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P.M. SESSION

SESSION I
CHANGING THE SYSTEM

SPACE

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BOWEN C. DEES: I'd now like to ask Drs. Frosch and Fletcher to come up and occupy seats at this table. We're going to have the following format this afternoon. Dr. Frosch will speak; Dr. Fletcher will discuss his presentation, then we will have some questions from the floor. Immediately after that, we're going to have a coffee break. Following that, we will have two additional presentations, discussions, questions from the floor. And, if all goes well, according to the schedule that we have attempted to outline, we'll be finished at 5, so that there will be plenty of time for you to prepare yourselves for the splendid affairs of the evening. Again, following the outline I gave a few minutes ago, I simply present to you, Dr. Robert Frosch of General Motors, Dr. Frosch.

(Applause)

ROBERT A. FROSCH: The title of this session is Changing the System, the Impact of Electrical and Electronics Technologies on Human Endeavor in the Second Century, and I am to speak on Space. I'll remind you first that 100 years is a very long time and second that predicting the future has a very poor history. No one

that I know of has succeeded in doing it by statistics or by numerical manipulation or by examination of friends and indeed it is not surprising because it appears in hindsight that the future depends on what I can only describe as very tiny giant steps which are not recognized for what they are at the time frequently but later have an important growth and an important history.

What one can do and perhaps it is just as chancey but I think it is more interesting is to discuss the creation of the future. What are the things that it would be interesting and useful to try to do given the tools that we have on hand now and the way in which they are developing and I would like to outline at least one such possibility, course. We can only, of course, set a course and be prepared to adjust it and look at the tools and possibilities that are thereby conjured up. This is an exercise of the imagination but it has to be confined in certain ways and it always a personal view. The confining of the exercise of imagination I can best describe by quoting Arthur Clark and then turning his quotation around.

Arthur Clark said, "Any sufficiently advanced

technology is indistinguishable from magic." I caution you to note that it is not thereby the case that any magic is indistinguishable from a sufficiently advanced technology. And I note the caution in the words of Francis Bacon, "Nature to be commanded must be obeyed." We would have to live within the framework of whatever the fules of the Universe turn out to be as we learn them in the course of the next 100 years.

But keeping that in mind I would like to describe a line of possible future.

I start from what I will take at least as my own hypothesis for a direction to be gone into in space. I take it because I think it is the right one, obviously. I take it also in this hall because I think it is one that Benjamin Franklin would at least have been extremely sympathetic with if not a leader in. And I take it because I think we are facing some problems in the human future on the planet that makes some alternatives at least interesting, if not important. The end desire I take to be for the next 50 to 100 years, and I caution you that the history of space thus far has had the accomplishments always occur before the time at which

they were predicted, is to explore and use the solar system. Now we have been talking about exploring it and to some degree actually exploring it throughout the history of NASA and the Space Program and occasionally we have talked about using it. I will leave the question of the rest of the universe for later in my talk.

In fact, when I say understand and explore and use, I mean literally in the sense of using energy and material elsewhere, as well as understanding what is there. Now why should we want to do that? Well, I think in the first place because it is a continuation of something we had been doing as a species for I suppose 50 or 100,000 years; namely, exploring, looking and using. Secondly, I would assert that some of the problems that we're facing as a species on the planet suggest that we may in fact succeed in making it a difficult place in which to live. And I am not particularly suggesting the nuclear war question but rather just the problems that are becoming a pressure on the use of the biosphere and the support of our own systems by our own numbers and existence and the way we use it. And I guess I have become, starting as a scientist, sufficient as an engineer,

so that I always like a hedge position in my technology. I think it would be nice for this species to have another place as well as the one which it is engaged in changing now. And it seems clear that the rest of the solar system is another place. Unfortunately, it is another place in which it is not either simple nor natural for us to live but perhaps that can be fixed.

At the moment it is extraordainarily expensive and difficult to do merely anything off this planet. In fact, the problem is that the expense is such that we are looking very hard for ways to find things which.... whose value commercially justifies that expense. We have found a few, Global Communications being one and some particular users of low gravity being others that are developing at the present time. But the question is, How could we make it economical and economically sustainable to be elsewhere than on this planet. What we're looking for is some form of self-sustaining, economic system upon which we can base our exploration, our development and our use of the rest of the matter and energy in the solar system.

Well, that too has precendence in the history

of human exploration. It's called "living off the land." That is, you don't go to the new continent or the far west, carrying with you everything you will need to sustain yourself, you propose to go in some way carrying the tools that will enable you to do most of the things you need when you get there but of course there are certain things that you expect to continue to import from the home country.

