Means, method and implications of the search for intelligent life beyond our planet

Philip Morrison

It is about thirty years ago that we human beings acquired an absolutely brand new capability—an ability unknown in any previous stage of our civilization. I do not believe that it is true that in our generation we are any wiser or smarter or more able than the long predecessors of learned and civilized people who go back certainly many thousands of years, and perhaps not even than those keen hunters who spread about half a million years ago from the African rift over the entire world. But we have done something. We built upon what was done in the past and every once in a while something new happens which we must note because it places humanity in a different position with respect to the cosmos. What happened was that, without our quite realizing it, the development of science and technology reached such a state that for the very first time we could make a signal here on Earth that could be detected among the distant stars—we could signal to the stars if we tried. This was not possible before the year 1960 or so with existing material. No sound we can ever make can go across that space. No fire or light we can make, not the explosion of a hundred hydrogen bombs amounts to anything compared to the light of the Sun or even to the variations and fluctuations of the light of the Sun that happen suddenly when a solar flare occurs. So, looking from far away, nobody will see us by light, nobody can hear us by sound. We say we have great probes and we have wonderful space probes these days. The most distant space probe launched in 1971 has now reached the fringes of the solar system and is touching the orbit or the planet Pluto in that region. It will take a hundred thousand years before that probe comes closer to any other star than it is to the Sun—a very slow means of progression, in addition to which of course it is only a bottle in the three-dimensional ocean of space. So that method is also very difficult. But with the development of high power radio, we did have the means of communicating across the depth of space, and from that understanding I think we came to realize that we could do that.

We are not in fact doing that very systematically, we should not probably, but if we can do that, others in our position might do as well. Indeed, I shall argue, much better. I will simply put a simple question, and later on I will discuss more of its implications. The question is: In this vast universe are we alone as self-conscious beings, or have we counterparts, maybe strange, maybe familiar, somewhere else among the stars? I regard the question as of such manifest intrinsic interest that you do not have to justify it. (Those who do not feel that same way should by no means pursue this task.) The main point is that it is an extraordinary question to ask; seers and speculators have thought about it for many, many years but had no way to answer. I am not proposing that we have a sure way to answer, but we have a means.

In order to make this reasonable I would like to argue step by step, to begin by showing you the modern structure of the universe that we see in a very simple way. It is worthwhile to have it marshalled in front of you so you can see the force of the argument. When we made a TV programme on science I began by saying: 'I do not want to persuade you of the structure and order of the world by simply saying that I am persuaded, and that I have got a degree and I am a professor in a big university in Boston, and therefore you should believe me. That is not science. Any charlatan can say that (I must say that some do!). The way of science is to show you the same things that persuaded me, and if they do not persuade you, it is up to you to show whether I am wrong.' I am happy to learn. That is the method of science—not authority but evidence, evidence from experience, evidence from argument, evidence from mathematics, but all evidence. Not simply Bohr thought this, and Einstein thought this. I have nothing against them, these are great men, our teachers; we must study them but weigh their sayings. They told you why they believed something, and they demonstrated it line after line in their writings or in their experiments. That is the point of view towards science which in our day we often overlook, because there are such great results and we want to show the results. We do not carefully describe the basis of these results and the public accepts the figure of authority.

What specially makes me angry—up the wall, as they say in my country—is when somebody pulls out a printout from a computer and points at it with authority and says 'you see, that by itself demonstrates it'. It does no such thing. I never know how the

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computer can tell me the truth. I mean they do what they are told. Sometimes it is right, but more often it is wrong; the notion that the printout is all by itself evidence is ridiculous. Tell me what the program is, tell me what the assumptions are, tell me what the arguments are that the computer iterates. Sure, I understand it can do many wonderful things. But it does not do them by itself. Just because it's a printout does not make it right. When I was young, I learned very early that if you saw something in print, it was authoritative, you should pay attention to it. But it did not make it right. Indeed, now that I have written a few books, I know that not every sentence in my books is true, however hard I tried. That is a valuable lesson to learn. If you object to anything, I say splendid. You must think about it yourself, but you must be able to knock down some arguments. It is not necessary that I disagree with you. You have to say: 'If it is the way I think, then I can show you that this will happen. That is my task.'

