know that wavelength and will be tuned in on it. But scientists are not certain that they will use it. Some say twice or half that frequency would be better, so if we were listening on twice the right wavelength, we would miss contact, even though we were doing approximately the right thing. You can also see that there are risks arising from the rotation of the earth; they might spend 12 hr transmitting to us when we are on the other side of the earth. Furthermore, it will have occurred to everyone that this requires political stability for a period of 200 yr.; it means that once we have raised the money to do the job, we have to have the same kind of funding carried on for about 200 yr. Now we have not had science funding for very long and we have not had a project with dependable funding for a whole generation, so it is hard to see how we can plan for more than a whole generation. Thus we are confronted with very serious difficulties.

Part of our problem in thinking about this is that we tend to think of communication like a telephone conversation, I say a few words to you, and you say a few words to me, and there is an interchange. But interstellar communication will not be of that kind, quite clearly. There will never be a conversation of that character between two inhabited planets. You will be able to say, “Hello, how are you?”, but 200 yr. from now it will be a descendant of his, many times removed, who says, “I'm fine, who are you, he was fine.” Thus the communication that we are discussing is of an entirely different nature. It is an interaction between two cultures. Two cultures will be able to influence one another, but individuals will never be able to interact. The cultures can interact in a very real way in the sense that we could suddenly find ourselves in possession of the next 100-yr worth of physics and chemistry. That would have a real effect on our community-to suddenly be presented with the discoveries that we would expect to spend the century making. That would be remarkable. It would no doubt have a very strong impact on biology and medicine. If the people in 1870 had suddenly been presented with the next 100 yr. of physics and chemistry, it would have made a very great difference to things as they actually developed. So communication, once started, will be on a time scale that is slow by individual standards, but it will nevertheless be very real.

In the preceding discussion we have tried to make the point that if 100 light-years is the distance to the next inhabited community, trying to reach them by radio will present extraordinary difficulties and may be doomed to failure. So we must apply our minds to a procedure that would contain the key element needed to set up communications.

Let us suppose that you sit down to teach someone you do not know to play chess. You could read him the full rulebook, without his saying a word, and at the end he might in principle be able to play. But we do not do it that way. You explain that the rook travels in straight lines, and he questions the direction in which the rook may move. You answer that question, and now he knows how the rook moves, but until you have that little bit of feedback, and there have been a certain number of round-trip loops, he really does not know for certain. You will make a few oversights or omissions that need verification, so there will be a certain number of round trips. You will not be able to do it in one. To start with, if you have never met him before, there will have to be at least one interchange while you decide whether he speaks English or French. And the interstellar case is one where you have not met the people before. So a certain number of conventions have to be established, which require loops. In ordinary conversation we have so many of these feedback loops that we just lose count of them. We throw them in in great redundancy. But if each one took 200 yr., that would make the picture entirely different. It seems that such feedback is extremely effective and in order to have it, we just have to reduce the loop time. Thus we arrive by that line of reasoning at the conclusion that in order to set up the conventions, to set up our wavelengths, to set up a time schedule for transmissions so that the sun or the earth does not get in the way, to agree on a code (this will not be trivial-how are we going to discuss how to discuss what language we will use?) will require these round trips, and they must be reduced to essentially zero time so that a large number of them can come well within the lifetime of one individual who can handle the whole thing. All those round trips must take place with political stability and also within the stability or permanence of a single individual.