Well, how can one go about doing this? I guess it is my ascertain and I borrowed the idea from many colleagues that we are in fact embarked on the technological directions that will in fact bring us quite automatically to the technological possibilities for doing so. We have begun to construct out of the technological materials of computers, communications, electric motors, network thinking, system ideas, software and the whole litany of things that make the electro-technological revolution. We have begun to construct systems that are more and more self-sustaining. Ten years ago I think this was a laboratory discussion; today, it is a factory reality and while much of it is still an aspiration for factories, it is an aspiration

which is rapidly being contructed. And that is to say the productive unit, let's not argue about whether it's a whole factory or a part of a factory, which is in fact a self operating unit on a fairly large scale. We're certainly building and talking about self-operating manufacturing cells. Certainly those that take in partly finished parts and end up with assembled units and many that take in raw materials and end up with partially finished parts. It is not a very tremendous step to doing mining on the same kind of basis. It seems curious that people need to be in the minds to operate the machines when the presence of the people rarely changes the nature of the minds in some ways that's rather inconvenient when we can perfectly well do most of that without most of the people in the minds but we'd still need the people to run the machines from elsewhere. We can certainly do the chemical beneficiation and the chemical separations and the creation of the material, mostly without people. So, the ascertion is that one can, in the course of time, put this together into what amounts to a self-replicating machine which starts with raw materials and solar energy and is

a factory which ends up with the capability to construct another factory next to itself just like the first one.

Now, there are lots of questions of the convergence of this process and lots of questions as to whether one can do everything that is required in it. For purposes of economics, however, and for the purpose of exploration and use, it is really not necessary to have a completely convergent, self-replicating system. In fact, we probably wouldn't trust it if we did as the history of nearly any industrial process and all of the historical events in the space program have tended to suggest, there are moments, which I will call epsilon when you really need somebody to kick the wheels or unstick the hinge or really think of the software that was thought about five years ago and were perfectly adequate but isn't quite right now and so on. So that perhaps we can only get to self-replication (inaudible) epsilon and the epsilon is extremely important because we need the people there to make sure about the epsilon and I guess epsilon can be described as the piece which is the difference between it works and it almost works.

I would call this the robotics route to a

self generating economic system. The energy is available, the materials are available, although some of them are a little bit loose and not as available as one would like, I think we are developing the technology and such a thing gets to be extremely interesting.

Why is it economically interesting? I think it is economically interesting in the following definition. That if one constructed a first machine or two of this kind and simply set them out in a suitable place, after a while there are four machines and then there are eight machines and you all know the biological meaning of an expenential (phonetic) and this is an expenential. I remark that it does not violate the first and second laws of thermodynamics, we're using a very hot heat source called the sun, there's plenty of material and we're rejecting to a very cold heat sync called the rest of the universe.

This is all seems a perfectly reasonable technological direction and one which would make it possible except perhaps for the epsilon to build an industrial capability off the planet using a single export of machines in order to do it. I think we would

send some people with the machines, both because we want to be there and because of epsilon.

Now, there may be lots of things, which like the pioneers going west, we do not care to try to manufacture in sitto, it would be easy enough to import and export them. For example, in the current technology I rather suspect we might want to export the chips from the ground, at least for a while. What would we pay for them then. Well that it is an economic question and not a technological question. Gold, if anybody wants it, uranium, if anybody wants it, or energy, if anybody wants it and not necessarily radiant energy, energy can be shipped in solid and liquid form and beneficiated minerals can be considered as either materials or energy, depending on how you choose to use them.

From an investment point of view it's a very large investment but the ultimate gain is presumably infinite. There is a rare out time but the ordinary terms of depreciation and ammorization, it seems to me, do not apply for this situation.

What would such a program look like? Well, my assertion is that the central core of the technological

program, that is, the self replicating machine, is simply a continuation of the industrial program on which many corporations are already embarked. I know of nobody who is embarked on the whole program, but everybody I know seems to be embarked on a piece of the program and so in the end it seems possible that that technology will develop in the normal course of events out of our current developments in electrotechnology materials and mechanics.

What we don't understand nearly so well are the details of how to operate under the various conditions that will be required between here and the manufacturing site and at the manufacturing site, whereever it is that we choose. Nor do we really understand the industrial conditions when vacuum is free but materials mostly don't come very neatly concentrated and we don't really know the value of certain things to be done without gravity because we have that capability available to us as well. So we need some starting points in which to learn how to begin to use such a technology and that's really what the significance of the space station kind of direction is for me. It is likely that there will be

some commercial enterprises that will be important in a space station and it is certain that we will do a good deal of science from it as well as a great deal of scientific exploration quite independent of it but perhaps most important is the fact that it will be a place in which we can tinker with things. I think the history of science and technology demonstrates that one of the most important possessions of the technical professions is a place and an opportunity to tinker under the circumstances that are interesting. After all, low temperature physics was not invented out of whole cloth and all of the experiments conjured up without anybody having available a low temperature laboratory in which to try things. Nor has this been true of electricity or anything else. If you want to find out whether it is interesting to do in zero g then you had better go there and make a few mistakes of the kind that will enable you to discover some things that you hadn't found otherwise.

