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COMMERCIAL COMMUNICATIONS SATELLITES

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HEARINGS
BEFORE THE
SUBCOMMITTEE ON APPLICATIONS AND
TRACKING AND DATA ACQUISITION
OF THE
COMMITTEE ON
SCIENCE AND ASTRONAUTICS
U.S. HOUSE OF REPRESENTATIVES
EIGHTY-SEVENTH CONGRESS
SECOND SESSION
ON
COMMERCIAL COMMUNICATIONS SATELLITES

SEPTEMBER 18, 19, 21, 27, AND OCTOBER 4, 1962

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NOTE.—The chairman of the full committee and the ranking minority member, Hon. Joseph W. Martin, Jr., are ex officio members of all subcommittees.

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COMMERCIAL COMMUNICATIONS SATELLITES

TUESDAY, SEPTEMBER 18, 1962

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON APPLICATIONS,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
Washington, D.C.

The subcommittee met at 10 a.m., Hon. Ken Hechler (chairman) presiding.

Mr. HECHLER. The committee will come to order.

This morning the Subcommittee on Applications is commencing hearings on the development of communications satellites. The subcommittee intends to investigate the various proposals and concepts with a view to determining the most effective and less expensive system for commercial development.

This country cannot afford to commit vast resources to an operational system without first having determined the most appropriate and effective system to meet the demands of worldwide communications.

We are going to discuss in these hearings some of the advantages and disadvantages of medium altitude and synchronous orbit systems and the relative capabilities of each in future requirements.

We are pleased to have our colleague, Congressman Karth, sit with the subcommittee. Congressman Karth's subcommittee investigated the military requirements for communications satellites. It is very useful to have that continuity with your presence, Congressman Karth.

This morning we have before us in these hearings representatives of the Hughes Aircraft Co., the prime contractor for NASA on the Syncom satellite development, following which tomorrow we will hear from representatives of the National Aeronautics and Space Administration.

This morning we will start the hearings with testimony by Dr. Fred P. Adler, manager of the space systems division, aerospace group, Hughes Aircraft Co.

Dr. Adler, it is a pleasure to have you before the committee. Would you care to introduce anyone that you have with you?

STATEMENT OF FRED P. ADLER, MANAGER, SPACE SYSTEMS DIVISION; ACCOMPANIED BY C. GORDON MURPHY, PROGRAM MANAGER, SYNCOM, HUGHES AIRCRAFT CO., CULVER CITY, CALIF.

Mr. ADLER. Thank you. Mr. Chairman, Congressman Karth, distinguished members of the committee, it is a pleasure to be here; we appreciate very much being invited to appear before this committee to tell you a little bit about the Syncom program which we are doing

under contract with NASA and to tell you about our thoughts and opinions on the subject of communications satellites in general.

As you know, we have been active in this area since early 1959 and we have been vitally interested in communications satellites ever since.

We have a prepared statement for the committee today and I would like to at this point introduce Mr. Gordon Murphy, who is the program manager of our Syncom programs at the Hughes Aircraft Co.

Mr. Murphy will read the statement and subsequent to that, any further questions you have, we will be very happy to answer.

Mr. HECHLER. You may proceed, Mr. Murphy.

Mr. MURPHY. Mr. Chairman and distinguished members of the Subcommittee on Applications, as Dr. Adler said, the Hughes Aircraft Co. has been active in the development of communication satellites since June of 1959. At the present time we are under contract to the National Aeronautics and Space Administration for development and launching of the Syncom satellite and for advanced technical development leading toward a stationary satellite with truly operational capability. We expect that the later contract will lead to an initial operational communications satellite system demonstration in the first half of 1964. We call the advanced satellite Syncom Mark II.

The Hughes Aircraft Co. has been firmly convinced since 1959 that the use of a synchronous, spin-stabilized satellite will provide the optimum operational, communications system for both commercial utilization and for military requirements. We have consistently proposed a specific synchronous-satellite design based upon one-axis spin stabilization rather than some type of three-axis stabilization such as Advent was to have employed. Because of the simplicity of a spin-stabilized design we will be able to complete our satellite development in a shorter period of time than would have been possible for any other synchronous design.

Because of the simplicity and light weight of our concept, we are able to use existing rocket boosters. This is a very important point; we are not dependent upon new rocket developments. The first Syncoms will be launched using the thoroughly proved Thor-Delta booster and the Syncom Mark II will be launched by the Atlas-Agena booster. Both of these rockets are of course in use today and they have been quite thoroughly tested. As a matter of interest, the Atlas D-Agena D has the ability to lift more weight into transfer orbit than we will require. The communications capacity of the stationary Syncom Mark II satellite will thus only be limited by its ability to generate electric power from its solar cells, not by any weight restriction.

The simple Hughes Aircraft Co. control system and our advanced lightweight electronics, which make practical the present Syncom design, were developed by company investments in research during the period between June 1959 and the time when we received our first contract from the Goddard Space Flight Center of NASA in August 1961. In the intervening 2-year period we constructed a complete satellite suitable for environmental testing. As far as we know the first free-enterprise spacecraft, this satellite was designed to be launched by a Delta booster and weighed 122 pounds, very close to the weight of the first Syncom.

As a result of those 2 years of company-funded effort, we were able to undertake the NASA Syncom contract on a very tight schedule. We have completed construction of the first prototype satellite which is currently undergoing environmental test.

In addition we are in the advanced stages of fabrication of three flight spacecraft. It is our understanding that the NASA intends to have the satellite launched shortly after January 1, 1963. In other words, we expect to be able to launch the satellite only 17 months after receiving our contract.

The Syncom satellite is a research tool which will have only limited communications capability. It will, however, demonstrate all of the principles of satellite orbit injection and control upon which the Hughes designs are based; and will provide information on the characteristics of the communications transponder and of the command and telemetry systems. Having verified the basic Syncom concepts, it is our expectation that the NASA will supplement our existing advanced stationary satellite contract with the funds required to build and test a prototype and to build and fire flight models of Syncom Mark II.

If our present advanced study is supplemented by March of 1963 with the funds to build such flight units, it is believed that the first experimental stationary satellite with truly operational capability can be launched by about the middle of 1964. If suitable ground stations are developed on a similar schedule, as they can be, it is our expectation that an initial commercial, stationary satellite system can be demonstrated by the middle of 1964 which would have all the features of an initial, commercial system. Specifically, the Syncom Mark II satellite will have the ability to handle up to 2,400 two-way telephone channels at a time or four television channels or combinations thereof.

The Syncom Mark II satellite will thus be in every respect that required by an initial operational system. It is our expectation that the early ground stations which we hope the NASA will have built to test the Syncom Mark II satellite will be supplemented by additional stations until a complete operational capability is available.

The first satellite, placed over the Atlantic, will provide the satellite portion of a complete transatlantic system. It will be able to "see" approximately 100 countries around the Atlantic basin continuously (not on an intermittent basis of 20 minutes per usable medium-altitude orbit, with only a small percentage of orbits actually usable). These countries, which contain 90 percent of the world's telephones, can thus be tied together with the first satellite that is installed over the Atlantic. A second satellite, placed over the Pacific Ocean, will tie together the countries in eastern Asia, Japan, Australia, the Hawaiian Islands, the west coast of the United States, and the west coast of South America. So with the first two Syncom Mark II satellites, we will interconnect the bulk of the existing telephones in the world and provide continuous TV coverage to the Atlantic and the Pacific areas. A third satellite, placed over the Indian Ocean, will complete the system's worldwide coverage since the area of view of the third satellite will overlap the areas of the first two.

In this way, we will meet President Kennedy's challenge of July 1961 to make available to all the World the benefits of our communication satellite developments.

It is our opinion that the synchronous orbit system will be clearly superior to any medium-altitude system so far proposed, including the very spectacular results obtained from the Telstar experiments. The reason that the synchronous satellite system is superior is three-fold: First, a complete operational, synchronous system can be installed quicker than any medium- or low-altitude system; second, the synchronous system will provide superior quality of transmission with fewer technical problems; and third, and most importantly, the synchronous system will be much less expensive than the low or medium altitude systems.

A synchronous system can be installed sooner than a medium altitude system because fewer satellites will have to be launched and because the ground stations of a stationary system will be much simpler and can, therefore, be installed much more quickly. Only three synchronous satellites are required in order to have a complete worldwide continuously operating network. With a medium altitude or low altitude system about 50 satellites must typically be put into orbit before almost-continuous communications are available between any two points on the earth.

The synchronous orbit system will provide higher quality service than the medium altitude system for several reasons. The stationary-satellite system will not be affected by the variations in frequency resulting from the relative motion of the satellite and the ground receiving stations. These frequency variations, or "doppler shifts," in turn produce difficulties in obtaining high-quality reproduction when multi-channel operation is conducted.

In addition, in the medium altitude system, the relatively limited mutual visibility and the doppler shift precludes, in practice, a very important feature of the stationary system called multiple access. "Multiple access" means that any ground station can talk to any or all other ground stations, within sight of the satellite at all times, up to the capacity of the satellite. Multiple access will permit all nations of the world to economically install relatively modest ground stations and to participate in the benefits to be gained from this application of space technology. Small nations will not be forced to use the facilities of a third, more economically advanced nation.

We believe that the synchronous satellite system will provide the lowest cost service that can be made available by any satellite communications system being seriously considered so far. These lower costs derive from two factors. First, a very few synchronous satellites are required. These satellites are at an altitude where the environment is relatively benign as compared to that of the medium- or low-altitude satellites. As a result, we believe that the synchronous satellite can be made to have a longer useful life in orbit, which in turn will result in a lower yearly cost for satellite replacement.

The ground stations of a stationary system can be much less expensive than the ground stations of a medium altitude system. The ground antennas of the stationary system will not have to track satellites as they move across the sky. Only one fixed antenna will be required at each site if a stationary system is put into operation.

The ground station of a medium altitude system will require at least three antennas. Two are needed for continuity of communication during the handover from one satellite to another, and a third is required as a spare while maintenance is performed on the others. In addition, the ground station of a stationary system can be sized in accordance with the local traffic requirements.

The medium altitude system requires large, expensive ground stations of large capacity; it is a "cable in the sky." Syncom can operate economically as a "network in the sky." Because of multiple-access, small, inexpensive ground stations can be economically installed wherever needed. The large expensive ground stations of a medium altitude system, will, of economic necessity, be restricted to the wealthy nations of the world. The less developed nations of Asia, Africa, and South America will not be able to afford such expensive stations.

To show the relative cost advantage of the synchronous satellite, we have prepared a rather simple analysis of the two most important elements of cost—the annual cost of the satellites, and the annual cost of ground stations. Admittedly this is not a rigorous analysis, but we believe it is representative of the relative costs of the two systems. Certain assumptions will have to be made, we hope they prove to be realistic.

We will assume that 40 satellites of the medium altitude type are required in order to have a reasonably continuous communications capability between two widely separated points. Assume further that the medium altitude satellites can be successfully launched five at a time with each Atlas-Agena booster, a quite difficult and as yet unproven task. If the individual satellites cost $\$1\frac{1}{2}$ million each, which seems to be a reasonable figure, each payload of satellites will cost five times that amount, or $\$2\frac{1}{2}$ million. The approximate cost of an Atlas-Agena, including its launching costs, is $\$8\frac{1}{2}$ million. The cost per shot, therefore, is the sum of the above two figures or $\$11$ million. If it is assumed that one out of two shots is successful, a reasonable assumption from tests to date with the Atlas-Agena, the cost of launching 40 satellites into orbit will be $\$176$ million. Let us finally assume that the satellites' useful average life is 2 years. The system cost per year for satellites will be, therefore, one-half of the $\$176$ million, or $\$88$ million per year.

The ground stations will require at least three large tracking antennas similar to the horn at Andover, Maine, or to the parabolic antennas that are being built by the NASA in North Carolina. These antennas and their associated electronics will cost at least $\$4$ million each (based upon budget estimates that were included in the NASA budget for reproducing an 85-foot antenna identical to the one that had already been installed at the North Carolina station). Although the actual figure may well be three times as high, we will use $\$4$ million to arrive at a very conservative estimate.

If 20 stations are required in order to have an initial system, the total cost will be 20 times $\$12$ million per site or $\$240$ million. This figure is probably understated based upon the Andover site. If we assume that the ground stations will be depreciated over 20 years, their annual cost will be $\$12$ million per year.

The total annual cost of the initial medium altitude system in this case would be \$88 million plus \$12 million, or \$100 million per year, for the depreciation of capital equipment.

We have left out such costs as annual operating costs, electric utility expenses, the cost of obtaining financing and the necessary profit return on investment.

Let us now compare the stationary system on a comparable basis. Again assume a 2-year useful satellite life even though the environment at 22,000 miles is much less severe than that of the medium altitude satellite. If three satellites are required every 2 years for worldwide coverage, and if a 50 percent launch success rate is again assumed for the Atlas-Agena, then six launches every 2 years will be required. Assume only one satellite will be launched per booster; then three launchings will be necessary each year. The cost of a single Syncom Mark II type synchronous satellite will probably be \$1½ million. The cost per launch, therefore, would be 8½ million for the booster and its launching costs, plus \$1½ million for the satellite or \$10 million per launch. With three launchings per year, the satellite costs would be, therefore, \$30 million annually.

Fixed ground stations of equal capacity to that assumed above for the medium altitude system, namely 300 2-way voice channels or one TV channel capacity, will cost approximately \$1 million each. If again we require 20 stations in order to have an initial system, the total cost of the ground station investment would be \$20 million. If this is again depreciated over 20 years, the annual cost will be \$1 million for ground stations.