I begin with the famous seven luminaries, well known in this country back to the time of *Rigveda*, and I am sure before that, but unwritten. Again, history is not all that good, because history depends upon written evidence. The archaeologist can go beyond history. I dare say even beyond the first artefacts we have there was human mind at work, only we just do not know about it. You only can know about that for which you have evidence. Everyone knows that all the luminaries, the Sun and the Moon, the planets and the stars, all rise and set daily. Nobody has to be told that about the Sun, few people have to be told that about the Moon, more people have to be told that about the stars. But the slightest attention to the sky will show you that. If you watch a bit, you will come to see that the star patterns remain fixed, they move together but the patterns never change, no matter where you go, no matter how long ago you studied the maps of those who mapped the sky a thousand years ago. They show sensibly the same patterns: the constellations are unchanging—that is why you call them the fixed stars.

They are not fixed in the ordinary sense. They rise and set like everything else in the sky. But they are fixed in the sense that they remain recognizably in the same arrangement, very striking because of course the Moon does not do that. The Moon moves across the starry sky in a cycle of about a month. You will see that the Moon has a different star background day after day, and in a whole month we more or less come back to the same place. That is speaking only roughly. The details I leave to the astronomers, but the rough fact everyone can notice and think about. The Sun each day of course rises and sets like everything else. But in a year it goes right around the sky, from high to low and high again, and we all know that it changes the seasons, the yearly seasonal change of weather. That is surely strongly correlated with the angle of the Sun. What is the evidence that the Sun is against different star patterns? (It is, though not what the astrologers tell you in the papers.) It is not easy to see the star pattern among which the Sun stands, for when the Sun is out you cannot see the stars. That was the first hurdle for the professional astronomer three thousand years ago: to figure out where the Sun was among the stars, without being able to see the Sun and the stars together. What did they have to do? Of course they noticed very carefully the stars just before sunrise and again just after sunset, and they put two and two together and the pattern they saw was continuous. They could tell what sign the Sun had to be in by knowing the continuity of the heavens. You have to watch the sky for a long time to get all that straight. But they did it, and we can use that result.

Finally the planets: the Greeks called them wanderers. The planets have a motion of their own. They dance about, not so rapidly as the Moon, but some quicker and some slower. Indeed, that is a characteristic result of the simplest kind of geometry. If I move my hand in front of my face, it flicks by. If you move your hand, I can see it quite well. If I watch the telephone poles as I drive, they go by rapidly, but the houses move by more slowly. The mountains do not move at all: I can drive for hours and still see the mountains shining white in the distance, and the Moon follows you all night long. When you move, distant objects do not change their apparent direction very rapidly. Moreover, something which is farther than another thing can never occult it, cannot pass in front of it. When you hold up one hand in front of the other, the nearer one covers the other from sight. There is then no doubt about which hand is farther away. When the Sun passes in front of a star, when the Moon passes in front of a planet, we learn the order of distance, the basis of the fundamental nature of our simple cosmology. Thus we have this remarkable result, that we live in a system in which the Earth is one among a number of planets and they are scattered out in space and the Sun dominates this system—tremendously bright, tremendously hot, it gives life to earth and illuminates the entire solar system. That much has been known for a very long time. It requires not much instrumentation, just a little careful recording, and a little tradition to pass from one generation to the next what was going on. These things do not happen everyday but you have a memory, or you have an enduring school that you believe in and they tell you 'we saw this happen'. Finally, you can understand it.

In all cultures throughout the world, some features of this general cosmology are understood. Maybe in Delhi it is not so easy, but out in the countryside it surely is easy to see the famous little group of stars which we call the Pleiades. I think they are familiar to all those who know and watch the sky. In the constellation Taurus, there is this little group of stars. From time immemorial people who have seen it thought it was something to call attention to, because it is a little heap of stars. In Japanese, it's called 'the heap', a little heap of stars all together. The ancients knew that the people with the keenest eyes might count ten or a dozen stars, and old people could count only six or seven. There are lots of tales and legends about how they were once 12 and became 11 and so on, but all that is based on the fact that differences between viewers and conditions of the night sky determine how many are seen. For millions of years we saw the stars, and the keenest eyes could see in the Pleiades a few more stars than the others, but that was the end of our experience. And then, at the dawn of modern science, the development of instrumentation made it possible to see the same group of stars through a modern telescope. You still see the pattern of 5 or 6 quite bright ones, you still see half a dozen or 10 or 20 others that look almost as bright. But behind them, you see hundreds or even a couple of thousand faint stars. That is the enormity of the heavens, displayed by instrumentation and photography. I think it is nearly impossible to doubt, once you see a little bit of photography, a little bit of telescope for yourself, that there are stars that are not seen by the eyes but revealed only by the instrument. They are exactly continuous with the stars that we can see; there is no difference. It's only that our eyes are not good enough. Our artificial eye, the human-made eye of the telescope, brings us more information about the very same world in which we live. An old man is likely to see only 6 or 8 Pleiades stars; the same man when young could see 10 or 12. It's not that stars are taken away from old people, it's that eyesight is not as good.