So I think that is a first step. The technological directions are being fixed. In any case, by other interests of ours and the question is, What is

the right mix of people, machines and aspiration to begin to consider carrying out such a program. Now, I would argue that if it becomes possible, as indeed I have suggested, to be economically viable and perhaps nearly independent of the earth, in an industrial operation elsewhere, on the moon or an asteroid or mars, then a number of questions of the relationship of the new places and the old place arise and these are economic and will certainly be political, I described the new place, wherever it is, as being a hedge against some problems in the old place, it cannot be that unless it becomes a living place and it cannot be that unless we solve the biological problems that go with some places that are now steriled as compared to where we live now. So that implies in the long run some program of technology which we now do not understand, except in the vaguest outlines, that deal with the construction of ecological situations in circumstances where they cannot now be said to be any ecology at all but only the possibility of totally artificial arrangements. So that, too, I think, has to go into the program and while we are beginning to see the outlines of what a large scale

biotechnology would look like truly the relationship of those outlines to our current electrotechnology are scarcely clear at all, although it is certainly the case that those technologies involve communication, sensing, control and computing, so that surrounding the biology there is increasingly an atmosphere of electronics, electricity and computing.

I said that I would come back, towards the end of my talk, to the rest of the universe and that of course is where the great difficulties really arise as we see the physics at the present time. That is, there is nothing all that mysterious about going out and doing something in the solar system, the times to get there and the energies and the expenditures are commensurate with what we know and understand but the rest of the universe has times and difficulties that are not commensurate with what we understand. But on a 100th Anniversary, it is worth at least making the following comment. A 100 years ago we did not even know that the velocity of light was a natural speed limit for velocity in the universe so we had no idea at that point that there was any time and speed barrier to doing what we wanted. I

have no idea, none of us do, whether there is any way around that problem but it is certainly clear that the universe is being seen to consist of some very curious physical objects and whether that will in the next 100 years change our ideas about how to move around in it and what we can do is not clear but if I may I would like to conclude again by quoting Francis Bacon, whose comment I leave you to interpret but I think it makes the point, "There are poor sailors who do not believe in the land when all they can see is the sea." Thank you.

(Applause)

JAMES C. FLETCHER: That's a pretty hard act to follow, Bob. Ladies and gentlemen, I am the (inaudible) to Dr. Bob Frosch, having preceded him at NASA and being a consultant to him after he succeeded me.

Talking about the space program, I have to go back to 1958 and remind you of a question that was asked a very distinguished government official, whom we all know, what are your plans for the Space Program and the answer came back, it seem humorous at the time, but it seems very apropos now, That space is a place, not a program. And I think as time goes on, we're becoming more and

more aware of that and Dr. Frosch has talked about big space like the universe and small space like where resources might be but let me remind you all that space begins somewhere between 20 and 100 miles up and they're still arguing about the in the United Nations. It must be lower than 100 because we have space things going around at 100 miles up and it must be above 20 because we have airplanes and balloons at least flying at 20 miles up. So somewhere in between that is space.

On the other hand, the other end of space must be at least, what would say, 15 billion light years away, something of that sort, and so we really have to focus first at what we might call near earth space and that's what I'll try to talk a little bit about. Near earth space being the bottom, the lowest altitude, whatever we want to define it at and let's say the moon, or at least the moon and the so-called a Appollo asteroids which are the nearby sources of materials. I left out Mars and maybe that's wrong but nevertheless in the near turn if we want materials to be collected and mined and used in the self replicating system by Dr. Frosch, we have to look at the so-called Appollo

asteroids and I don't need to remind you what they are. They are in the same orbit as earth and they come very close to the earth theoretically. The only ones we can see are about 2 kilometers across. The moon, you all know about, presumably. That's where are resources might be. I guess we could collect solar dust and things of that sort but Bob I think you would agree with me that that's not the best place to start. You can start on the moon or in the asteroids.