The capital cost, therefore, of the satellites and the ground stations in a stationary satellite system would be \$31 million per year. Again certain costs have been left out, such as operating, utility, and financing expenses. These costs should be comparable for the two systems. Actually, the simplicity of the ground stations in the stationary system should result in lower operating costs and the lesser capital requirements will mean lower financing expenses.

We see, therefore, that in terms of the annual equipment cost an initial system of worldwide satellites plus 20 ground stations would run, in the case of the medium altitude system, \$100 million annually, and in the case of the stationary system, approximately one-third as much or \$31 million, per year.

It is very important to note the additional costs that will accrue if the systems are to be expanded beyond the minimum systems that have been assumed above. The cost of additional ground stations for the medium altitude system is \$12 million per site versus \$1 million for a Syncom Mark II type ground station of comparable capacity.

The \$12 million stations with three antennas can operate in only one direction at a time. If the medium altitude ground station is expected to communicate both to the east and to the west, an additional pair of antennas will be required. If the same ground station talks to the south as well, perhaps another two antennas will be required, and so on.

In the case of the synchronous station only one antenna is required per site. This one antenna can talk to any or all other ground stations, that are within sight of the satellite being employed. Indeed, it is our expectation that the antennas for the synchronous satellite

system can be fabricated with poured, reinforced concrete. The fixed antenna construction will be very similar to modern swimming pool construction. Such antennas should be quite inexpensive. We have received estimates from our suppliers which indicate satisfactory concrete antennas can be made for \$30,000 or less. This kind of antenna will lower the cost of the stationary satellite system a great deal below those costs which we have assumed in the very simple analysis presented earlier.

It is quite often stated that the medium altitude satellite has been demonstrated and that we should install a complete system as quickly as practical. Telstar has, of course, been a great success of which all Americans are justly proud. The Syncom has not yet been launched and a conservative investor would not be willing to invest a great deal of money in a Syncom system until the satellite has been demonstrated.

The NASA has quite judiciously limited our Syncom Mark II program to advanced technical developments until Syncom Mark I has been demonstrated. The benefits to be gained from a synchronous system are so great, however, that we should certainly wait until the Syncom design is proved in that utterly conclusive test—a successful flight launching.

Suppose we go ahead with a medium altitude system which directly serves only the "have" nations. Then let the Soviets follow with a stationary multiple-access system which ties all the "have not" nations to the U.S.S.R. Who will have won this vital race for men's minds?

It has been stated by some that there is a need for both medium altitude and synchronous systems. Let's build the medium altitude system now, they say, and add the synchronous capability later when it is proved practical. We think this plan would be a very great mistake. If we can have a synchronous system, we do not ever need a medium altitude system in our opinion. If a complete medium altitude system is ever installed, very expensive ground stations will be required, as has been shown above. If these ground stations are once installed, the FCC will be obligated to maintain a system of international telephone and television rates that will be high enough to permit the recovery of the expensive medium altitude ground station investment through the tariffs charged to the public. The rates will remain much higher, therefore, than they would otherwise have been if the very expensive ground stations associated with the medium altitude system had never been installed in the first place.

It seems, therefore, highly desirable to wait until we see whether Syncom will work before proceeding with any system. If Syncom does operate as expected, then we need never make the large outlay for medium altitude ground stations. Hopefully, the regulatory agencies can pass on to the consumers, in the form of much lower rates, the lower capital depreciation costs that will be associated with the synchronous system.

It seems quite clear that the utilization of intercontinental communications follows what economists call a very elastic demand curve. That is, if the cost of the international telephone service is decreased, the demand for service will go up by a much larger factor than the decrease in rates. A rate decrease will result, therefore, in a much larger total revenue and more importantly a much larger usage of this very valuable new communication medium.

We believe, therefore, that an early decision to install a medium altitude system prior to the demonstration of the Syncom's capability would impede the establishment of the much superior system, the stationary satellite system.

We wish to comment on the applicability of the commercial Syncom-type system to the requirements of the Department of Defense as we understand these requirements. It seems quite clear that, as in the past, the DOD will be a large user of leased communications capability from the commercial communications satellite company which is now being formed. However, it is also clear that the DOD will have unique requirements which in turn will warrant the development of a satellite system peculiar to their requirements and the installation of a separate satellite system for the exclusive use of the Military Establishment.

In peacetime the military system will supplement the service leased from the commercial company.

The military has a requirement for the ability to operate while their system is being jammed and while it is being "spoofed"; that is, while attempts are being made to fool its command system. In addition, the military communication system should be able to withstand the rigors of an attack and still be able to operate. This is the feature called "survivability."

Many of the features of the advanced Syncom Mark II design which we are now developing for the NASA can be applied to a satellite designed to meet the military needs. There are certain items, however, which need to be developed to meet the peculiar requirements of the military system.

First, a communications repeater must be developed at the military frequencies which meets the band-width requirements and other unique requirements of the military system for secure antijam operation. Included in this transponder development will be a new traveling-wave tube at the military frequencies and a satellite antenna subsystem at these frequencies.

Second, it is necessary that we proceed with the development of a command system which is able to operate in the presence of enemy jammers and in the presence of devices designed to spoof it or give it false commands.

The civilian system of satellite command is being designed to operate in a world of international law and to have the ability to withstand only unintentional jamming or spoofing signals. The ground stations of the military system are expected to bear little resemblance to the civilian ground stations.

It seems quite likely that other features of the military satellite will be different from those of the civilian satellite. Suffice it to say here that it is clear that a military satellite program is required and that there will be unique developments associated with it, although many of the technologies which have been developed on the civilian program can be readily applied to the military satellite system.

Because of the unique requirements and the extreme urgency for a military system, it is essential that the military satellite development be undertaken as soon as practical. It has been said to us many times that perhaps the DOD should wait until the NASA develops the Syncom Mark II system and then use the satellites resulting from

that development for the military's needs. If we wait that long before starting the military development program, then the operational date of the military system will be delayed by at least a year and perhaps as much as 18 months beyond that which will be possible if the two programs were conducted almost in parallel.

A stationary satellite system is, we believe, particularly suitable for the military application since, in addition to the advantages quoted for civilian use, it can provide significantly higher survivability. The Department of Defense is, of course, considering many different methods of achieving a stationary system and we hope that one method which will be followed is the adaptation of the Syncom technology to the peculiar requirements of the military satellite. Such a development would require only a very modest expenditure of funds over and above the cost of the NASA programs. We are looking forward to an early commencement of a program designed to develop the unique features of a military spin-stabilized satellite design.

In summary, we would like to state that in the opinion of the Hughes Aircraft Co., stationary satellites provide the logical choice to fulfill both the needs of the civilian system and the military requirements. The most desirable way of obtaining a synchronous-satellite system is with a spin-stabilized design of the type now being developed by Hughes Aircraft Co.

The stationary system can be obtained at the lowest cost and is extremely flexible. It can provide the unique and important feature of multiple access. Large numbers of inexpensive ground stations can be readily incorporated into the system efficiently and it is more conservative of frequency spectrum.

A synchronous system of the Syncom Mark II type can be operational earlier than any other system so far proposed because fewer satellites are required to be launched.

An initial demonstration can be made by the middle half of 1964. With the first satellite on station above the Atlantic, communications among approximately 90 percent of the world's telephones can be provided continuously from the single satellite.

We therefore recommend that no decision with respect to an initial system be made for either civilian or military use until the Syncom program has had a chance to demonstrate the soundness of our basic design. If the first Syncoms demonstrate that the Hughes control system and electronics are satisfactory, then the initial system which is installed should be a stationary system of the Syncom Mark II type. It would be a large and unfortunate waste of funds if an expensive interim system were to be undertaken prior to the time that the capability of Syncom can be demonstrated.

The military system should be developed based upon the technologies which will have been demonstrated in Syncom.

No matter what is finally decided with respect to these difficult questions, however, we are sure to have an improved system of international communications resulting from the introduction of communication satellites.

We will have available to all the peoples of the world a capability for greater understanding, hopefully leading to a more peaceful world.

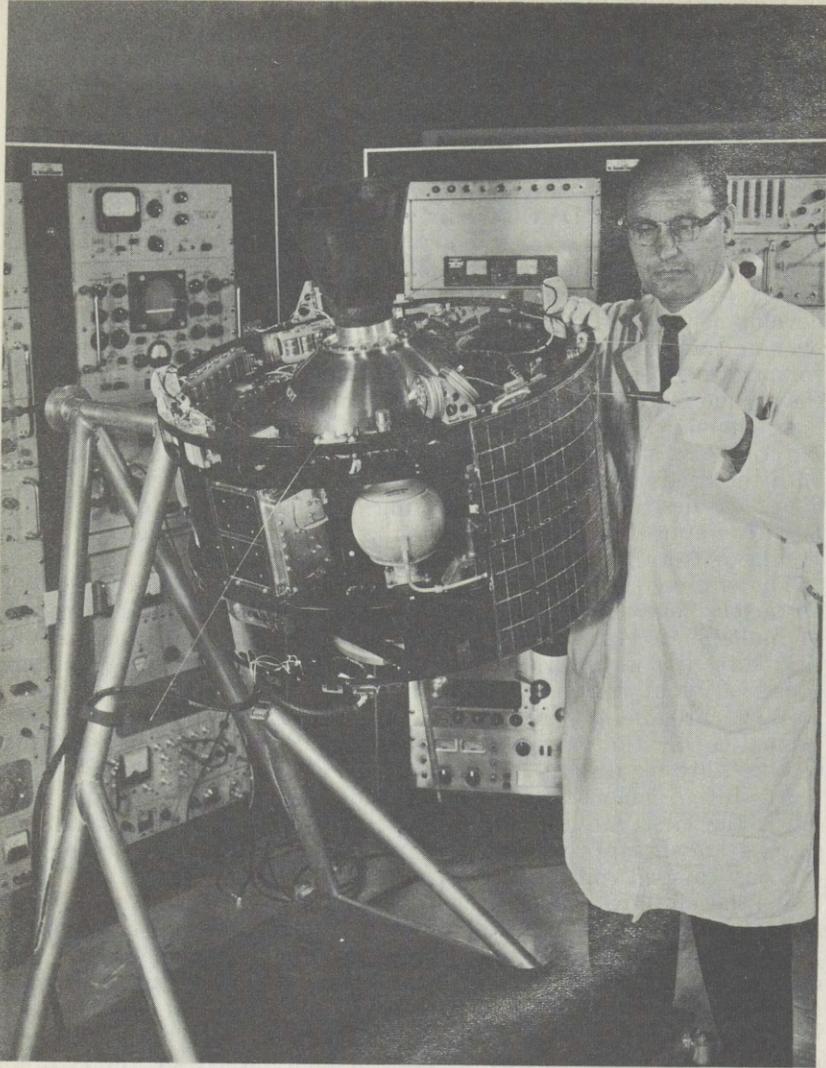


FIGURE 1.—The Syncom I Satellite.

Mr. HECHLER. Mr. Murphy, I congratulate you and Dr. Adler and the Hughes Aircraft Co. for the clarity and simplicity of your presentation. It shows vigorous confidence in your product.

When we poke around on this committee at various edges of this problem and raise questions about whether or not all that you claim can be accomplished, I hope you understand that this is for the purpose of receiving a full justification of what you believe in.

We do have many questions that we would like to ask.

Telesat of course has gotten worldwide attention for its spectacular achievements and, I think, with justification.

You are presenting here a different type of system.

I wonder if at the outset you could clarify one thing on dates for me.

You mentioned early in your statement that a stationary satellite with truly operational capability can be launched in the first half of 1964.

When would the second and third satellites be launched under such a schedule so that you had a complete system?

Dr. ADLER. Let me comment on that.

What we are assuming is the following: That, first, the Mark I, the current flight test program, is successful and is successful in early 1963; that at that time the NASA would start to fund, at an accelerated rate, the Syncom Mark II, the Syncom Mark I basic technology having been proven.

This would then lead to the first flight test of a Syncom Mark II about the middle of 1964, and this is the first one you have referred to.

The second one we could put up very shortly thereafter, I would say within a couple of months.

Mr. HECHLER. You are asking for a delay in the basic decision to commit to a medium-altitude system; is that correct?

Dr. ADLER. For a delay in the medium-altitude system, did you say?

Mr. HECHLER. You are asking for a delay on the part of the authorities NASA or the corporation to commit to a medium-altitude system; is that correct?

Dr. ADLER. I think we are asking possibly even for more than that. We are suggesting that since the stationary system is in our opinion the optimum operational system eventually, that we should commit only to that unless it is shown that there are some flaws in the basic concepts of our stationary system.

Mr. HECHLER. How soon in terms of timing do you feel that you could demonstrate the capabilities sufficiently to arrive at the kind of decision that you are asking for?

Dr. ADLER. We feel that Syncom Mark I would demonstrate essentially all of the basic concepts and features that are in question here, and this would be early in 1963.

Mr. HECHLER. Early in 1963?

Dr. ADLER. Yes.

Mr. MURPHY. I would like to expand on that.

Our present Syncom I contract calls for three flight models, and it is our understanding the the NASA intends to launch all three at about 2-month intervals.

The first of these will be available for launch just after the first of the year.

So that all three will be launched by May or June.

We feel that at least one of those three will be successful and will demonstrate the soundness of our design—hopefully, the first one will be successful—and by February then we should be able to say “This is the system we should go ahead with.”