Now Galileo did all this in six months' time in 1609 and 1610. Of course he did not end astronomy but he began it—I would say, with a bang. He showed many, many stars that nobody had ever seen before. Most importantly he showed the Moon in an absolutely new light, because he could see on it not just the patches of dark and light, about which the ancient philosophers had argued for a very long time. It was understandable that they were like nothing on Earth. But through the telescope he could see the shadows made by the mountain peaks, he could see that the Moon was mountainous desert, no different than the mountainous deserts on Earth. It was made of rock, it had mountains, it had shadows, it was no longer a half-darkened ball of mystery. It was a place like our own Earth. I believe that did more to make the Earth one of the planets than the simply geometrical point made by Copernicus that the motions could be understood by saying that the Earth too shares some motion around the Sun, more or less as the other planets do. But add to that the physical fact that looking closely at the Moon reveals that it is mountainous and you have something profound.

Looking closely at Jupiter, you saw first that it was not just like a bright star that didn't twinkle, but it had a disk. Indeed, the keenest eyes already had known that, but most people did not. But Galileo could see more. He could see that around that planet there danced four little stars that always accompanied the planet, round and round it in a regular pattern, and he said, 'There are the Moons of Jupiter, just as our Moon accompanies the Earth, and it is never very far away and never very faint.' We have the Moon at all times of the month. It is only lighted partially. The ancients knew for a long time that the new Moon was only dark but still there was a full circular disk, only it wasn't visible. If you are very clever and lucky, you can see the dark edge of the Moon, invisible to you, cross over a distant star or a planet and reveal itself. I have seen that from New Mexico, watching Jupiter being occulted by the dark edge of the Moon. It is quite a beautiful sight, which can be seen every few years.

I find it impossible to doubt. Of course a telescope could lie to you and in Galileo's time, the first telescope was much questioned, correctly, by the sceptics. They had been trying it out. They looked at the distant church and they could read the legend on the church. It was the same legend they could read by going up to the church and looking at it, maybe the name of the Pope who caused it to be built. Similarly, they could recognize the ship that was coming in. After a while they began to realize that they could trust this instrument, and that it was telling the truth.

The next step was then made very slowly, but within decades. All the astronomers of the day were sure, as only a few were sure when Galileo began, of a remarkable fact, which goes right against common sense. (Many speculative thinkers, specially of the British tradition, had guessed it long before they could demonstrate it, but they felt it was logically possible
it is often the case that the logical argument was in the hands of people who had no instrumentation but thought deeply about the continuity and order of things.) I can express this remarkable fact by one simple sentence: The stars are Suns and the Sun is a star. That's completely against common sense. The Sun is a hot burning disk which supports life. The stars, though fascinating and interesting, are little points of light, perhaps good for the navigator, but do not supply any heat or light that you can use in any important way. But the Sun is indeed our star.

But why do I say that the Sun is a star and the stars are Suns? Because, if it's true that the planets are like the Earth and influenced by the Sun and the whole geometry described is real, then it may well be true that to explain the stars we can simply say that the stars are distant Suns, and if they are far enough away, then they must appear so small and so faint that they can fit into the sky the way we see them. That was put forward by

Copernicus, and denied by Kepler, on a very sound basis. The great Kepler did not believe in Copernican arguments before the telescope. Only when he read Galileo's book did he change his mind. This is the fruit of the seventeenth century.