And, so, basically, looking at that region and thinking about it a little bit, 20 miles up embraces within 20 miles of every country in the world, not too different from the problem of our oceans and oceans have been investigated with the millennium and have been used for both commerce and warfare. If you would like you can extend the analogy a little bit further and say it's not unlike air. In the early days of aeronautics the Wright Brothers' experiment was kind of a gimmick for them, although they had some vision of the future, but nevertheless it was an experiment for them. Let's see if we can't sustain flight for a period of time without any help from the ground. And for 15 years

after the Wright Brothers' experiment, the U.S. did very little else but stunts, circuses, if you like. No (inaudible) of the forces but with World War I it became quite clear that aircraft were being used by the Europeans for observation of all things. You may not remember that. That's before your time. My father remembers it very well and perhaps Dr. (inaudible) who is a friend of my father's might remember those days. But nevertheless they did occur and we in the U.S. found ourselves behind and you all know the story of NACA, how it was created. It was created primarily because we saw ourselves falling behind the Europeans in the aeronautics business.

Well, space is not all that different. We started with an anxiety because of Sputnik and we established however in reaction to that anxiety and NASA, which was created out of NACA but more importantly perhaps it was created partially by combining some elements of the Rocket Program which really came from Germany. It came from Germany by way of U.S. and Russia but we won't go into that. By the way, Herman Obert, who was (inaudible) and wrote many of the early books on

space travel, is still alive and they're celebrating his anniversary I believe this month, I'm not sure, I think it's either this month or next month in Germany.

Let me go ahead with that analogy between air and space. It started out as a military idea, both on the oceans and in the air, and pretty soon, like decades, it became, at least both air and sea, a viable, commercial enterprise and that's about where we are now. It's true that we have T.V. satellites or communications satellites, very successful. That was an obvious extension of something we already knew about. We did not have good ways of getting television overseas and so it started with television and then it gradually moved to telephony and became instead of overseas domestic as well and now we have television programs coming out of our ears but that's a whole other story. It is not so obvious what has been happening in earth observations but the same kinds of things happened there but primarily government supported and we have the weather satellites which are now taken for granted. We also have land sats and the beginnings of ocean stats. These are primarily experimental devices. And on you can go and we don't

know where commercial enterprises will end but I'm sure that within three decades we will be mining the moon or the asteroids, whichever turns out to be easiest. We have been to the moon, we haven't been visting asteroids and I think the two obvious uses of material there will be: a) to build other stations. Bob calls it self replicating stations. I will call them lunar colonies alla Jerry O'Neill at Princeton. There certainly will be L-5 colonies or something similar to that or bases on the moon for either scientific or self replicating purposes.

It's not so obvious that you can do this with the power asteroids but this will go naturally toward some of its spinoffs from the space programs sponsored by NASA, some of its spinoffs from the military space program. I would like to just touch on one other aspect of the program which I don't believe is in any way trying to downgrade this projection of the future but over the millennia we did have to protect our trees on the sea and we did have to protect navigation and our various commercial enterprises from those adventurers who wished to interfere with these enterprises, pirates

or whatever or hostile countries, by patrolling the seas and people who patrolled the seas quite often controlled the commerce and that is what we are now facing in terms of a newly coined phrase "space warfare." It's a popular word with politicians nowadays but those of us who have been involved in the business know that space warfare really started in 1944 with the B2's when rockets with ordinary chemical warheads on were launched from Germany to the U.K. and these B2's had to travel through space. You may not remember, although those of you who are involved do, that the first space program started very soon thereafter, in 1946 in this country, when it was observed that if you wanted to get higher than air-planes and look at what the other fellow is doing you needed an observation satellite and so I guess it was Douglas Aircraft which became (inaudible) Corporation, the first observation satellit was born and we, as you know, used these for verification of the various treaties that we have made, (inaudible) the Russians and other countries, and so we, the space program, was born, the space program in NASA or anyplace else was born out of

these two enterprises, both of which were warfare. The B2 and the oberservation satellites.

In 1954, the (inaudible) Committee observed properly that what we thought was a gimmick; namely, V2's that could travel across the ocean, became a reality because it became quite clear that nuclear warheads; namely, hydrogen bombs, if you would like, were possible in a very small size and therefore it became possible for one country to more or less annihilate the other using nuclear warheads on the so-called ICBM's. I Happen to be involved in that program and I hope I'm not involved in another one because that is space warfare of the worst kind. But, nevertheless, ICBM's do have to travel up above the space limit, typically 400 miles, if it's an ICBM 6000 miles range, lower if it's an SLBM or still lower if it's an IRBM or tactic ballistic missile. It's inconceivable to me that we have lasted this long having the capability of passing weapons through space without having some sort of a space patrol. It took some of the youngsters to remind us of this. It was never in my mind when I was working on the ICBM Program. By the way, it started with the Thor, a

little one, then it went to an Atlas, a little bigger one, then a Titan (inaudible) forgotten. We found that we had to put them underground to protect them and that's when the Minuteman was born, then we had one, then we had two, leading up to the MX and the Russians are doing the same, apparently. We all thought that that was the way to protect our assets but it didn't occur to us, most of us, that you ought to have a way of preventing these things from going from one place to the other and just recently, in what is the last 20 years, we began to think of ways of stopping these warheads from coming by.