Mr. HECHLER. Do you foresee any danger in decisions by NASA prior to early 1963 that would knock out any features of your development?

In other words, if decisions were made to go ahead with construction of ground stations and decisions were made to capitalize on our success with Telstar, how would this hurt what you have in mind?

Mr. MURPHY. I don't think that the difficulty, or the danger, let's say, would result from decisions of NASA.

As we understand their position, they intend to forcefully push all development ideas, including passive satellites, medium-altitude satellites and so on.

I think the danger might come from one of two agencies. First of all, the new company that has been formed as a result of the satellite communication bill, might go ahead with the medium-altitude system and, secondly, the military, because of its urgent need, might go ahead with a Telstar system, which has already been demonstrated in part.

There is no question in anyone's mind, I believe, that a Telstar system could be built. There certainly is the question in a lot of peoples' minds about whether our system will work. We have to demonstrate it, just as Telstar has been demonstrated.

Mr. HECHLER. Let me rephrase my question to include decision by the new corporation. If such a decision should be made, how would this hurt your development?

Mr. MURPHY. If they made a decision to go ahead with a medium altitude system prior to our demonstration, then I think that they would ultimately add a synchronous system. But as we mention in our testimony here, the public will not be able to receive the full benefit of such a system if expensive ground stations, more expensive than necessary, have been already installed to work with the medium altitude system.

Mr. HECHLER. What you are afraid of then is that the investment of funds in a number of ground stations for the medium altitude system might preclude turning to Syncom?

Dr. ADLER. It would not necessarily preclude this, but it would take away some of the very important advantages of a stationary system, namely, its lower cost, because you will have already spent the larger amount of money required to put in a medium altitude system.

Mr. MURPHY. There is another factor, Mr. Chairman: As we know, from past experience with communications equipment, it is very expensive, and it is very involved as far as how it is used operationally. It is often difficult to introduce new technology in existing communications, even though the new equipment is clearly superior to some we have. It must also be depreciated over a long time.

Mr. HECHLER. There are many questions members of the committee and the staff would like to ask about such issues as reliability of the plans for insertion into orbit, and the reliability of the whole communications system.

Mr. Roush, do you have any questions?

Mr. ROUSH. Just to comment, in addition to your praise, on the statement.

I would like to add that the thing that struck me about the statement is its very competitive attitude. At least a competitive attitude is reflected in it. I for one appreciate that attitude. It is also a very persuasive statement.

I think, Mr. Chairman, I shall let you and the staff go ahead with the more technical questions.

Mr. HECHLER. Mr. Karth?

Mr. KARTH. Mr. Chairman, I want to join you in congratulating Hughes. I think this almost sounds as if I had written it. I agree. [Laughter.]

If you don't mind, Mr. Chairman, I would like to ask just one or two questions.

How much acceleration on Syncom Mark II is needed if Syncom Mark I, in the first flight of the launching of it, seems to be successful?

Dr. ADLER. Let me explain first what the Syncom Mark II program consists of at the present time.

It is basically an advanced technology development—we are developing four of the most critical items.

We are developing the hot gas control system, the electronic transponder; the structure itself, and the apogee booster motor.

These are the four items that are now in development, because they are the four items that require the longest leadtime.

Now, we feel that the rate at which the program is going at the present time is a very reasonable rate, and that the NASA has acted very judiciously in doing just what they did.

At the time that Syncom Mark I is proven we feel Syncom Mark II ought to become a full-fledged flight test program and enough additional money should be put into it to make the 1964 flight date that we have mentioned possible.

Mr. KARTH. How much is that?

Mr. MURPHY. The cost to our program to accelerate it next March would be approximately \$15 million.

Mr. KARTH. This is the acceleration you are talking about to get Mark II going?

Mr. MURPHY. To build a prototype and do its environmental testing and to build three flight models. To cover the Hughes' costs for preparation of flight models, for launch, and for controlling them in orbit.

Part of our contract with NASA includes our operating command and control stations. Three of them will be available.

Mr. KARTH. How much does Mark II weigh?

Mr. MURPHY. The Mark II satellite weighs 1,211 pounds when injected into orbit.

Of that 1,211 pounds approximately half is used to circularize the orbit at apogee at the synchronous altitude. This is the apogee motor that Dr. Adler mentioned.

Mr. KARTH. That is built right into the satellite?

Mr. MURPHY. It is part of the satellite structure; yes.

The satellite in orbit initially will weigh 545 pounds. The Agena has a capability, according to Lockheed, and we have confirmed their figures, to inject into orbit more than 200 pounds more than that. They can inject on the required transfer ellipse 1,470 pounds, by their calculations.

My understanding is that the Rand Corp. believes the Atlas-Agena can do even more than that.

So there is no weigh problem with the Atlas-Agena.

In the case of the first Syncoms the Delta can just barely inject our weight, if we want to be sure that the second stage of the Delta would fall in the Atlantic even if the fuel cutoff switch did not work.

Mr. KARTH. Some of the technology in Mark II is completely and totally new, isn't it?

Mr. MURPHY. The four items Dr. Adler mentioned are new. The rest we expect to be very similar to the Mark I.

Mr. KARTH. And even despite this you feel that if you had the acceleration necessary you could get an operational system of this type by 1964 or 1965?

Mr. MURPHY. Dr. Adler said that we could launch it by July of 1964. I think we could launch it actually ahead of that if there is extreme urgency. The Syncom Mark II program in my opinion will be an easier engineering job than the Syncom Mark I has been.

We will have delivered Syncom I satellites within 16 months of the time that we originally got the contract.

Mr. KARTH. If this acceleration came about, when would it be operational, when would the Mark II system be operational?

Mr. MURPHY. The Syncom II satellite itself will, in our opinion, provide all the communications capability required for an initial operational satellite, so the question—

Mr. KARTH. That would be 90 percent coverage?

Mr. MURPHY. We could have three in orbit we feel by the end of 1964.

Mr. KARTH. This is what you and I could agree would be an operational system?

Mr. MURPHY. No. It would be the operational satellite portion of a system.

When the ground stations will be built, and how long they will take, is of course involved with the formation of the new company, and how soon they will commit themselves to development of those stations, and so on.

Mr. KARTH. If the ground stations would proceed with the same rapidity we could have an operational system by the end of 1964; is that correct?

Mr. MURPHY. Yes.

Mr. KARTH. Mr. Chairman, I don't want to take a great deal of your time, but there was substantial testimony before my subcommittee a month or so ago where both General Schriever and Assistant Secretary of Defense Rubel testified that the medium altitude system was a much quicker system to come by. Your testimony today of course is that the Syncom system would be the quicker system to come by and, of course, much cheaper.

How could those of us who are interested in this communications satellite program, justify the disparity of opinion here?

Dr. ADLER. I think it is important to define what kind of medium altitude system you are comparing the Syncom system with.

I am sure that there are medium altitude systems which can be developed at a very fast rate, possibly faster than the dates we have talked about, which will give some capability to the military, not the same capability as either the stationary system would give that we have discussed or the capability a full medium altitude 50 satellite Telestar type system would give, but it might give a degraded, minimum capability of some use to the military at an earlier date.

So I think in this area both testimonies agree.

Mr. KARTH. How about the commercial system?

Dr. ADLER. If you want a fully operational commercial system—

Mr. KARTH. Let's say one that gives us 90 percent coverage?

Dr. ADLER. Yes, but which is commercial in the sense that it satisfies the ITU standards set by the CCIR and CCITT, and so on. Then we honestly believe that you can do this earlier with a Syncom system because of the fewer satellites that have to be built, the fewer satellites that have to be launched, and, of course, the simpler ground stations that have to be put in.

Mr. KARTH. Then why isn't this true of the military system, because you have to build in the same capabilities to both systems, that is, the encryptic capability and the antijamming capability, and so on?

Dr. ADLER. If you are talking about a full capability system, what you might call the ultimate military system, which will give the military the full required capability, then, if you are comparing doing that job either with a stationary system or with a medium altitude system, we feel, indeed, that this capability can be achieved earlier with the stationary system.

Mr. KARTH. But as far as the minimal capability is concerned, you feel that that might be possible earlier with a medium altitude system; is this correct?

Dr. ADLER. It might be. I don't think we are really fully qualified to state this, since you would have to define in detail what system you are really talking about.

Mr. KARTH. Do you want to comment, Mr. Murphy?

Mr. MURPHY. There is one other possibility for an early military system. The Syncom I to save money was designed to work with the Army Advent ground stations, so if the first Syncom I gets up and works we have a very limited communications capability but one that is available early in 1963.

Mr. KARTH. As far as the military ground stations are concerned, I assume this is pretty well on its way, and as far as integrating the ground station system with the satellite itself, that there probably would not be a delay?

Mr. MURPHY. The ground stations?

Mr. KARTH. As far as integration was concerned for the military, isn't this so?

This is my understanding, at least.

Mr. MURPHY. The ground stations that will be used to receive Syncom I are the ground stations that were intended for Advent.

By definition Syncom I had to work with those ground stations.

Those stations operated at a receiving frequency of 1800 megacycles, which is not accepted for use—

Mr. KARTH. Conversion is not a great problem, is it?

Mr. MURPHY. To convert to another frequency would be a significant problem, yes.

Mr. KARTH. It would be?

Mr. MURPHY. For any system, yes, sir.

Mr. KARTH. Just one other question, Mr. Chairman.

Insofar as TV coverage is concerned, would this capability be built into the system about as expeditiously as the telephone communications system? I mean, are you also talking about 1964, the latter part of 1964, for TV capability?

Dr. ADLER. Yes; the satellite which we have called Syncom Mark II here—this is, incidentally, not the official nomenclature—call it the advanced Syncom, if you like; that system, in any case, will have capability for both TV and/or telephony.

Mr. KARTH. But not both?

Dr. ADLER. Yes; it can have both at the same time.

Mr. KARTH. With the same weight?

Dr. ADLER. Yes. That satellite in effect carries within its space-frame four separate satellites, if you like. They are four quadrants and each of these is the equivalent of a 600-channel communications satellite, providing either 600 telephony channels or 1 TV channel.

So, for example, you could use one of these quadrants for TV and the other three for telephony, or any combination that you care to.

Mr. KARTH. Are you at all familiar with the Advent satellite in its present state of the art?

Dr. ADLER. Somewhat.

Mr. KARTH. The one that was recently declared obsolete?

Dr. ADLER. We are somewhat familiar with it.

Mr. KARTH. You are using an entirely different concept, I assume?

Dr. ADLER. Yes.

Mr. KARTH. The makeup of the satellite is quite different?

Dr. ADLER. Yes; both construction as well as its method of orbit injection are different.

Mr. KARTH. This orbit injection thing seemed to bother a great many people, including those who were in the military, in the Department of Defense.

Do you see this as a great problem that would be overcome only with substantial difficulty?

Dr. ADLER. Well, if you do not mind, Mr. Chairman, I will go into this a little bit—

Mr. KARTH. This seems to be one of the reasons why they hesitate, Doctor, in going ahead with the synchronous system, because they say this particular phase of the syncom system has not been worked out.

It is, indeed, very difficult?

Dr. ADLER. Not really.

Mr. HECHLER. Very complex?

Dr. ADLER. Well, let me make two statements about it.

One, of course, is that the basic features of it will be proven out—or disproven—with Syncom Mark I early next year.

I felt this question might come up in this testimony this morning, and I have a chart which, with your permission, I would like to use to explain a little bit what the system is—at least the basic concept—and why we feel it is within the state of the art.

Mr. HECHLER. Yes. I think it would be well to proceed with that right now, Dr. Adler.

SYNCOM MARK II LAUNCH SEQUENCE

HUGHES
THE SPACE SYSTEMS COMPANY
 SPACE SYSTEMS DIVISION

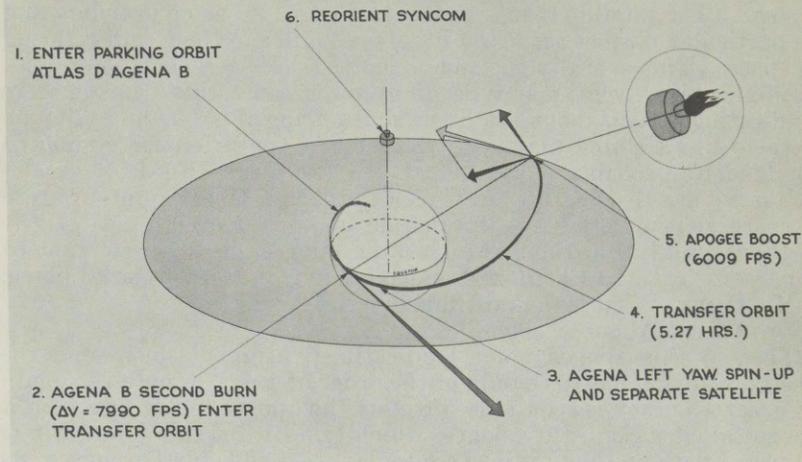


FIGURE 2

Dr. ADLER. This [indicating] is the launch sequence in basic outline for Syncom Mark II, for the operational type system, that will go into a truly stationary orbit.

We have the Earth in the middle here [indicating] and here the equatorial plane.

If you like, I shall submit for the record a smaller version of this chart.

The satellite would be launched at this point here [indicating], which is supposed to be Canaveral, at a latitude of 28.5° . It goes into a parking orbit at an altitude of about 90 miles until it reaches this point [indicating] the equatorial plane—it passes through the equatorial plane at this point [indicating].

If you let the satellite go on, it would pass again the equatorial plane at the opposite point here [indicating].