A little geometrical thinking will let you understand it. Kepler could figure out from the levels of brightness of the Sun and the stars (which he knew was a tremendous ratio, as he could calculate roughly from the available numbers) that the stars have to be very far compared to the Sun. We know that he was even underestimating how far they have to be—they are enormously far. It takes a spacecraft probably 15 years to cross the solar system but a hundred thousand years to get to another star. Kepler said, 'If the stars are far enough away to be as dim as they are, but are really like the Sun, that cannot be, because they look so large.' He guessed how big the stars were, as we all could, by looking with the eye. The stars, he said, were about as big as the smallest planets. But the image of a star in the eye is not a perfect image of the star; it depends upon the atmosphere and the eye. It does not depend only upon the nature of the star. The telescope could magnify the stars thirty-fold, yet the images of the stars were no longer in the telescope than looking directly with the eye. But the image of the planet was bigger by thirty-fold, and the distance of the nearest stars was bigger by thirty-fold. So Galileo said, 'The size of the star's image is not given by the star, but its distance and size by the twinkling and wavering of the atmosphere, and imperfections of the eye.' Which turned out to be true. Many tests demonstrated it. The stars are far away and after the telescope even Kepler believed it.

I have not told the whole story but I have given the rock-bottom evidence for why we believe these things. The astronomers confirmed the distance to the stars by saying, very crudely, that a star is like the Sun. Of course they aren't always right. Some stars are brighter than the Sun, some stars are fainter than the Sun. But making allowance for these things, the rough average is not very misleading. Approximation is the soul of the new science. Don't try to get the last word, try to get the first word: the first word is that the stars are Suns, that they are more or less as bright—some brighter, some fainter—and in a rough way, they are as far away, as they have to be in order to be as faint as they are compared to the Sun, if they are like the Sun. Of course, even if the stars are seen through the telescope, they are very faint and very far.

Let me describe the following remarkable result, which is easy to understand. It illuminates all that I am going to say in a bright light. I now carry you to 1980 instead of talking about 1680, as I am now. Suppose we imagine that we are removed from our happy place near the Sun to a distant place which bears the same relation to the closest star to the Sun as we are now on Earth with respect to the Sun itself. Now, by looking at all the stars that are bright enough and measuring their distances (the astronomers know how to do it with some degree of reliability now), we learn that the nearest star after the Sun is a star called Alpha Centauri. This is the brightest star in the constellation of Centaur, which is hardly seen from Delhi. It is deep in the southern sky, and could probably be seen from Cape Comorin on good days but not as far north as in Delhi. I have seen it only by travelling to South America. Alpha Centauri is the nearest star to the Sun. Let us suppose that we are orbiting around Alpha Centauri, the way we are here around the Sun. What would we see in the sky—what would the sky look like? This makes very clear the model that I am talking about. Well, you no longer see the Moon, you no longer see the Earth, Jupiter, or the planets, they are so faint that they can never be seen from the distance of the star. But all the stars are so far away that even moving to Alpha Centauri would not change the pattern of the fixed stars noticeably. Nothing would be different, barring technical measurements of great sensitivity, except for one thing. The constellation Cassiopeia, which looks like an M or a W, as can be seen on summer nights, low on the north, would be different. Another star would be the sixth star among the five stars of the M or W, about as bright as all the others. How could we have added another star, by just moving over to Alpha Centauri and looking at the night sky? All the constellations are directly recognizable. Conscientious stargazers will say, 'Yes, I see Taurus, I see Orion, I see the Dipper, I see Sagittarius, I see Capricorn, but one constellation that I see different, Cassiopeia, has another star in it.' What do you think that star is? The answer is clear but hard to think of. That star would be our Sun, because from Alpha Centauri, our star is projected against Cassiopeia, and our Sun is so far away from Alpha Centauri that it is no brighter than the stars in the constellation Cassiopeia. So you simply see another star in the constellation Cassiopeia just by translating to the nearest star. So that's really the nub of the situation. You can't see the Earth or planets, no Delhi, no oceans. All you would see is the faint light of the Sun, a star like other stars, among the thousands of stars that we see there. Some are brighter than the hundred million stars that you would see if you turned a big telescope on the sky, from either here or from Alpha Centauri, looking all just the same, with a few tiny exceptions that the astronomers would be able to tell you about. But once I tell you that a tremendous conviction I think will come upon you. You cannot be alone.