The way to set up the conventions is to have a probe which would be launched from the one planet into the vicinity of the other planet. When that probe arrives, we have the possibility of communicating with it on a rapid give-and-take basis, and we can set up all the conventions needed so that the discovery or contact phase is handled in that manner. Then, when we have set up all the arrangements, we can go right ahead and communicate back to home base with a prearranged system. That of course will take us 100 yr-there is no way to avoid that. Nevertheless, a stream of information will then begin. We will start streaming information towards them, and since we are going to have to wait 200 yr. for a reply, our initial statement had better be a very long profound statement, something taking about 100 yr. to say. Now that statement will consist of essentially our whole culture. We can transmit the whole of the *Encyclopaedia Britannica, Webster's Complete Dictionary* with illustrations, and all our music. Our art might prove baffling to them, but they would probably be interested in it, and we would have to microfilm the contents of all our museums. In fact, it would be difficult to find something that would take 100 yr. for us to say, unless we sent them telephone directories of all cities, and threw in old sports results for good measure. Then we would get something back from them, and what would happen then is another story.

That is the proposition. When their probe gets here, there are various conceivable possibilities, but this author feels that there has to be a probe. The probe could simply be one aimed at detecting whether there was life here. It could arrive here, look around, see signs of life, and then radio back to the home base that this was the place to shoot for. If that is the situation, then that message could already be on the way back. The probe could have arrived, it could have been circling around in our solar system, heard our first radio communication, and sent word back. So the message could be on its way back now. The difficulty with sending such a probe is that most of the planets that such a probe visited would not be inhabited. Therefore their probe would probably be equipped for exploration not exclusively concerned with the finding of life. It might count the planets, measure their general parameters, size and shape, and do all sorts of space science and report back those basic statistics. That would be of some interest-it would be an extra entry in their catalog. But even that is fairly dry, so they will probably include a beacon for the purpose of attracting our attention. It would be a shame if it had been here, sent back word, and was now lying dead out there near Jupiter somewhere to be photographed by the Pioneer spacecraft, with its lifeless antennas all sticking out. It is not likely that they would do that. They will send one here that will attract our attention, and when it has attracted our attention, then it will talk to us. So there are at least three phases in this whole procedure. It has to attract our attention, convey the identity of its home base, and set up codes and schedules for communicating with the parent star.

This phase completely circumvents the risk that we are not listening on the day they have allocated to us, since the probe will remain in action once it arrives here. The part of the budget of their Space Administration devoted to interstellar contact is spent not on power for hit or miss transmissions but on launching one probe at a time at a rate in accordance with the ruling economic and political conditions. As each probe reaches its destination, it fires its one remaining rocket and goes into orbit around the sun at the distance where the temperature is right, deriving its power from then on from the sun. It could of course carry its own nuclear fuel, but since it might have to remain on the alert for thousands of years, it would be wiser to make use of solar energy. That might seem like a long time to wait patiently, but the same patience would be required if radio transmissions were beamed directly from the distant base. There is a big difference, however, between the ongoing running costs in that case and the one-shot expenditure in the case of the probe.

On arrival, the probe will turn on its radio receiver and listen for manifestations of intelligent life. The presence of radio signals will inform it beyond doubt that communicating entities are about. No doubt it is feasible to design an elaborate probe that can locate and descend to a planetary surface, but that would not represent an optimum search strategy. On the contrary, the more modest the probe the more planetary systems can be explored. The rather simple orbiting radio receiver is an effective means of inducing those communities that have reached the point of communicating, to report in.

How they might attract our attention requires some thought. The idea of powerful bursts of radio or optical emission, perhaps separated by intervals to allow even larger peak power, suggests itself, but some precautions are needed to guarantee against failure on our part. Even the emission of a very strange program would not necessarily attract our attention when you consider the psychology of people tuning radios.

The following is a proposal for a radio transmission that automatically guarantees that the frequency is in use on the earth, that ionospheric or other effects will not prevent its reaching the earth, and that when the signal reaches the earth there will be a receiver tuned to that frequency at the time. The plan is simple, it requires little power, and it is free from problems connected with the ionosphere, local interference, and time schedules. You might be sitting, turning the dial of your receiver, looking for some particular program, but you wouldn't stop to listen to things that you are not interested in. Perhaps you are trying to pick up the news from Moscow, and you get this faint rumbling sound which is the first message to man from interstellar space; you listen to it carefully and as soon as you can distinguish that it's not what you want, you just tune away from it. Yet it could be the most conspicuous thing. It could be a voice saying, “I am the man from outer space,” and you would immediately tune away from it, because it's not what you want. To assure that its transmission would be noticed, the probe would listen to what it could hear, and whenever it hears a broadcast, it transmits on exactly that wavelength. This automatically guarantees that someone is listening, because no one transmits if nobody is listening. It knows there is a receiver tuned to that wavelength, so it gives out on that wavelength. What should it give out? If it gives out something that you don't want, this may just turn you off, you will go away. We propose that it would transmit back what it heard;