At either one of these points [indicating], we would start the second burn of the Agena. As you know, the Agena has a restart capability and at this point [indicating], we would add about another 8,000 feet per second of velocity, the original velocity here [indicating], being about 25,600 feet per second. This then places the satellite into the transfer orbit shown here [indicating].

Now shortly after the second burn we spin up our satellite to about 100 revolutions per minute. We also position it in the right altitude appropriate for the final apogee boost—which I will explain in a moment.

For this purpose we use the Agena guidance system.

So what we then ask of the Agena is that it can position the satellite to within about 1° at this point which occurs about 20 minutes after liftoff.

This accuracy is well within the capability of the Agena guidance system.

Now, at this point then [indicating], when we have positioned the satellite in the proper attitude and spun it up, we separate it from the Agena and do not make any further use of the Agena guidance system. The satellite then acts as a free gyro; it has no bearings, and no particular torques acting on it. It is similar to the Earth rotating in space. This is really the fundamental trick here, that you do not rely on any conventional type of gyros, because this transfer here [indicating], lasts about $5\frac{1}{2}$ hours and during this $5\frac{1}{2}$ hours if you were to use a stable platform, or inertial type reference system, it would drift probably more than the drift we can afford.

But we use the satellite itself as a gyro, as a freely spinning gyro in space, so it merely keeps its attitude as it goes through until it gets to this point [indicating], which is its apogee, or furthest point of departure from the Earth, and which again is in the equatorial plane.

Mr. DAVIS. What is that altitude in miles?

Dr. ADLER. About 22,300 miles.

Then at this apogee point [indicating], using a timer—and the accuracy of that has to be only of the order of 1 or 2 minutes, so again no great accuracy is required—we start the apogee motor; we give it the so-called kick in the apogee, which takes it off this [indicating] elliptical path and puts it into a circular path and, furthermore, puts it pretty precisely into the equatorial plane.

In terms of the speeds here, at the end of the ellipse the satellite has slowed down to about 5,000 feet per second, to which we add enough velocity to give it a total of about 10,000 feet per second, which is the synchronous speed.

The key point I wish to make here has to do with the accuracy required. I mentioned that down here [indicating] we rely on the Atlas-Agena guidance system to give us about 1° of accuracy, which is within the state of the art. Up here [indicating], at apogee, we can allow a total inaccuracy of about 2° in the direction of the applied thrust. We can also allow about $1\frac{1}{2}$ percent variation in the impulse from this motor, which is, again, within the state of the art.

We have calculated that the worst total error that we then will have to correct is about the equivalent of a velocity error of 300 feet per second, so we have allowed this much correction capability in our satellite design for the initial alinement of the satellite, to make it truly stationary initially.

Incidentally, we have also looked at the accuracy with which the recent Ranger IV shot, which landed on the backside of the Moon, and the recent Mariner R, now on the way to Venus, were launched. These were launched using the Atlas-Agena guidance system also. If we could have the equivalent accuracy in our launch, then we would only need 50 feet per second of correction capability rather than the 300 feet per second which we have actually designed for.

So we have been quite conservative in our assumptions regarding the accuracy of the Atlas-Agena guidance system—at least as demonstrated in these two flights that I mentioned.

Mr. MURPHY. I might make one point that you might have overlooked, Dr. Adler.

We have, on board, the ability to correct out 2,300 feet per second.

Dr. ADLER. I come to that later.

We have supplied 300 feet per second, which we figure is quite enough for the initial orbit correction to get it into stationary orbit initially.

We have also designed the satellite so it could stay in a synchronous orbit for 5 years or more. For that we have supplied an additional 2,000-foot-per-second capability of correction.

Now, actually, due to the effect of the Sun and the Moon, you need to correct for about 170 feet per second per year of orbit inclination change and then the triaxiality of the Earth requires about another 20 feet per second of velocity correction; this is due to the fact the Earth is not really round at the Equator but has a bulge.

So we have actually supplied enough here [indicating] to give a thousand feet per second in each of two redundant systems or a total of 2,000 feet per second.

So we feel we have a lot of control capability once we are in orbit.

Mr. KARTH. How about the drift of that spin system?

Are you concerned about that?

How much did it vary and still fulfill its responsibility?

Dr. ADLER. We would like to keep the satellite within about a tenth of a degree. A correction would be made whenever it gets to about 0.05 degree. We would give it a correction to make it drift back to center, so to speak.

A tenth of a degree at this altitude is equivalent to about 30 miles. So the picture would be of a satellite drifting very slowly back and forth over this [indicating] distance and being given a correction maybe every 2 weeks, or something of that order.

Mr. DAVIS. When you say a degree, are you calling a degree a departure from the equatorial plane?

Dr. ADLER. A departure in any direction from the stationary point you like to have in the equatorial plane or out of it; that is, either in latitude or in longitude.

Because the ecliptic and the Equator are not in the same plane, the satellite is caused to drift out of the equatorial plane, that is, it acquires some inclination and this inclination we then have to take out, using our correction capability which is supplied by the gas jets that we have aboard.

Mr. DAVIS. That degree that you are talking about, the angle, in other words, would be from a line drawn from the satellite to the center of the Earth, and then back out to a point over which you wanted the satellite to go?

Dr. ADLER. Yes. You would like the satellite in a particular point in the sky. If you were to draw a line to that point, it is relative to that line that we measure.

Actually a tenth of a degree allowance is what I mentioned.

Mr. DAVIS. Yes.

Mr. KARTH. You do not see any great problem in the drift of this spin system; is that correct?

Dr. ADLER. No, we do not—not with this kind of a scheme. I think, again, the important point to make is that if we did not separate the satellite at this point, but relied on the booster guidance system all the way to this [indicating] point, then we would probably be in trouble, because then we have the guidance system drifting for about 6 hours—and now we are talking about something that is better probably than current ICBM technology.

Mr. KARTH. Once in orbit, you see no great problem?

Dr. ADLER. No. Once in orbit, you have lots of time to observe and plenty of correction capability.

Mr. HECHLER. Are you talking about current booster capability now or are you talking about the time when this will be launched in 1964?

Dr. ADLER. No; we are talking strictly about current booster capability and the current Atlas-Agena guidance system. That is why I wanted to emphasize the comparison with the two recent launches of Mariner and Ranger, which use the same kind of booster.

Mr. HECHLER. So you think you might even have a better margin in 1964, as boosters and guidance systems are improved?

Dr. ADLER. Yes; that is a very good point, because Lockheed is indeed working on some improvements to the Agena guidance system, and those would make this job even easier.

Mr. HECHLER. I would like to ask you a question, Dr. Adler, on reliability.

When you have three satellites up at 22,000 miles, there is a loss of a fraction of a second, as I understand it, between the transmission of the signal and its receipt on the ground, which might create an echo or feedback.

What have you done to suppress this or iron it out?

Dr. ADLER. Well, I think there are two problems: One is a problem that you can do nothing about. That has to do with the finite speed of light or radio waves, the time which it simply takes in getting from one ground station to the satellite and to the next ground station on earth. This takes about 0.3 second.

So there is this 0.3-second delay, or a total round trip delay of 0.6 second.

This is the delay, and we distinguish that from the echo problem you brought up. The delay is a fact of life that is inherent in the laws of physics and there is nothing you can do about it.

A lot of experiments, however, have been done to investigate its effect on the quality of telephone conversations. The Stanford Research Institute has been doing this for quite some time, under a NASA contract. I believe that the Bell Telephone Laboratories have been doing similar experiments.

As far as we can tell, I think a fair summary of these experiments would be that this delay is not objectionable. Indeed, it is often not noticed.

So we don't feel the delay is a problem per se.

Now it may be a problem in some cases where you have two people trying to interrupt each other, or trying to count off numbers, or in some very special situations, but in general the delay we do not feel would be a problem.

Let's talk about the echo for a moment. If you have ever talked over a trans-Atlantic cable you have noticed a little echo of your voice coming back.

Since it comes back with very little delay, it is not very objectionable. If it were to come back with the 0.6-second delay, it would be objectionable. So what is required are better echo suppressors.

We have echo suppressors in operation now. We need better ones for this kind of a system. And a number of companies, General Telephone & Electronics in particular, have worked on this problem, and

as far as we can tell have a workable solution to a better and adequate echo suppressor.

Mr. HECHLER. What do you mean by "a workable solution"?

Does this mean something is available now?

Dr. ADLER. Something is available now. I would say not really completely operational in form, but in the prototype form where it can be demonstrated, and has been demonstrated. In fact I believe they are available on the open market.

Mr. MURPHY. That demonstration was done over 2 years ago by the General Telephone Co., and as far as I know, it is completely producible, and is not a problem in getting the system into operation.

Mr. HECHLER. I would like to read a couple of lines from a statement that Commissioner Craven of FCC made before the Senate committee last month.

Quoting from Mr. Craven:

I have had some conferences with the representatives of the British Post Office. At this time they are not convinced that the high level synchronous orbit is satisfactory for their purposes, because it requires a double relay between London and Australia. So we are going to have international disagreement until we can prove it will work.

Could you comment on that?

Dr. ADLER. It is true that if you want to go completely via satellite from England to Australia, you need in general two bounces, and the 0.6 second delay that I talked about then gets doubled and becomes 1.2 seconds.

Again, as far as we can tell, the Stanford Research Institute studies show even that delay is not really objectionable.

We are, however, aware of the position of the British Post Office and hope they will eventually change their position.

Mr. MURPHY. I would like to add this: There are ways of solving this double bounce from eastern Australia to London. One is to go by landline to southern Europe and then directly through a satellite.

A second method is to go to western Australia, which can be reached in a single bounce, and by landline across Australia to Sydney.

There is a third possible way. That is to use the submarine cable from England to New York, across the United States by microwave, and then through the Pacific satellite to Australia, which again can be done in one bounce.

Mr. HECHLER. I am sure Mr. Boone and Mr. Hammill have questions.

First, Mr. Waggonner and Mr. Davis, have you any questions?

Mr. DAVIS. No.

Mr. WAGGONNER. No.

Mr. HECHLER. Mr. Boone?

Mr. BOONE. Dr. Adler, I think you should clarify—this double bounce business only pertains to voice communication, does it not?

Dr. ADLER. Yes. That is a good point. If you are sending television there is no problem. You only go one way then.

The same is true if you send data, facsimile, and so on.

Mr. BOONE. Thank you.

Mr. KARTH. Mr. Chairman, could I have one question?

I have to leave.

Mr. HECHLER. Yes.

Mr. KARTH. This is in connection with our hearings on the military satellite. If you got the go-ahead on this and if Mark I proved to be successful, do you then have the capability to give the military an operational system by 1964 or 1965, via the Mark II method?

Dr. ADLER. I would say that would be roughly the time period. You must recognize, of course, in addition to what we would be developing for the NASA there would be other unique developments required.

Mr. KARTH. I mean if Mark I proved to be successful, so that the system was OK, then you could actually, if the military was desirous of going ahead, you could actually give them a system by 1964 or 1965; is this true?

Dr. ADLER. Yes, in that time period.

Mr. KARTH. Thank you, Mr. Chairman.

Mr. BOONE. In line with that question, do you consider Syncom I is a prototype development?

Dr. ADLER. Syncom I is not a prototype. Syncom I was basically conceived as an experiment to prove out certain concepts of orbit injection or orbit control, and so on. It can however be given, as has been pointed out, some communication capability. You can put in the proper kind of transponder to link together ground stations and talk or send data over Syncom Mark I, and we have, indeed, proposed such applications.

This will be strictly an interim capability, strictly a degraded capability, but very possibly a quite useful capability.

Mr. MURPHY. It would be a continuous capability—which is important.

Mr. BOONE. I think in the Advent hearings we were told there are certain new technologies that should be discussed in any subsequent Advent development.

Are you aware of these and have you included these things in your Syncom I, or did you intend to do them in Syncom II?

For example, the traveling wave tube.

Dr. ADLER. The traveling wave tube, of course, is what we do use, both in Syncom Mark I and would be using in the so-called Mark II.

This traveling wave tube for other applications—military application—would be a different tube, different frequencies, and so on, and would require development.

Mr. BOONE. Could you tell us in a little more detail what the difference in Syncom I and Syncom II is, to take care of this 300-pound difference in weight?

Mr. MURPHY. In Syncom I we have an orbit correction capability of just under 400 feet per second for the 80 pounds that the Syncom weighs once it gets up into orbit.

For Syncom II, as Dr. Adler mentioned, we have 2,300 feet per second correction capability for the 550 pounds.

So we have many times the control system capacity.

In addition, the Syncom II will have on board eight wide-band transponders and the Syncom I has on board two narrow-band transponders.

We have 4 times the communications weight and some 1,200 times the communications capacity.

Part of the increase in capacity comes from a very significant increase in the antenna capability of the satellite.

The Syncom I radiates an antenna pattern that looks like a pancake. The Syncom II radiates a pattern which looks like a pencil. It is a pencil that is kept pointed at the earth all of the time and it is just the width of the angle subtended by the earth at 22,000 miles.

These are some of the differences.

Mr. BOONE. This is a directional antenna.

Mr. MURPHY. It is more directional than any we have seen proposed for a three-axis system, as a matter of fact.

Mr. HECHLER. In terms of receiving and transmitting, doesn't spin-stabilization have less capability than a three-axis stabilized satellite, as the antenna would always be pointed to the earth?

Dr. ADLER. We are just covering that point. We are proposing a pencil beam pointed at the earth. There are two ways you can do this.