What would it be like, if we lived among one of those stars in the Pleiades, if we lived way out there among those millions of stars? The Sun is then just one of hundreds of millions of stars and all that we have and all that we hold and all that we have done has disappeared in the distance. We are just another star. The slightest degree of empathy, of putting yourself in another's place, I think, should make you realize that, maybe as we look at the stars, there may well be among them planets and Delhis and oceans and everything else. I don't say that there surely are, but I can't say either that there are not. Then you ask the question, 'Are there many stars?' You say, 'Yes.' There are 200 million stars, just taking those that are close twins to the Sun, that have the same behaviour as the Sun. Then you begin to ask more technically the question, what is it that makes our life possible near the Sun and what do we derive from the Sun?

The Sun of course provides the pull that keeps the Earth steadily in orbit. So you must have a planet, and you must have a star. The star must provide enough heat, so that the planet is not frozen, so that water could exist, things move. Above all the Sun must last for a long time, because the evolution of life is no overnight proposition. We know there were all those forms for 3 billion years. Of course you don't know the time everywhere—it might be 1 billion years, it might be 5 billion years—but you can hardly imagine things a million times faster. So you want a stable star.

You need material, of course. What is the material of life? It is the same material as the stars—carbon, hydrogen, nitrogen, phosphorus, sulphur, iron, sodium, potassium, magnesium. All these atoms on their own are the most abundant and central atoms of living forms. But there are also clustered atoms that we see in the atmosphere of the Sun and in all the stars that we have measured, hundreds and thousands of them, in the molecular form. In the cold depths of space, where matter is refrigerated, they can gradually collide and become more complex, refined, remarkable substances, such as ethyl alcohol or long carbon chains. With the requirements of energy and collision, they have been simply built up, given the laws of chemical binding. These are the same kinds of molecules we used to regard as solely the products of living forms. That is not true. Atoms like to come together and when they can, they will build up gradually, not the complex intricacies of life, but the simpler matter of molecular chemistry. Of course, it requires time, as I said 300 or 400 million years. A star must be stable under those circumstances. With all those conditions, if a single, stable, warm star becomes too bright, it can't last. If it becomes a faint star (faint stars are more common than bright stars), then it can hardly do because it needs enough warmth to make something like life. The planet must not be so close to the star that its orbit becomes endangered and instabilities of the star affect the planet. If you make these calculations it turns out that there is a domain, that is stars rather like our Sun are very favourable. Which is not unreasonable.

Now, of course this is a very unimaginative argument. Could there be other forms of life that don't require planets, that don't require water, that are made of silicon carbide? I don't know. Nobody knows. It doesn't matter. All we do is add to the argument, we don't take anything away. And I would like to argue from what we know, which is not very much. Only by analogy, can we argue that most biochemistry seems to depend on water and hydrogen bonds? If there is something else, fine, but we will take as a minimum that we are looking for those places which might have this. After all, water is remarkably abundant. It is made of two of the three most abundant atoms in the universe, which we find in every star. So there is no need to search for weird items. They might be real, they might be interesting, they might be important, but they don't do more than augment and strengthen the argument that I am making. We have not yet seen for sure even one planet near another star. Slight variations in the apparent positions of certain nearby stars suggested unseen forces pulling on those stars which could only come from planets, too faint to see from a great distance but perhaps as big as Jupiter or a few times bigger. Nowadays, the work of a computer and effort to reproduce these data have shown that in fact it's probably wrong. That method was not good enough.