thus if there was speech coming out it would transmit the speech back. We would hear the program that we wished to hear, followed by an echo, with a time delay corresponding to the time taken for the signal to go out to the probe and back, which would be of the order of minutes. Now that's something that would be very conspicuous indeed. We know that this is so because on the rare occasions when people do hear long-delay echoes, they always notice them. The people who listen to long-distance radio are very familiar with the echo produced by passage of a radio wave completely around the earth which takes 1/7 sec, and they get used to that time delay which is quite recognizable as such. But when you hear the announcer say, “Well, that's the end of the news, goodnight,” and then 5 min later, just as you are about to get up and switch the receiver off, a voice repeats, “That's the end of the news, goodnight,” you will certainly notice it. That is why it seems that it would be a good strategy for them to do that very simple thing--just install a receiver, an amplifier, and a transmitter.

How would we tell it that we have heard it? Until we do that, we will not hear the message that it contains. There would be no point in its spilling its program as soon as it arrived here; first it has to attract our attention, and then we have to let it know that we have heard it before it will come out with the good news that it has.

It seems that we can build up a complete system of communication on the very simple idea of repetition that has already been introduced. All we would need to do after the first excitement of noticing that the echoes were reproducible, would be to set ourselves up with nothing more than facilities for repeating back to it. How conspicuous to it that would be! In the early twentieth century it would have begun to notice our radio emission, and after years of listening to our programs and playing them back endlessly, all of a sudden one day, it would get played back at itself. It would be preprogrammed to notice that, and it would immediately deduce the time delay, and hence how far away we were, and it would know that it was in communication with us. To verify this, it would repeat back to us again, and we would again repeat back.

This procedure is similar to the one used by the Count of Monte Cristo. You remember he was imprisoned in the Chateau d'If which had extremely thick walls, and the next dungeon was thirty feet of stone away, but he got into communication with the prisoner there by tapping on the stone. The first time he tapped, the man on the other side heard it but did not do anything, but after days of hearing these taps it occurred to the other prisoner to tap back, so he tapped back. Now that tells the first man that the second man has heard him, but it does not tell the second man that the first man has heard the reply. What is the solution? When you get that exciting first return, then the next thing to do is set up a code so you send out two taps, and then when two taps come back, you and he both know that you are communicating. Now you are on the way to building up a higher form of communication by somehow agreeing on a Morse-type code. But how do you teach the man on the other side of the wall Morse code when neither you nor he knows Morse code, though you know that such a code exists.

The problem is quite fascinating and could be the basis of a game in which you exchange notes with a friend on the understanding that you would use no known code and that communication was to be established starting from absolutely nothing. It would be quite challenging.

There would be some essential preliminaries in the dungeon problem such as determining when the other prisoner sleeps or is otherwise preoccupied, and clearly the acknowledging tap permits this. If one had to tap out signals in Morse without knowing whether anyone was listening, the chances of being understood would be hopeless. The closed loop makes the essential difference.