You can either stabilize the whole satellite with the three-axis system and then have, for example, a parabolic antenna or something equivalent that is always pointed at the earth. This is one way.

We feel this is the hard way of doing it.

What we propose to do with the spinning satellite is equivalent to this, but it is simpler. What we do is form a pencil beam and we electronically spin this pencil beam with what is called a phased array. We change the phase of the microwave energy that feeds the antenna in an appropriate manner so that this beam spins at an equal and opposite rate to the spin of the satellite and thereby is kept pointed right at the Earth continuously.

So we do have a pencil beam, but do it with a spinning satellite, and furthermore, we do it without any moving parts, purely electronically.

This, incidentally, is also one of the present advanced technology developments that we are doing on the NASA contract.

Mr. MURPHY. We have demonstrated that antenna; it is not a paper proposal. We have the hardware in operation. We demonstrated it to the NASA before they actually give us the Syncom II advanced technical development program.

Mr. BOONE. Don't you feel that we will ultimately go to some other stabilization in the satellite?

For example, do you not consider phone conversations between two satellites in orbit?

You have to have some directivity at that time, do you not?

Dr. ADLER. Oh, yes. I don't think we are meaning to say that the design that we have described here and elsewhere, the so-called Syncom Mark II or advanced Syncom, is by any means the ultimate design, nor that eventually you will not have more than three or four satellites.

You may have quite a few more. You may have more advanced designs. Designs in which, as you point out, you may have inter-satellite communications, but I think there we are talking about the second generation of an operational system rather than the first generation.

Mr. BOONE. I wanted to ask, are you on schedule with your development program in Syncom I, and what problems do you foresee here?

Dr. ADLER. I think it might be worth while, Mr. Chairman, if you agree, for Mr. Murphy to give a very short rundown on where the Syncom Mark I program stands in terms of schedule and performance.

Mr. HECHLER. Proceed, Mr. Murphy.

Mr. MURPHY. The contract for Syncom I called for delivery of the two flight models in 13 month after go-ahead, and we expect to deliver within 16 months, so we are 3 months behind.

When you consider the number of new technical features in the system I think most people are surprised we have been able to do it within that time. We have run into difficulties. So far all of them have been solved. We now are at a very crucial point. We are putting the system into environmental tests. We will admit that some very difficult problems could arise.

NASA follows a plan—which I agree with, and is perhaps the reason for their high success rate—they subject their satellites to one and a half times the stress in every regard that they expect it to ever see in operation, the theory being that if it can stand 150 percent of the worst condition it could possibly see, it is probably going to work.

We are about to subject ours to that 150-percent stress as a system. We have conducted a number of tests already of this magnitude. For example, the satellite has survived what is considered by ourselves and NASA to be the worst test, 150 percent of the worst vibration that it will see in launch.

We had a number of things fail there, but they have been corrected and have now passed.

We also operated the electronics in one and a half times the worst thermal-vacuum environment it will see and only one part failed. That has been changed, been replaced.

We are within 3 months of the original schedule, which everyone said was unduly optimistic.

Dr. ADLER. To explain what that original schedule was: the contract was let in August 1961 and originally called for September 30, 1962, delivery of the first article, first satellite—first two satellites, rather.

We are now talking about a December delivery instead of September.

Mr. HECHLER. I want to put this a little bit into the perspective of the space race.

You have made reference to how, if we concentrated on what you are recommending, we would win the space race in the communications satellite field.

I wonder if you care to comment on this observation of Senator Symington before the Senate Foreign Relations Committee.

Science and technology are racing along. We are bound to see vast improvements in space communications satellites over short periods of time. One of the big reasons for this is that we do not wait. Telstar is, in fact, a much more sophisticated system than the synchronous-orbit, one-telephone-channel satellite that we now have in development.

* In closing that statement, Mr. Chairman, I want to say that on another committee, the Subcommittee on Military Appropriations of the Appropriations Committee, we went through this problem in a different way. We kept on putting off, postponing, the concept of a satellite, because we had something better just around the corner.

Nobody ever quite found the street the corner was on, however, and the next thing we knew, the Russians had their sputnik in the air, and we did not get a satellite up for many months.

And so I would hope, technically speaking, we would not put off utilizing the Telstar or something comparable, say the Relay, waiting for a development which, as of now, is only one telephone relay circuit. Under those conditions we can be certain the Russians will again be first in a space field.

I would like to have you direct your comments to this, because, in essence, what you are asking for is a delay until you have developed your system, which you hope to be superior.

Now, I wonder if you would underline again what you feel the advantages of your recommendation would be in the space race.

Dr. ADLER. First, let me say that we are not at all opposed to capitalizing on Telstar and later on Relay as really great national achievement vis-a-vis the Russians.

I think it is a great achievement and I think we ought to make all the hay out of it we can. No question on that.

I think our comments are really directed at what kind of a worldwide commercial operational system we should invest in.

So I think there is a little distinction here between what you do as a national prestige item, on the one hand, and what you really put in as a commercial system, requiring large investments of money, on the other hand.

It is with the latter that we are concerned when we say let's not make the major investment required to put in a Telstar-type worldwide operational system.

I don't think I would argue with Senator Symington at all that we should not capitalize on the achievement that Telstar represents and on the achievement that Relay may represent when it goes up.

Now, when we are talking, however, about an operational system which will tie different parts of the world together, then I think it is important to stress again the advantages that can come with the stationary system.

We did this a little bit in our prepared statement, but perhaps I can, if you like, elaborate on it now.

We mentioned the feature called multiple access. We also mentioned that the ground stations are relatively cheap for a stationary system and that, furthermore, they can be sized in accordance with the traffic requirements.

In other words, if you have one of the newly emerging nations, like Ghana, or some other developing nations in Africa or Asia, their traffic requirements are relatively small, they are too small to warrant putting in a full Telstar type of ground station, which would require investments in excess of \$10, possibly \$30 million.

However, if we are talking about an investment required which is a fraction of a million, which would be adequate with a stationary system to handle their traffic requirements, then that can be economically justified.

By that, I mean that such a nation, or a private company, could actually make a profit were it to put in such a system.

So the point I make is that if we have a stationary satellite up, then all nations would be in a position to directly communicate with that satellite and therefore with each other, directly, without having any ground lines required. This is in distinction to the Telstar type system where if you are talking about the African nations you might have one large gateway station in Africa, like in Johannesburg, and you would have to route all the traffic to this one station and take it from there.

In terms of national pride, this is clearly undesirable and in terms of economics it is also undesirable.

If we are talking about tying these nations into the Western system, I think you want to do it with a multiple-access stationary system where you can tie them all directly into your stationary satellite system.

Mr. HECHLER. Can anybody use this system?

Can companies in the Soviet Union, Red China, and others, tap into it?

Dr. ADLER. They cannot tap into it at will, because of the way the system would work. If you wanted to talk you would have to have one of the various channels—2,400 channels, in the particular design we talked about—assigned to that station. If you wished to talk from Africa to Rome, Africa would place the call and ask for assignment of the line, this would be assigned, the same assignment would be made to the Rome station, and they would then start talking to each other.

Obviously, prior arrangements have to be made to make this system work. Therefore not anybody could tie into it.

Mr. HECHLER. I would like to ask you your comments on some observations which Dr. Hugh Dryden made on the Syncom system. He was not nearly as optimistic as you have been on the success of either the boosters or the guidance, and in his testimony last month he indicated as follows:

I might say that putting an object in a synchronous orbit around the earth is a very difficult technical problem.

The requirements are greater than those for sending an object to the distance of Venus, for example, because you not only have to get it to this altitude, but then you have to change its course, so to speak, so it is traveling at just the right speed with respect to the earth.

We find that it takes more fuel to put an object into synchronous orbit than to send the same object away from the Earth completely.

Then he goes on to say—this is the thing that really stopped me—quoting Dr. Dryden:

I have faith that eventually a high altitude system will be developed. My own guess is it will be 10 years.

He says 10 years. And you say 2 years.

Would you care to comment on Dr. Dryden's observation? Because this committee, of course, respects his technical competence, and his analysis of the situation has been fairly accurate in the past.

Dr. ADLER. Yes. We certainly fully respect his technical competence, and I am just wondering if perhaps he and we are talking about different techniques for achieving the synchronous orbit, and about different types of operational systems.

Mr. HECHLER. He also goes on to say:

It is going to take bigger boosters than we now have. Probably the development of new stabilization techniques that do not depend on the use of gas bottles for their function.

I admire your optimism and confidence, but at the same time what this committee is interested in is pinning down whether this confidence is justified.

Mr. MURPHY. What Dr. Dryden seems to be predicting is that Syncom I and Syncom II will not be successful. There are other people that have predicted the same thing, and I think that we could talk

here for a long time and try to give you our mathematical analysis of why we feel we can do what we have said, but the only thing that will ultimately convince anyone is whether it gets up there and stands still.

Dr. Dryden has approved, as I understand it, at least our attempt to try to get it up there, and one of the two of us will probably be proved wrong.

Mr. HECHLER. That is a courageous statement. [Laughter.]

Mr. MURPHY. Incidentally, Dr. Dryden has been of great help to us in understanding this program, and has made very valuable suggestions.

We do respect his judgment.

Mr. HECHLER. Frequently we find skeptics are the strongest supporters of experiments.

Mr. MURPHY. I would like to comment on one other statement you made, since it has been put into many records, the statement about our having only two communications channels.

Mr. HECHLER. Yes.

Mr. MURPHY. The reason that we have only two channels in Syncom I is not through any inherent lack of capability in the satellite itself. Very wisely, to save Government money, we were required to use the existing Advent ground stations and to operate with them with as little change in the ground stations as possible—again to conserve funds.

Now, Syncom I will work with 30-foot ground stations, one-half the size of the Andover Horn, and with this relatively small antenna we could still provide a 18 two-way voice channel capability without changing the satellite. In addition, we could expand that quite a bit by making some minor modifications in the transponders and the antennas, as Dr. Adler indicated.

So we are not inherently a two-channel system, even with our first satellite.

Mr. HECHLER. You mentioned, in your statement, that Syncom Mark II would have the ability to handle up to 2,400 two-way telephone channels.

How does that contrast with the state of the art of the medium altitude system?

Mr. MURPHY. As I understand it, the Bell designs are based upon 300 two-way channels, but there is no reason why they could not have the same capacity if there was a demand.

It is more difficult to economically incorporate a 2,400 channel medium altitude system because it is essentially a gateway system, it is not a multiple access system.

It is very economical for us to expand the size of the satellite to cope with the total traffic requirement, due to this feature of multiple access.

It is not any more difficult, perhaps, technically, for them to expand, but economically it may not be as desirable.

Mr. BOONE. Mr. Chairman?

Mr. HECHLER. Mr. Boone.

Mr. BOONE. Going back to this question about installation time, or operational time, don't you feel that a number of these estimates are based on when, say, an operational system having more reliability is available, rather than, say, an experimental system—which the Telstar certainly is—and I would think Syncom I is also?

For example, I think the day-to-day communications system require considerably more reliability than we have experienced in any of our satellite systems.

Mr. MURPHY. In the testimony which we made before the Senate Space Committee we proposed an initial syncom system that would cost \$75 million to install, and we went through an analysis similar to the one I made—admittedly a rather superficial analysis—but one which indicated that system would begin to make a profit when 44 channels of the 2,400 were employed.

Less than 2 percent of the capacity was the break-even point with a satellite that lasted only a year.

If that satellite only lasted 3 months, you would still be under 5 percent for your break-even point. The economics of the synchronous satellite system are overwhelming when you first begin to talk about them.

Mr. BOONE. In line with this, there have been a number of estimates whether you need 3, 9, or 19 satellites in synchronous orbit.

Have you investigated that aspect?

Mr. MURPHY. The International Common Carriers, in their submission to the FCC a year or so ago, stated there would be a requirement just to and from the United States alone of 4,770 channels by 1970, and 14,000 channels by 1980.

This is a phenomenal growth in demand.

We would be the last ones to try to pass judgment on whether these are reasonable figures. I think technically we can meet them.

For example, we can easily expand the Syncom Mark II system from eight transponders to many more by using Titan III which would be available by this period, still using the same basic spinning control system.

We can also, we feel, put satellites closely spaced around the Equator, even on the same frequency, and not have interference.

There are calculations made that these satellites could be placed as close as 10° around the Equator.

So you could have at least 36 on the same frequency. By doubling the bandwidth, you could put another 36 up there.

There is plenty of space there for them.

Mr. DAVIS. Mr. Chairman?

Mr. HECHLER. Mr. Davis.

Mr. DAVIS. One question about the 2,400 conversations that could be set up.

You said before two people could talk, some sort of prearrangement would be necessary, through switchboard operator, so to speak.

Dr. ADLER. Yes; through a central station.

Mr. DAVIS. Would it be possible for the Soviet Union to monitor all 2,400, even though they cannot engage in a two-way conversation?

Dr. ADLER. They could, if they tried hard enough, set up listening

stations which could receive the reradiated signals from the satellite, because, you see, your pencil beam hits all of the earth, so therefore, part of the U.S.S.R., in general. They could have listening stations that could hear part of the conversations.

Mr. DAVIS. Then if our military, for example, wanted to set up a system, it would have to rely on coding its information for security purposes?

Dr. ADLER. Very definitely.

Mr. DAVIS. That is all.

Mr. MURPHY. The present radiation transmissions have the same problem. The HF circuits can be heard by anyone who has the equipment.

Again the military uses a considerable amount of HF communication around the world. They send some in the clear and use an encrypting system too.