But only in October 1988, in Baltimore and in Toronto, we had the first reports of the probable, not yet confirmed, discovery of planets around some distant stars. Two groups, one from Victoria observatory in Canada—Dr Garrison and his co-workers—using very subtle spectroscopic means, looking not for the position change, but for the speed changes of stars, and another group from Harvard, doing the same thing, reported that they had evidence of heavy planets around certainly two or three stars, and maybe as many as eight or ten. We had earlier known that there are dust rings around some stars. That was as close as we could get to seeing planets. I look forward to the launching of the space telescope into orbit in 1990 as it contains photographic capabilities which may show such planets directly as little spots of light. It's very hard to do it, because the planets shine by reflected light as a tiny spot against a gigantic star. You can't see the planets in the daytime, when the Sun is up, nor can you see the faroff ones with a telescope because the star is so bright you can't see the planets. There is a special means to blot out the star's image and show only the reflected light, and that way we may succeed. But until then we have to rely upon these tiny indications. I think by next year they will be confirmed or excluded. It would be very exciting to find for the first time that we have other planets in the universe. We do not know that now, we couldn't tell you if all the stars like the Sun have planets; or if only one, our Sun, has planets. We really couldn't tell you that for sure. But of course, any optimist, I think, would take the view that if there are 200 million stars just like the Sun, not double stars, stable, they do all the same things, then why should they not have planets? We cannot answer that fully because we don't really know the origins of planets very well. We used to think that planets were made by rare stellar collisions; that is pretty well excluded. We now know that they were probably made in the same act that forms the star itself. If it's true, then probably planets are very common. I myself tend to take that view, but I can't be sure. However, that's only the first step.

Now, it would be nice to know more about the planets, but it's very hard to do. You say, let's send a probe. Well, maybe, but I explained that a probe takes 100,000 years, and it's very hard to direct. That would get you only to the nearest star. If you are looking for stars that bear planets, that bear living astronomers, then indeed we can do something better than sending probes. A probe anyway costs a billion dollars, and you have to wait for 100,000 years. But it only costs a dollar, in the energy language, to send a very long telegram to the nearest star by radio technology! That's how powerful the radio technology is. As you all know, we have radios for a few hundred rupees that could listen to the whole world. The stations are not very expensive, they are in every town.

Radios are powerful means of crossing space. Systematic study has demonstrated that nothing can go faster than radio or light speed. That is the fastest and most economical signal that can be sent across the depths of interstellar space. It passes through interstellar space, it passes with high speed, it requires the least energy. It's not a mere matter of economics though that's quite important, too, as you will see, because signalling to the stars is no mean trick. It's important to be economical. Even the distant beings that are signalling to us (we hope) must be concerned about the economics and considerations of maintenance. They can't waste energy either. But even if they could, there is another reason why they should do it economically.

In order to find a signal that might be sent we must know something about it. The best way to know something about an unknown signal is to have that signal based on some significant property of the physics of the world—an economical way to send a signal that's also elegant and aesthetic. Don't make a wasteful signal, make an effective, efficient signal. We can figure that out, because what makes efficiency is the same here as among the farthest stars. The light and the physical nature of the medium between the stars govern what would happen. The signals that we know how to make that can go to the stars are limited. They can't be of a very low frequency, for the gas between the stars absorbs that. They could be the extremely high-frequency gamma rays or anything else: low-frequency radio, medium waves, short waves, microwaves, infrared, visible light, ultraviolet light, X-rays, gamma rays—we looked at each one systematically, not from the point of view of human culture, like when did we discover it? No, we know them all now. We know the whole continuum and we ask which one has the least competition among the stars—as we say, the best ratio of signal to noise, because then you are sending a signal. If you are trying to shine a light from the Earth, you have a very hard time because the light of the Sun is so much more important that far away nothing we can do can make the slightest important disturbances to the total sunlight. It will be drowned out in the Sun's starlight. So, visible light is no good. Even powerful lasers are hardly valuable, compared to the bright stars. They're not as powerful. But equipment in a few places in the world—the Arecibo dish and a couple of other radio astronomy centers—can now make a signal, using their dish and their existing transmitter. That signal is not like the Sun, which sends its light in all directions and at all frequencies. They focus is one direction to a star, and in one narrow band on a radio dial tuned very sharply. With those two forms of concentration, the signals that we could make could reach right across to the stars, hundreds or thousands of light years out into space with a signal strength stronger than the radio signal from the Sun, i.e. the natural signals from the Sun. That's the marvel of radio technology. We can't compete in bright light, we can't compete in a great many ways. But strangely enough, by focusing our attention on one narrow band and on one narrow direction we can outshine the Sun toward any receiver lucky enough to be pointed at us and tuning at the right frequency.