Similar preliminary essentials confront the probe. Soon after the first contact, it is likely to set below the discoverer's horizon, and then to our great disappointment we will realize that it is no longer there. It is very important for the probe to discover at a very early stage precisely what schedule we plan to keep. It can do this by monotonously going through repetitions in order to avoid loss of part of its message. It can determine the sensitivity of our equipment by turning its volume down, and as it turns its volume down, it gets to the point where we no longer respond. Then it brings the volume back up until we do respond. It can also tell the band over which we can tune. Since we are moving relative to it, it knows we can tune our receiver to compensate for Doppler shift, so it deliberately goes off frequency a bit, and then of course we discover what it is doing and repeat back, and it goes a little farther, and this way it will discover that when it gets down to the penetration frequency of the ionosphere, we give up because we can not get through. Then it can explore in the other direction and find that the oxygen and water vapor cut us off at another wavelength. It would like to know the information rate that we can accept, because if we are not capable of recording very rapidly, there is no point in its playing its message too fast. It can find out all these things and many other details just on the basis of knocking on the wall and listening for returns. Quite a sophisticated picture of our capacity for communication can be built up by this simple preprogrammable technique.

Preliminaries of the simple kind mentioned above may determine whether the whole project succeeds or fails. To give an idea of the contingencies for which the probe must be prepared, just imagine a planet where afternoon thunderstorms during the summer are of such intensity that all radio communication is overwhelmed by static. Or suppose that ionospheric storms causing radio blackouts come with greater frequency than on the earth and that the solar rotation period of 27 days and the solar cycle of 11 yr., which dominate such things, were different. Outbursts of solar radio noise are not an embarrassment to radio communication on earth but might well be in another planetary system. Thus before launching its message, the probe must satisfy itself of many preliminaries to avoid sowing its seed fruitlessly.

Methods for deciphering messages arriving direct by radio from alien planets. have been discussed by others, and it is generally considered to be feasible, so we need not dwell upon the matter other than to remark that the situation is improved when the possibility of feedback is present. Without feedback, massive redundancy is required to guard against un-foreseeable losses of unknown duration with a consequent heavy penalty on the chances of success in making a successful transfer.

Case III, The Nearest is Remote

Despite the difficulty of doing what has already been proposed, nevertheless let us now suppose that it is 1,000 light-years to the nearest superior community. In this case we can do a further calculation which is really quite fascinating. Table 7.2 summarizes some earlier calculations for reference and includes similar results for d = 1,000 light-years where we see that the number of superior communities in the galaxy $N_c = 10^4$, and their frequency of occurrence among likely stars is given by $p = 10^{-6}$. If among 1 million likely stars, only one has a superior community, then under a condition that we may refer to as secular equilibrium, the average

Table 7.2

d, light-years	N_L	N_c	p	Δ, yr.
100	10^3	10^7	10^{-3}	5×10^6
1,000	10^6	10^4	10^{-6}	5×10^3
2,000	10^7	10^3	10^{-7}	500

duration Δ of a superior community will be p times the time taken for a likely star to produce a superior community. Adopting 5×10^9 yr. for the latter, we find that Δ = 5,000 years. It may seem surprising at first sight that given the distance to the nearest superior community, one can then estimate how long it has before collapsing, even if only on some average basis. But suppose that the duration of a superior community is 5×10^6 yr., that is, 10^{-3} of the preceding evolutionary development. Then it is very hard to see why the frequency of occurrence of superior communities should not be one in a thousand, with the consequence that the nearest neighbor, on the average, could not be as far away as 1,000 light-years.

This type of calculation requires elaboration to take into account the changing parameters as the beginning of the universe recedes into time. Perhaps there are existing relics of a chain of galactic communication that was established long ago when distances were smaller. But there has been ample time for the birth and death of stars and their civilizations, if any, as witnessed by the fact that our own sun is a second- or third-generation star condensed from chemical elements that themselves were brewed in earlier stars, long since exploded. Consequently, the statistical calculation of duration, though crude, has to be faced.

If d = 2,000 light-years and Δ = 500 yr., it appears that Case III confronts us with a situation where the longevity of civilizations is not sufficient to permit both of the participating civilizations to know that contact has been made.