Mr. HECHLER. Mr. Waggonner, any questions?

Mr. WAGGONNER. No.

Mr. HECHLER. Mr. Hammill?

Mr. HAMMILL. Just one, Mr. Chairman.

If the corporation which will be established under the terms of the Communications Satellite Act, recently adopted, decides to establish a system using intermediate altitude satellites, and the ground stations which have to be designed for that particular system, do you feel this would preclude the possibility of later establishment of the syncom type system, or do you feel that the demand might be such that we might have use for two systems?

Dr. ADLER. I think we have gone a little bit into the economic problem here, early in the testimony, from the point of view that if you first set up a medium altitude system, you will have to put in a very large investment, which would not have been necessary if you had put in the stationary system to begin with.

So from the economics point of view it is undesirable but not impossible.

I think one area where you will, however, run into difficulty is that of interference among the different satellite systems.

There are different kinds of interference. There is interference between the two satellites systems themselves, and there would definitely be this kind of interference.

In addition, there are also interference problems with the existing microwave links on the ground. This interference can be completely eliminated for stationary systems, but cannot be completely eliminated for random low-altitude systems.

It is pretty clear that you will eventually run into an interference problem, because it certainly would seem reasonable that eventually there will be more than one satellite system.

For example, some other nations will want to put up systems, just as now many nations, even some small nations, have their own international air carriers that fly partly for reasons of national pride.

I think the same will eventually happen in the communication satellite field.

So you then would have to take into account the problem of interference among these different satellite systems.

Again, the point to be made here is that different stationary systems will not interfere with one another, but different medium altitude systems can interfere and, furthermore, there will be interference between the medium altitude and the stationary systems.

This problem has been studied in some detail, and in more detail than I probably should go into here, but with your permission, Mr. Chairman, I would like to place in the record three papers on the subject, which I can leave with the recorder at the end here, which deal with the interference problem between different types of systems.

Mr. HECHLER. You have partially commented on this, but on the question of international allocation of frequencies, in terms of frequency spectrums will multiple use by many nations be feasible, and would joint use of frequencies with ground networks be possible?

Dr. ADLER. I think that eventually there will be enough demand for communication that you will have to operate on the same frequencies, that you will have to have so-called cochannel operation. A.T. & T. in their testimony, for example, as I recall, estimated some of these satellites may eventually have bandwidths as wide as 2,000 megacycles.

So when you talk about this much communication capacity obviously you will not be able to separate all the frequencies and will have to have cochannel operation.

Again, in the documents I would like to place in the record, this problem is analyzed and it is shown that cochannel operation is possible with stationary systems.

Cofrequency operation as far as we can tell is not possible without interference with other types of systems.

(The material handed to the official reporter for inclusion in the record is as follows:)

Documents
C. C. I. R. Study Groups

Doc. IV/4⁵
(U.S. Sub-Group F)
16 July 1962

Received:

Subject: Draft Report
Question No. 214 (IV)
Study Program No. 174 (IV)

UNITED STATES OF AMERICA

(Original language: English)

INTERFERENCE FROM COMMUNICATION SATELLITES TO
TERRESTRIAL RADIO RELAY RECEIVERS

1. Introduction

The first communication satellites will transmit signals which will be too weak to cause harmful interference to terrestrial microwave receivers, even when the latter have relatively high antenna gain toward the satellite. Whenever economics and technological advances permit the use of more powerful satellites, the use of stronger satellite signals will become advantageous for the following reasons: to provide greater baseband capacity within the same r. f. channel width, to provide greater margin against propagation degradations, such as from heavy rainfall, and to permit the use of simpler and less expensive earth receivers having higher noise temperatures (i. e., less sensitivity). Additionally, microwave receivers in the future may have lower noise figures and greater antenna gains; thus becoming more susceptible to interference from satellites.

Since present microwave antenna gains are in the order of 40 db, with correspondingly narrow beamwidths, successful frequency sharing with high-power satellites may depend on keeping such satellites out of the antenna beams of terrestrial microwave receivers. This report examines this problem and shows that satellites in a circular equatorial orbit can enter horizontal antenna beams from not more than two directions; these directions being simple functions of latitude. Hence, antenna augmentation of interference from circular equatorial orbit satellites, and possibly from those in certain other orbits, can be controlled by locating microwave receivers to avoid directing their antennas toward the satellite orbit.

2. Antenna Beam Elevation and Satellite Orbit Relations

Terrestrial microwave antenna beams are predominantly horizontal, even in mountainous terrain, because differences in antenna elevations necessarily are small compared with the 40 to 50-Km path lengths. Some

antennas are directed upward at a passive reflector which directs most of the beam horizontally, with some spilling around the reflector. Any satellite interference which spills around such a reflector will be neglected in the present report, partly because of the low probability of a satellite being overhead. Elevated antenna beams sometimes are used to relay programs to a broadcast transmitter on a nearby mountain, but in this case the program receiving antenna is directed below the horizon. Hence, in general, a satellite must be close to the terrestrial microwave receiver's horizon in order to enter its antenna beam.

A satellite in a polar orbit with a period unrelated to that of the earth's rotation may cross the terrestrial microwave receiver's horizon in any direction. In fact, when within view, its most probable elevation angle will be zero with the least probability of its being directly overhead. A similar statement applies to a satellite in an inclined orbit unless the microwave receiver is located near or beyond the orbit's upper latitude limit in which case the satellite may never cross some arc of the horizon toward higher latitudes. Any globally useful satellite communication system will have its satellites coming in view of most of the world's microwave receivers.

If a satellite has a circular inclined orbit with a subsynchronous period, one which is an exact submultiple of the earth's period, it may rise and set in two fixed directions from a terrestrial microwave receiver. For any such orbit, these two directions would be functions of both the longitude and latitude of the receiver's location.

A satellite in any circular equatorial orbit would rise and set in not more than two directions determined only by the orbit height and by the receiver's latitude. From a receiver on the equator, these directions would be due east and west. At a northern latitude, the two directions would be equally south of east and west. Denoting the deviation angle from east or west as δ (a southward deviation in the northern hemisphere or northward in the southern hemisphere),

$$\delta = \arcsin \frac{\tan \gamma}{\sqrt{\left(\frac{R}{r}\right)^2 - 1}}$$

γ = the receiver's latitude
 R = radius to the circular orbit
 r = earth's equatorial radius.

Figure 1 shows the geometry and derivation of the above equation. Figure 2 shows δ vs latitude, γ , for radii ratios, R/r , from 1.1 to 6.61,

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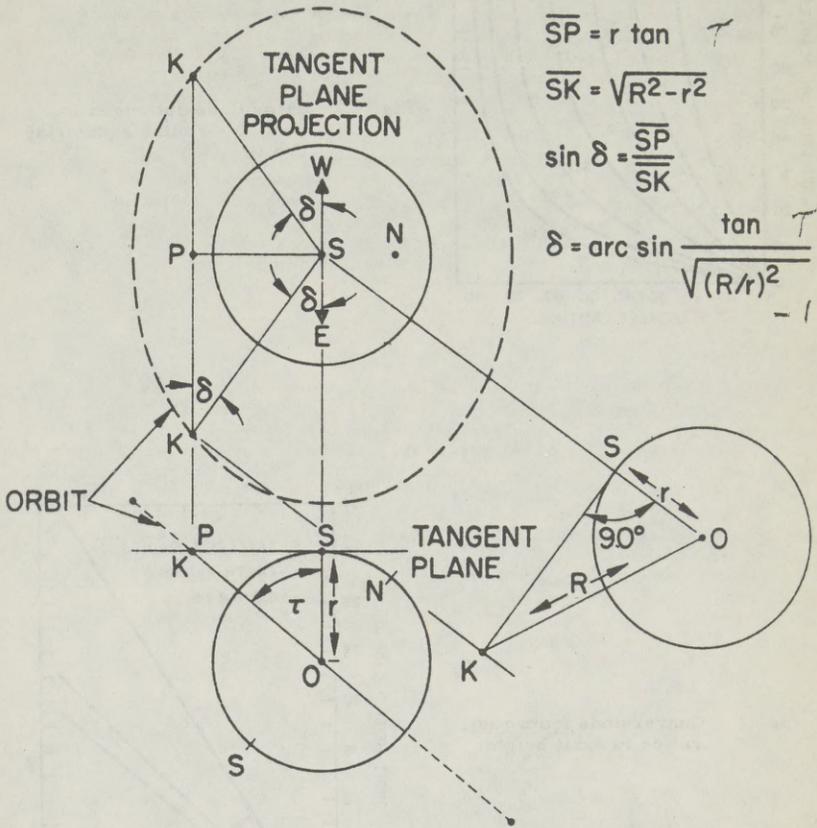


Fig. 1 Geometry of horizontal directions to circular equatorial orbits

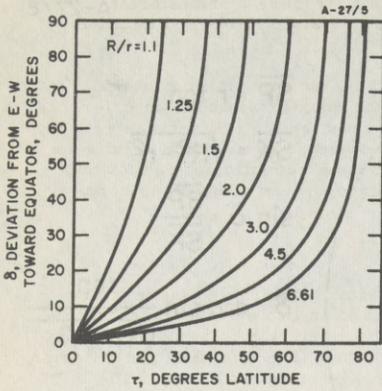
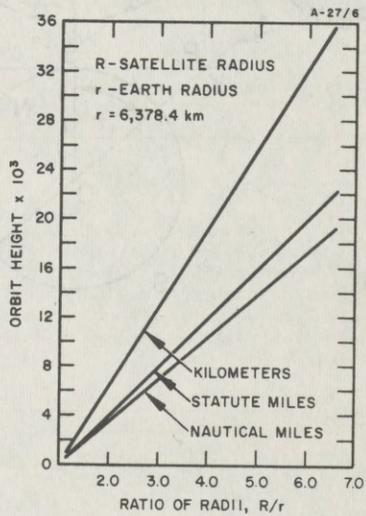


Fig. 2 Azimuth deviations from E-W to circular equatorial orbits

Fig. 3 Conversions from radii ratios to orbit heights



the latter corresponding to the stationary orbit. Figure 3 shows orbit heights above the equator, in kilometers, U.S. statute miles and nautical miles, as functions of R/r .

If a microwave receiver avoids directing its antenna in either of these two directions toward a specific circular equatorial orbit, interference from satellites in that orbit will not be augmented by the full antenna gain of about 40 db. A reduction of 20 db may be obtained by avoiding relatively narrow azimuth arcs, about 5 degrees, whereas a reduction of 40 db would require avoiding larger arcs of about 30 degrees, even when using horn-reflector antennas.

3. Satellite Transmitter Power Relations

Annex I shows calculations of the maximum tolerable transmitter power for satellites at three orbit heights based on two quite different interference criteria. Part A assumes the satellite emission to be noise-like with a flat spectrum and negligible carrier spike. The interference criterion is a 3-db loss of fading margin by the microwave receiver having a 10-db noise factor when the interfering noise power equals the receiver noise (-134 dbw per megacycle of bandwidth). A 3-meter antenna aperture of 55% efficiency is assumed. The analysis in Part B is more accurate for phase-modulated satellite and microwave systems with the former fully loaded and with large frequency deviation. The interference criterion is a 9-dba0 interfering signal power in a telephone channel during non-fading periods. The corresponding interfering carrier powers and loss of fading margins for two microwave systems are shown in the following table.

TABLE I

System	Nominal Frequency	Interfering Carrier at Receiver-Converter	Interfering Carrier to 40 db Antenna	Loss of Fade Margin
TD-2	4 Gc/s	120 dbw	160 dbw	2.2 db
TH	6 Gc/s	125 dbw	165 dbw	1.6 db

The flat spectrum assumption of Method A is a reasonable one for fully loaded SSB and small deviation PM or FM systems, but is optimistic when applied to wide deviation modulation which has an approximately Gaussian frequency spectrum. Nonetheless, agreement between the two methods was relatively good in this instance with Method B leading to interfering carrier powers which were lower by 3.8 db for the TH system and by only 0.6 db for the TD-2 system.

4. Effect of Satellite Antenna Gain Relative to Limiting the Maximum Permissible Satellite Power

Considering terrestrial microwave antennas of fixed aperture, the

algebraic sum of the antenna gain and the free-space path loss is dependent only on path length, hence on satellite orbit height and independent of frequency. Hence, for a given interfering frequency power spectrum and interference level at the terrestrial receiver, the maximum permissible earthward-radiated power from the satellite depends primarily on the orbit height. In turn, the corresponding power from the satellite's transmitter depends on the satellite's antenna gain.

Early communication satellites, particularly those having relatively low orbits, are not apt to employ directive antennas for reasons of simplicity. Satellites in higher orbits, particularly stationary satellites, will need antenna gain to conserve power, though this will require directional control* of the earthward beam. Since this antenna beam will have an earth-subtending angle, its gain also will depend on orbit height and not on frequency. Table II of Annex I shows that the satellite transmitter power density is essentially the same for a 5000-Km satellite with no antenna gain (3.2 watts/Mc/s) as for the 36,000-Km stationary satellite with an earth-subtending antenna (3.55 watts/Mc/s). The latter, however, would be radiating 166 watts/Mc/s toward the earth's horizon (3-db beamwidth) and 332 watts/Mc/s toward the center of the earth.