That of course is the basis for the search for communicative civilization among the stars. I will only add a few more points. First, we will probably not send, we will receive. Why? Because receiving is inconspicuous and cheap compared to noisy and energy-demanding sending. We are expert receivers and very poor senders across the prodigious depths of space. So we have elected for many years, and probably for many years to come, to try receiving and not to send. (I will come back to one difficulty over that.) We are after all only amateurs in this game. We first began to understand the possibility only thirty years ago, after 3 billion years of evolution. We have known about radio technology or microwave technology for forty years—that's a very small fraction of time, a blink of an eye. When a hundred years or a thousand years, or a million years or even a billion years have dawned on us, maybe it will be different. In any case there are many of us who think that we have the most adaptive technology; that is very unlikely. I suggest you question those persons who think that we will have infinite technology, do anything shine, like a whole galaxy. It is not true; you see evidence of that. We have had false alarms of that kind, but nobody believes that. I believe that all our dreams of our general search are limited to a broad range of capabilities, as much greater than our own as we are much greater than the hunters in the Kalahari desert who wander in little bands of 20 people around their world and live by hunting. We can do more than that, a great deal more, and we can do a great deal more in another hundred thousand years. But we won't wholly transcend what they can do.

We all have something. They have fire, we have fire; they depend on the Sun, we depend on the Sun. I believe we all remain in equivalent times. The finite resources of the Earth and the planetary system are heavy constraints on our economic capabilities. I do not think we will ever shine like the Sun, certainly not like the galaxy. We are looking for our counterparts; we expect them to be much more adept, much senior, much wiser, much better scientists than we are, and maybe they can maintain for a very long time a few, maybe many, signals looking for newcomers like ourselves. That's what we are looking for. By now, maybe a hundred different groups in about ten countries in the past thirty years have developed a poineer effort in this domain. Nobody has had a strongly dedicated system, a fine receiver, a heavy computing capability. Rather they tried looking two months at this place and one month at that place; some have even simply parasitized. That is very clever, because radio telescopes are often not being used for any experiment, you know. They lie pointing out at the sky, quite still, and nobody is working on it. They've gone home, they are asleep, or they are working on the calculations. For the moment the dish is not being used. Well, some of these clever fellows have managed automatic systems that use a telescope when it's not being pointed at anything else, when it's standing still and not being used, to search the sky. Of course it's not very helpful, because it's entirely a random survey; you don't know when you are going to look at the sky, but of course the telescope scans the sky as the Earth turns. Finally they do get some kind of criss-crossing. They don't know what frequency they can have next week: they can't choose anything. But of course they don't spend any money either!

That is not clean enough to make a search among 200 million Sun-like stars, among all the possible directions in the sky, focusing in each direction, among all the possible times that some signal is being sent our way, and, above all, among the many points in the radio dial. You might say, maybe there are an infinite number of positions on the dial. Let me point out that the narrower the band on the dial that you are using in your radio station, the less energy you need to make a signal of a given strength in that narrow a band. So you say, well, the narrower I make it the more energy I save. The best answer is to make it infinitely sharp. And then I have a huge number of places to search in. That does not work. So here is the nature of the argument we make: We look at the physics of the gases in space, to learn how they drift around a bit. They will perturb every signal and give every very sharp radio station a little messy width. There is no point—they know it as well as we do—in sending out a signal that will be messed up by space. Prepare your signal already about as wide as what space can transmit; that's the minimum, the best you can do. That has led up to the kind of search we are making. So we look for significant frequencies, significant widths, significant directions, (we have many gases, we don't know a unique answer) as the means for exploration.

Since 1960 that has been done. We point, we listen, we tune again in frequency, again and again and again. It's like seeking a needle in a haystack. Since the time of 1960–62, when we first began to think about these things in some detail, it seems we have gotten little better. The dishes, the big bowls you see in the pictures, have gotten only a little better. Do you know the Arecibo dish still remains the largest dish in the world after these nearly thirty years? That's amazing, but true. But what has changed we all know, the biggest change in any scientific technology. Everybody knows what it is. It is computing. Sixty years ago, there were no computers. Thirty years ago, the computers were rare, expensive, touchy items that a few airlines and laboratories had. Nowadays, they are everywhere, they are cheap and marvellous. The power you can get in a 500-rupee calculator is the power which in the fifties at Cornell occupied a whole room and was the delight of the university! It cost hundreds of thousands of dollars then. Exactly that same thing has entered the radio telescopes, and what does it do for you? It doesn't make it more sensitive, it doesn't make it better able to point, it doesn't make it better able to listen to weak signals, but it does one wonderful thing. It enables you to sweep the signals out over many channels at once.