Now I should say that patrolling started before that because we began to watch what the other fellow was doing. We're allowed to watch by flying over his territory with airplanes. That was illegal. See, that's why we get into an argument about 20 miles versus 100 miles. So really to fly over the other fellow's territory, that is not apparently illegal to pass a satellite over his territory and as you know we pass satellites over everybody's territory several times in a month. NASA has one, for example, that looks from

550 miles up, that goes, what was it, every nine days, Bob, something like that, two of them,....nine, depends on whether it's one or two, nine days or 18 days, looking at every part of the world every nine or 18 days. So we are beginning to patrol in a sense of watch but then we began to really watch some of the treaties and we used to....I used to be in the Arms Control business and we used to talk about verification. If we agree to do this and you agree to do that, we will watch to make sure that you do what you say you were doing with the appropriate observation satellites. Now we don't talk about verification anymore, we talk about enforcement, that's a different kind of a problem because, all right, so I noticed that you were cheating on the agreement that you made with me, what do I do about it and we found not a heck of a lot. That's what leads us to think that new treaties ought to have some sort of enforcement. I don't mean by enforcement, dropping its bombs on the other fellow, either. That's not a very good way to do it. But it was the case....let me just suggest that because space is a place and it's only 20 to 100 miles from all of our countries, we really have

to think about the problem of keeping space peaceful and I think all of these things that Bob Frosch talked about, including even going to the next star, doesn't look so difficult to me, all you have to have is a more efficient propulsion system and a little courage to wait....what would it be, four years each way, as a minimum, that's not too bad, I think all of these things can be worked out but we do have to make space peaceful and we do have to patrol it and if we continue in a wise and careful way, I think the space place and the space program will flourish for decades and hopefully for many centuries to come. Thank you very much.

(Applause)

MR. DEES: Now is the time for questions and I, on behalf of the organizing group, will ask that as you ask your question you identify yourself. Who has a question for either of the speakers? I don't believe it. Doc Schwan. Dr. Schwan has a question at this time.

HERMAN P. SCHWAN: I read with great interest your article (inaudible) in which you described the potential might be....what we might be able to do for the defense system. I read the article by Dr. Keyvoos

and it was the last article (undistinguishable) formed opinion didn't succeed at all and it seemed very confusing to me. In your article, as I read it twice, you seem not to take a final stand, you just outlined potential (undistinguishable)....could you care to comment on that.

MR. DEES: I'm going to say a little about the question so that all of you know what was asked.

Dr. Schwan comments on having read the articles in the first issue of Issues, the new National Academy of Science's Journal, one of which was written by Dr. Fletcher, one by Dr. Keyworth and others. The question is, Did Dr. Fletcher really form an opinion or what can he do to have Dr. Schwan form an opinion on these contrasting articles.

MR. FLETCHER: Well, that was an accurate observation, Dr. Schwan. By the way, I want to make sure that my colleagues are not neglected, the other article was written by Drs. Ponansky and Drell (phonetic) from Stanford University.

My role is that issue of Science and Technology was to simply not take a stand but to expose at least in

the open literature what were the results of a study that was done a year ago on whether this space defense initiative, as it's now called, we call it defensive technology study, could work. Could work. And the answer we came up with is, yes, it could work but as somebody mentioned earlier, according to C. P. (inaudible), politics and technology have to work together and this is why I said this has to be done very carefully. One just can't go ahead and develop a defensive system and by the way it can be done, there's no question about that, but it depends whether it works or not, depends on what the other fellow decides to do. I think if we have a peaceful relationship between the two countries we would develop a defensive system together. If we don't have a peaceful relationship between the two countries then we have to take other steps. That means we have to take some initiative, much the same as we did, I'm not sorry to have to say it, but with the so-called H-Bomb. There was a lot of controversy at that time on whether we should go ahead with such a terrible weapon but in retrospect we had no choice and I think that's the position I took in that paper. Now, there are others

that think we have no choice but to deploy the system. I think that's what has to be done very carefully and that depends on both politics and technology and I only discussed technology in that article.

MR. DEES: Dr. Frosch, do you have any comments on this question.

Any other questions?

Then we are going to break for 20 minutes for coffee and I hope to see you back in here very shortly after three.

(Applause)