Any limitation to be placed on satellite power must be in terms of its earthward radiated power; hence its product (db sum) of transmitter power and antenna gain, considering the orbit height and the rf spectrum of its modulation under minimum traffic load conditions and considering the interference susceptibility and antenna gain of future microwave receivers. It may be premature to attempt to establish such power limits before the preferred characteristics of probable communication satellite systems are better established. However, with present terrestrial microwave systems such as TD-2 and TH with antennas directed toward the satellite and for 25 Mc/s wide-deviation satellite modulation maintained even at light traffic loads, the satellite transmitter power limit would lie between 30 and 100 watts, either for a 5000-Km satellite with a zero-gain antenna, or for a stationary satellite with an earth-subtending (19.7 db) antenna. The transmitter power of early communication satellites is not apt to exceed 5 watts, but this is only an order of magnitude less than the probable safe limit.

As explained in the introduction, one can foresee the desirability of stronger satellite signals and their availability at some not too distant

* Note that this directional control does not necessarily require full attitude stabilization of the satellite. A spin stabilized satellite can have a phase-rotated earthward antenna beam.

date. Such stronger signals could result, even at present satellite transmitter powers, from the use of greater satellite antenna directivity to concentrate its power over some one continent or smaller area of the earth. For example, a 2-degree beamwidth corresponds to 38-db gain; more than 18 db over that of the stationary satellite's earth-subtending antenna. With non-stationary satellites, the use of these narrow antenna beams appears more difficult and less probable.

5. Interference Control with High-Power Stationary Satellites

Stationary satellites seem most likely to radiate strong signals whenever technically and economically possible. One reason for this prediction is that such satellites appear most attractive for multiple-access systems, wherein many earth stations can communicate with each other through the same constantly available satellite. Reducing the total cost of these earth stations may justify the increased cost of a high-power satellite.

Earlier in this report it was shown that the stationary orbit is a particular circular equatorial orbit and that terrestrial microwave receivers can control antenna augmentation of interference from a circular equatorial orbit just by avoiding two narrow arcs of antenna azimuth. Interference could be thus reduced from all future stationary satellites. For an individual stationary satellite, the problem of interference control via earth-antenna directivity control is even simpler, as will be shown.

Horizontally beamed earth antennas cannot be directed at a satellite unless located in a narrow belt at the satellite's earth horizon.* Only a stationary satellite has a stationary interference belt. Terrestrial radio relay antennas used at 3.7 Gc/s and higher frequencies normally have beamwidths of two degrees or less. The angular width of the interference belt, measured from the earth's center is half the antenna beamwidth and therefore is in the order of only 100 kilometers wide. Most of this narrow belt will pass over oceans and land areas where the transmitter density is low. Among the relatively few receiving antennas within such an interference belt, all antenna azimuths should be equally probable and only the beamwidth fraction of such antennas would be directed at the satellite. Hence, not more than a few receivers, probably none or only one, would have the satellite interference augmented antenna gains within 20 db of their maximum value. These few would always have interference, whereas all the

* This concept of tangential interference belts is developed more fully in U. S. Draft Report IV/11, 12 July 1962, "Interference from All Co-Channel Radio Relay Transmitters to a Satellite Receiver." The present inverse-case treatment follows from reciprocity.

other receivers would never have as severe interference from this stationary satellite. Hence, it would seem preferable to correct so few cases of interference rather than to restrict stationary satellites to otherwise non-interfering powers.

ANNEX I

Permissible Power Radiated from a Satellite

A. Approximate Analysis

For cases where the satellite and terrestrial microwave modulations and the microwave receiver's signal-to-noise transfer characteristic are not known, assume that the satellite modulation is noise-like with no significant carrier spike and that its r.f. spectrum is sufficiently broad and flat to use a megacycle as the unit of power spectral density. Assume that the microwave antenna has a 10-db noise figure and that its antenna has a 3-meter (9.68 foot) aperture diameter and 55% aperture efficiency. Consider the threshold of harmful interference to be that at which the interfering noise power per Mc/s at the receiver input equals the receiving system noise, -134 dbw/Mc/s thus produces a noise degradation of 3 db.

For illustrative purposes, consider orbit heights of 5000, 13,000 and 36,000 kilometers (equivalent to 3100, 8100 and 22,300 miles) and frequencies of 4 Gc/s and 8 Gc/s. Table I shows the corresponding tangential (longest) path lengths, path losses at the two frequencies, earth-subtended angle from the satellite, possible antenna gain, etc., leading to satellite powers per Mc/s in db relative to one watt (dbw). Since the gain of the 3-meter microwave antenna and the loss of the space path both vary with frequency squared and since the satellite antennas would have constant beamwidth, hence the same gain at all frequencies, one anticipates that the maximum tolerable satellite power will be independent of frequency but will depend on the orbit height

B. Phase Modulated Satellite and Terrestrial Systems

Curtis* has studied the permissible interference between a TELSTAR-type satellite (TSX-1) system and the AT&T type TD-2 (4 Gc/s) and TH (6 Gc/s) microwave systems arriving at the following interfering carrier power objectives at the microwave receiver converter: TD-2, -120 dbw; TH, -125 dbw. With the satellite system fully loaded, its large frequency deviation results in a Gaussian spectrum and negligible carrier spike. A 40-db antenna gain was assumed for both systems.

* H. E. Curtis, "Interference Between Satellite Communication Systems and Common Carrier Surface Systems," Bell Syst. Tech. J1., Vol. 41 May, 1962, pp. 921-943. See Tables III and IV in which powers were expressed in db relative to milliwatt.

It is interesting to compare the Curtis results with those of the preceding section; recognizing that the methods and assumptions are dissimilar. Considering interference to a TD-2 receiver from a stationary satellite:

Satellite carrier power at TD-2 receiver	-120 dbw
TD-2 antenna gain	40 db
Satellite power at TD-2 antenna	-160 dbw
Space loss at 4 Gc/s	195.6 db
Satellite antenna gain	16.7 db
Power to satellite antenna	18.9 dbw = 78 watts
Difference from Table I value, 89 watts	-0.6 db

For the TH system, the satellite carrier power objective is 5 db lower; whereas the space path loss at 6 Gc/s is 1.8 db greater leading to a satellite power of only 37 watts, which is 3.8 db less the Table I value. Note that these power differences are independent of orbit heights.

TABLE II

Orbit height, Km	5000	13,000	36,000
Earth angle from satellite, degrees *	67.0	37.8	17.1
Tangential (max.) path length, Km	9500	18,340	41.9
Path loss, db, at 4 Kc/s	178.5	186.8	195.6
Path loss, db, at 8 Kc/s	184.6	192.8	201.6
3-meter antenna gain, at 4 Kc/s	39.4	39.4	39.4
3-meter antenna gain, at 8 Kc/s	45.4	45.4	45.4
Receiver noise density, dbw/Mc/s	-134.0	-134.0	-134.0
Power density from sat. antenna, dbw/Mc/s	5.1	13.4	22.2
Power density from sat. antenna, watts/Mc/s	3.2	22.0	166
Satellite antenna gain -3 db *	4.9	9.8	16.7
Power density to sat. ant. dbw/Mc/s	0.2	3.6	5.5
Watts per Mc/s	1.05	2.3	3.55
Watts for 25 Mc/s bandwidth (flat spectrum)	26	57	89
With 20 db earth antenna gain reduction	2.6	5.7	8.9
KW/25 Mc/s			

* The satellite's earth angle is taken as the 3-db beamwidth of its antenna; thus, the beam-center gain for this angle is reduced by 3 db. Actual satellite antennas would be enough broader to allow for attitude errors. A 3000-Km satellite probably would not use a directive antenna, whereas a 13,000-Km satellite might and a stationary satellite certainly would.

INTERFERENCE PROBLEMS OF CO-CHANNEL
COMMUNICATION SATELLITE SYSTEMS

by

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INTRODUCTION

Among those studying satellite communication systems there are still proponents of many different orbits: low, medium, or high; circular or highly elliptical; polar, equatorial, or inclined at any intermediate angle. Of course, all of these proposed systems will not go into operation, but two or more may. What interference problems could arise between systems employing different orbits? There would be none, of course, if each system could have its own frequency band. Frequency separation may not remain an acceptable solution, however, as we shall discuss later. With co-channel operation, intersatellite interference will occur whenever a satellite comes too close to an antenna beam which is tracking a different satellite, perhaps one of a different orbital system. The severity, duration, and frequency of such interference clearly depend upon many factors and assumptions, as this paper will discuss in an exploratory manner.

When satellite communication service starts, and for a decade thereafter, intersatellite interference may be infrequent and tolerable. Ionospheric HF communication had few interference problems at first, but they multiplied with growth of use of this portion of the spectrum. We should plan for the future of satellite communication, toward best and fullest use of this new technique, recognizing and controlling interference problems which otherwise could become intolerable.

HOW TRAFFIC CAPACITY CAN GROW

Traffic growth forecasts will be dispensed with by the observation that communication demand has always pushed its supply, and probably always will. Though the potential capacity of satellite communication seems staggering and virtually inexhaustible today, we cannot assess the requirements of yet-uninvented services, any more than Morse or Bell could contemplate television and its need for coaxial lines and microwave chains. It seems safe to postulate that satellite communication of the common-carrier type will grow rapidly to such an extent that individual satellite repeaters will increase in bandwidth to the limit of their frequency allocation, probably 2 Gc or less.^{1,2} We further postulate that two or more independent satellite systems will share (or try to share) this

band, basing this on the following reasons:

1. We could have one or more large-volume governmental systems, in addition to a common-carrier system.
2. Certain other nations, or groups of nations, might not be satisfied with participation in our common-carrier system, or with accepting its service. Establishing their own system might become a status symbol. Note that many nations operate intercontinental airlines, duplicating each other's service.
3. Even if there is but a single international operation, it soon may need to operate different orbit systems. Satellite service may start from nonstationary orbits, such as have been proposed by A. T. & T., G. E., and others. Proponents of such systems point to the stationary satellite's 0.6-second conversation delay, and to certain of its state-of-the-art technical difficulties. However, they generally admit that stationary satellites will have compelling advantages for most other services, such as television and one-way record communication. Assuming that there is a large early investment in a nonstationary satellite system, it certainly will be followed by a demand for stationary satellite service, because of its many advantages.³ Hence, both orbit systems would need to share the spectrum, at least during a change-over period.

In view of this probable need for satellite systems to share frequencies, this paper will explore certain interference possibilities and coordination problems which may be encountered. McMillan⁴ has discussed some of the inter- and intra-system coordination problems, suggesting computer assignment of satellites within a random-orbit system, with looser (restricted tracking) coordination between systems. He stated that "one simply cannot tolerate . . . intrusions of a 'foreign' satellite into the beam of a terminal's antenna."

INTERFERENCE BEAMWIDTHS
OF TERMINAL ANTENNAS

The required isolation of interference depends on the standard of service and on the modulation employed. For example, frequency modulation receivers can suppress interfering signals which are weaker than the desired signal. Glaser⁵ has recommended interference suppression of 60 db with single-sideband modulation (without

compondors) and 30 db with wide deviation FM, for common-carrier service. This means that a terminal antenna's interference beamwidth would be its 60-db beamwidth for SSB, and its 30-db beamwidth for wide FM. For the new 3600-square-foot horn-reflector antenna being installed in Maine, Glaser reported the following interference beamwidths:

Modulation	Frequency		Suppression
	1.0 Gc	4-6 Gc	
Single Sideband	35°	9°	60
Wide Deviation FM	4°	1°	30

Interference suppression of 45 db might be adequate for SSB, using compondors. However, large parabolic antennas have worse sidelobes than were predicted for the large horn-reflector, so their interference beamwidth for compondored SSB might remain near 9 degrees. The far sidelobes of large parabolas sometimes are approximated by an envelope of isotropic gain, on which basis there would be no directivity for interference suppression in excess of the beam gain.

What about the use of smaller terminal antennas? The first generation of satellite systems needs large high-gain antennas and low-noise receivers just to compensate for the limited satellite power available from solar cells and for the large basebands desired for television relaying. With adequate satellite power, what are the possibilities of cutting the cost of light-load terminals? Could small antennas be used? Fig. 1 shows smoothed (envelope) directivity patterns of TD-2 microwave antennas at 4 Gc.⁶ For these, the following interference beamwidths would apply:

Interference Suppression	30 db	45 db	60 db
Horn Reflector	4.3°	10°	70°
8-foot Parabola ⁷	6.0°	65°	86°

Though the above beamwidths would be improved at 8 Gc, it seems clear that attempts to use these small antennas would increase the difficulty of interference control. It would seem better to cut costs by using large fixed antennas with stationary satellites.

GENERALIZATIONS CONCERNING ORBIT SYSTEMS

Emphasis will be placed on systems employing essentially circular orbits, hence having essentially constant orbital velocities. Such orbits seem most probable and are easiest to treat. The elliptical orbit has minimum velocity at its apogee and maximum at its perigee. High northern apogee systems have been proposed to optimize coverage of higher latitudes of the northern hemisphere, but extensive use of such systems now seems improbable.

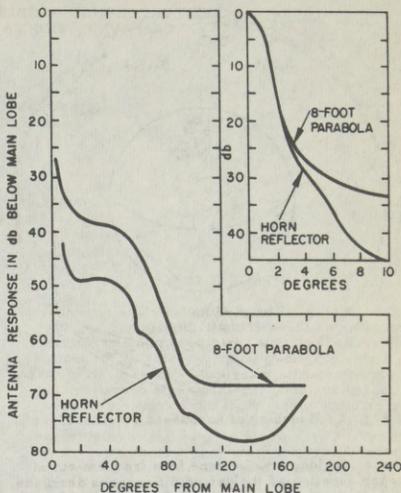


Fig. 1. Directivity envelopes of TD-2 antennas at 4 Gc (Curtis⁵).