At Stanford now, John Linscot has made 'silicon engines' (he has already sold one to NASA)—a receiver, capable of tuning to 20 million independent channels of radio signals all at once, each one carefully read and separately printed out, if you like. If you see anything in any channel different from the random noise in any of the channels it will tell you. It will tell you the probability of that difference, and it will show you what kind of signals are there in that channel. With that, we have a possibility of eventually searching all the bands and all the directions you can think of, and sweeping over the entire possible domain of all those signals.

This is proceeding in two places, so far only two. In one place, it is really a marvellous one-man proposition. Paul Horowitz, professor of physics at Harvard University, and his hard-working undergraduates and graduate students (with only 100,000 dollars from the famous cinema producer Spielberg) have made a kind of amateur set-up. Horowitz is known all over the world for his remarkable understanding of electronics. He has written the best book in electronics for scientists. He made the first of these multichannel detectors—an 8-million-channel detector which runs on an oil-fashioned dish, a big one that stands and looks at the sky, though abandoned by Harvard long ago. It was abandoned because the bearings broke down. These are heavy objects; the weather is bad for them and, after a while, if they are not up-to-date, they are not worth refurbishing. They lose the capability of pointing. My wife says cleverly that the Harvard dish has the possibility of saying 'yes' but not 'no', it can only nod and not turn. But of course if you nod it's good enough if you are patient, because the Earth turns. So, you sweep the sky day after day. Every morning a neighbour comes in to move the dish one half of a degree. Then you scan the sky again for a day and then again and then again. The equipment calls up Prof. Horowitz ten miles away at Harvard University everyday and says, nothing exciting today, here is a list of what we saw. The computer prints it out. He has it in his office, a very beautiful automatic detector. Of course it's not a very big dish and it does not have a very tight beam; it's primordial if you like. But it is really happening, after two or three years of searching at certain bands of frequencies, 10 million channels at a time—a very wonderful thing. His search has done more in its first ten minutes than all previous searches did before that!

Now, NASA, after a long, long soul-searching, has received a promise that it be enabled to use big dishes with still better electronics, to search the sky in two different ways. First, they will point and look for a very long time, in many wave bands, at each of the 800 nearby stars like the Sun that we know about. That's only 800 and it may take them 800 days or 1600 days or so to do it. Then they will look around the sky the best way you can at many, many frequencies. Each hour they search is like a month of Horowitz searching. So things will improve.

But it is a slow process, like looking for a needle in a haystack. I do think it's worthwhile, because of only one question. Are we alone? Of course, intelligent beings may not have radio transmitters, may not care about us, may not send a signal our way. Why should they? But if they do, and I assure you there are persons on the Earth—I am one of them—who would do so if they could. They may have done it too from time to time, not perhaps all the time, but now and again when they get the idea to do this which is so easily possible for them. It's not quick; it is searching for a needle in a haystack. You can't just walk up and grab a handful of hay and search it for two minutes and announce: no needle in the haystack! That's not the way to do it. You must meticulously search and search and search. We'll take decades, maybe centuries. Many people have entered the game, and more will continue to do so as time goes on. But what I think about it is that it is a new kind of archaeology; it is, if you like, the archaeology of the future. It is quite likely that, if we ever find such beams, they represent what we are headed toward in some way. We know what a spade is for the archaeologist. We know also that archaeologists know no sure things. You may dig and find a little bit of dirt, or you may dig and find a wonderful monument. We are doing the same thing, but our spade is the radio telescope. Our archaeology is the archaeology of the future. But if we find something, we may be very impressed by it. It might guide us in many ways. If we find nothing, that too is important, as it suggests that the archaeology of the future is not going to contain us, unless we behave well, try to live together and make the world as good as it can become. I do not know whether we'll succeed or not, but I think If you are told what will happen in the future, you might review all that. And you have a spade, not too expensive indeed, not a gigantic worldwide project, but a few astronomers, in each country. We can support it. It seems to me that we should acquire materials, take the spades, and dig. That's what I have to say about the search for extra-terrestrial communication.