We should not despair entirely at this, because even a one-way flow of information would be significant, both for the recipient of the alien culture and for the sender, whose interest would lie in the preservation of its tradition, though not of its population. Nevertheless, the technical feat of transfer is even more difficult to imagine.

Of course, there can be all kinds of departures from an average, so even if N_c is only 10^4, some of them may have solved the problem of how to survive longer than the average. They may have gained control of the circumstances that lead to short average lifetimes, and for all we know, by accident of proximity, some of them may be in communication with one another and have spread their secret. But it will not be easy for us to be inducted unless by a further accident.

Case IV, Extragalactic

If the nearest superior community is not in our galaxy at all, it is quite clear that we must point at the Andromeda Nebula and explore carefully for a radio signal. We know where to point, and they know where to point so the geometrical difficulty is eased. But how do we know there is no other superior community in our galaxy? We do not, but after a reasonable interval of looking for nearby life, we might as well try elsewhere. The message has to be one of extreme redundancy so that one can tune in at any time and still get something; it is a strictly unidirectional flow. Would it even be worth answering? Of course, if we first make contact within our own galaxy, we will get the answer to what, if anything, is streaming to us from Andromeda, as well as a partial story on the lines of communication that are already buzzing within our galaxy, so we should direct our efforts at local contact first.

Conclusion

We conclude that d = 10 implies improbably high density of life, d = 1,000 requires improbable durability, and that d = 100 is the case we have to face seriously, even though here also a remarkably high density of life of all types is implied.

Careful attention should be given to the method of contact by probe, but, because of the times and distances involved, we will have to be patient. Our contact, when it comes, will not be the first of its kind and therefore we will be brought into touch with a chain of communities already in communication with each other who know quite well how to go about doing it and who are not as impatient as we are. They know they only succeed every few centuries (?) in adding another link, and they are not in any hurry, whereas we, of course, wish it would happen sooner. They may have tried us 1,000 yr. ago with a probe that has now run down and be planning to try us again 1,000 yr. from now.

Even when contact comes, the flow of information may for a long time be unidirectional-one might say unidirectional both ways. We will receive the impact of the quantity of information that the probe brings with it, and long after that their home planet will begin to receive a stream of material from us, but it will be even longer before interaction reaches the point of our receiving answers to questions. Or perhaps this underestimates the capacity of a probe--surely biology teaches us that the capacity of a human individual can be contained in a space the size of a human head. Therefore, why should not a substantial reference library be compressible into a further small volume. Thus, when our probe comes, we can prepare for a major cultural impact which will be greater than if our first contact is by direct radio.

The Message

Bracewell has told us of some of the difficulties of establishing communication with extraterrestrial civilizations. In the following chapter, Frank Drake investigates some of these difficulties further, including our present technological capability of sending and receiving signals, and the problem of what that signal content should be like.

One of the problems raised by Drake is the problem of the message content of an interstellar cosmogram. Drake tells us that one of the highest information content types of messages would be a two-dimensional picture. The information content of such a picture is very high, only if we can utilize our own cultural and technical background to draw inferences from simple representations within the picture.

Drake is probably right that this is the best way for a message to begin. This is probably the best way to define symbols that will be used in one-dimensional language communication later on in the message. The repre-sentational technique of laying out a message with the number of meaningful cells being the product of two prime numbers could be generalized to the third dimension if this was desirable for some special purposes.

However, it must be remembered that the time interval required between sending a message and receiving an answer to specific information content within that message is probably many years, tens of years, or centuries. Most of the information content in the world literature lies not in two-dimensional representations of data, but rather in one-dimensional representations of data called words and sentences. Thus the type of picture technique described is probably a good teaching tool to demonstrate to us how to receive the remainder of a message, which may be centuries long in transmission, and which may have further pictures as illustrative material throughout. However, if the sender were not sure that his message was being received, he would have to repeat his tutorial material frequently throughout his message, if he wanted to make sure that someone coming “on line” in the middle would be able to understand it.