In general, intersatellite interference control is possible with any one system of satellites having the same management, with good prediction of the orbits of all satellites and good coordination between terminals. Trouble is most probable when there are several satellite systems under different managements, with imperfect coordination between terminals; interference or undue constraint seems certain when these independent systems employ orbit systems of different types. For example, with systems in equatorial orbits at different heights, equatorial terminals cannot avoid having satellites of a foreign system pass through their antenna beam.

It is convenient to talk about many satellites occupying the same orbit, whether they are phased or not. Actually, if these satellites are in the identical orbit they have identical periods and therefore must be in phase with each other. In saying that they are not phased we imply that they are in slightly different orbits having slightly different periods, as indicated in Fig. 2. Bunching of such satellites is analogous to the "beating" of rotating vectors having slightly different periods. The period T between conjunctions of satellites in a common plane, with periods T₁ and T₂ is

$$T = \frac{T_1 T_2}{T_1 - T_2} \quad (T_1 \neq T_2)$$

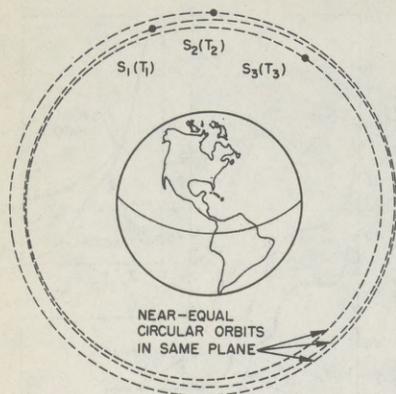


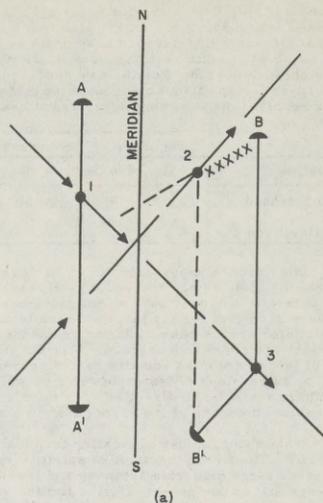
Fig. 2. Bunching of nonphased satellites.

Hence, conjunctions become less frequent but of longer duration as the period differences decrease. Such conjunctions bring both satellites into the beam of an antenna which is tracking either of them.

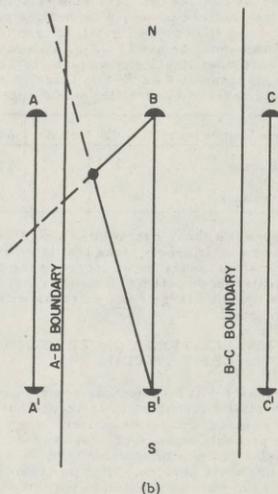
As generally used, the term "random-orbit system" does not imply randomness of all the orbit parameters of each satellite, or equal probability of there being a satellite over any given area located anywhere on earth. Rather, this term implies that all satellites have orbits which are similar in height, ellipticity, inclination, etc., but which have one or more of their orbit parameters randomly related. Thus, the nonphased system of Fig. 2 can be considered random in the sense that the periods of its individual satellites may be randomly distributed about the mean period. The random polar-orbit system which will be considered later is one in which all satellites have circular polar orbits of equal height, with uniform orbit spacing in right ascension, but with random time (or position) of each satellite within its orbit. With such a system the satellite density will be greatest over the poles and least over the equator.

BOUNDARY COORDINATION TECHNIQUES

As previously mentioned, McMillan has suggested the possibility of a "loose" intersystem coordination technique, based on observing certain intersystem tracking boundaries. For example, two systems using low-altitude satellites would always keep their respective fields of view on opposite sides of some line, such as a meridian. This technique would be workable in simple situations, such as shown in Fig. 3(a), in which the systems each consist of a pair of terminals for nearly-parallel routes. Here terminals A-A' of



(a)



(b)

Fig. 3. Interference coordination by field-of-view boundaries.

one system could track satellite 1 up to the position shown, but not beyond, or else their fields of view would cross the boundary meridian into the other system's territory. To the east, terminal B' could track satellite 2, but B could not. Instead, these terminals could use only satellite 3, for the short time that it remained in their mutual view. Adding more systems, or more terminal pairs per system, soon makes this technique inoperably restrictive. In Fig. 3(b), the boundaries have been drawn close to the A-A' and C-C' paths, presumably to give B-B' a good wide corridor. However, though A-A' and C-C' could track all satellites west or east respectively of their lines, B-B' could not track to the east or west without their field of view crossing the boundary. Hence, all territory between the A-A' and B-B' lines would be wasted by this overly-restrictive technique.

To an extent, the boundary technique can be liberalized by restricting the position of satellites with respect to the boundary, instead of restricting the terminals' fields of view. Fig. 4 shows terminals A-A' and B-B' having end-to-end paths, each having its own satellites at slightly different heights. System A knows the positions only of its satellites, as does system B. Hence A-A' can use

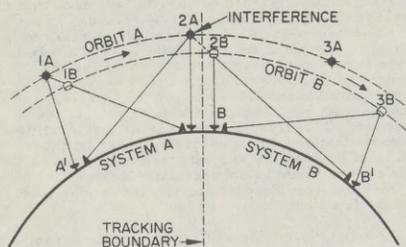


Fig. 4. Satellite boundary coordination technique.

satellite 2A up to the boundary, but must then shift to an ascending satellite, 1A, to avoid the possibility of interfering with a B satellite which is in use. In shifting to 1A, terminal A could illuminate a foreign satellite, 1B, as shown, but it is not in the beam of a second terminal. However, when B' starts tracking 2B it also could illuminate 2A, because of its slightly higher orbit, and thus interfere with system A.

Though refinement of the tracking boundary could avoid this source of interference, the problem could again be made intolerably complex and restrictive just by changing the paths and adding a third pair of terminals, as in Fig. 5. Here the three tracking boundaries cross at O, and L_N denotes the satellite visibility limit from terminal N. Satellite 1 passes over system A territory,

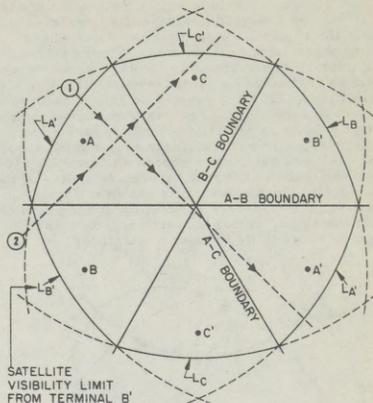


Fig. 5. Extension of boundary coordination technique.

except for crossing tips of B and C sectors, near O. Terminals A-A' might well take a chance and track this satellite throughout its mutual visibility. Satellite 2, however, would be less useful to A-A', still less useful to C-C', and virtually useless to B-B'. Clearly, it would be better (if possible) to assign 2 to a pair of terminals for use throughout its period of mutual visibility, but this would require close coordination. In general, these loose boundary coordination techniques seem undesirable, at least with many satellites in low orbits. Boundaries would be applicable, however, and simple, if all satellites were in the stationary orbit, because the boundaries then would be between the orbit stations.

PHASED POLAR-ORBIT SYSTEMS

Webb⁸ has discussed polar-orbit systems of relatively low altitude in which phasing would be maintained between satellites in a common orbit and between orbit planes, and intersatellite relaying would be used. An example proposed 18 satellites 20 degrees apart, in each of eighteen (nine) 450-mile polar orbits in planes separated 20 degrees, totaling 162 satellites. Since the 450-mile period is less than 2 hours, these satellites would cross over the poles at a rate of more than one per minute. Webb seems to have neglected the interference problem near the poles in concluding that "the north polar region might well become the center of future world-wide communications If one could project himself about 20 years into the future and gaze up into the northern skies, he might witness a continuous swarm of satellites like giant insects converging near the rotational axis of our Mother Earth."

The point worth noting is that such a phased polar system prevents intersatellite interference within the system, except near the poles where two or more satellites can come within a terminal's interference beamwidth. Polar interference could be controlled by using fewer satellites around fewer orbits of greater height, phased with respect to each other. For example, these could be two 8000-mile orbits, in planes separated by 90 degrees, with four satellites equi-spaced about each orbit and both orbits phased so that each satellite would cross the pole between satellites of the other orbit. Such a system is shown in Fig. 6. However, this approach to satellite communication lacks the ability to increase its capacity by any large increase in its number of satellites.

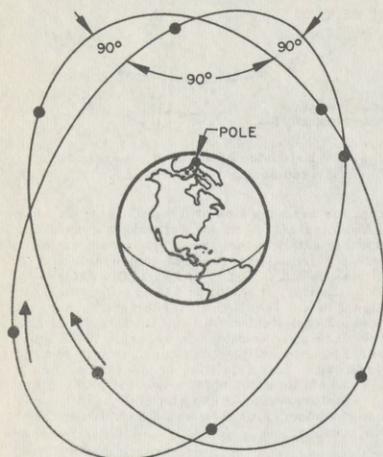


Fig. 6. Eight-satellite phased polar-orbit system.

EQUATORIAL ORBIT SYSTEMS

In comparison with preceding systems, the simplicity of equatorial orbit systems lies in there being but one orbit plane. With this simplicity comes the limitation of being unable to cover the polar regions, but such regions are primarily of military interest. From the 22,300-mile stationary orbit, the earth's horizon extends to $81\frac{1}{4}$ degrees, and even a 6000-mile orbit would provide coverage to the highest heavily populated latitudes.

If all satellites are in, or close to, the same circular equatorial orbit, the bunching of

two or more satellites within a terminal's interference beamwidth would constitute the principal interference possibility, and one which could be intolerable. Hence, only phased equatorial systems are generally considered. One such system would employ ten or more satellites, phased equally apart around a 6000-mile equatorial orbit. One advantage claimed is that this lower orbit would reduce the pause-to-reply delay in telephony to about 0.2 second, compared with the stationary orbit's 0.6 second delay. Whether this latter delay will be accepted or not is still a pivotal issue in the future of satellite communication. It is an issue which makes it desirable to examine next the problem of using low- or medium-orbit systems for telephony, while using stationary satellites for other delay-insensitive services.

STATIONARY AND LOWER EQUATORIAL ORBIT INTERFERENCE

Obviously, if an equatorial terminal tracks a 6000-mile equatorial satellite across the sky, its beam also would sweep the many stationary satellites. Similarly, if an equatorial terminal were beamed vertically at a stationary satellite, through a ring of ten equi-spaced 6000-mile (7.33-hour period) equatorial satellites, one of the latter would pass through its beam every 44 minutes. For a 1-degree interference beamwidth, each satellite would produce interference for 44 seconds, or for 1.67 percent of the time. This would increase to about 15 percent of the time in the case of a 9-degree interference beamwidth and would become correspondingly higher if more than ten satellites were placed in the 6000-mile orbit. Clearly, such interference would be intolerable on or near the equator. Of course, one could argue that satellite communication is most needed at higher latitudes and that the inability to locate terminals close to the equator would be unimportant. However, agreement from Equador and similar nations could not be expected!

Only terminals sufficiently removed from the equator would be immune to this interorbit interference. With exaggeration, Fig. 7 shows that a terminal using its maximum beam elevation would have both orbits within the interference beam unless the terminal's latitude exceeded β degrees, or v miles from the equator. Plane geometry leads to the values shown below.

Modulation	Interference Half-Beamwidth $\alpha/2$	Latitude β	Distance from equator v miles
Wide FM	0.5°	$1^\circ 00'$	69.1
SSB	4.5°	$8^\circ 56'$	662.8

The above values are optimistic in that the paths to the orbits are about 3000 miles longer at minimum beam elevation, requiring that the distances from the equator be about 50 percent greater than shown above.

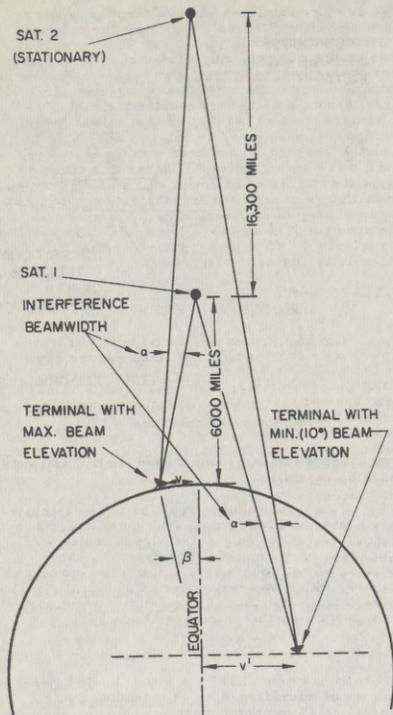


Fig. 7. Interference geometry for equatorial orbit systems.

INTERFERENCE BETWEEN RANDOM POLAR AND STATIONARY ORBIT SYSTEMS

Interference with polar-orbit satellites can occur anywhere within the large coverage area of a stationary satellite, at least if each polar orbit's period is not integrally related with that of the earth's rotation. With a multisatellite random polar-orbit system, the probability of interference with a stationary satellite will be least at the equator, where the density of these polar satellites will be least, but it will increase markedly at higher latitudes, as is evident from Fig. 8. Interference probabilities have been calculated, using methods discussed by Sinden and Mammell⁶ and assuming 50 satellites in 6000-mile circular polar orbits.

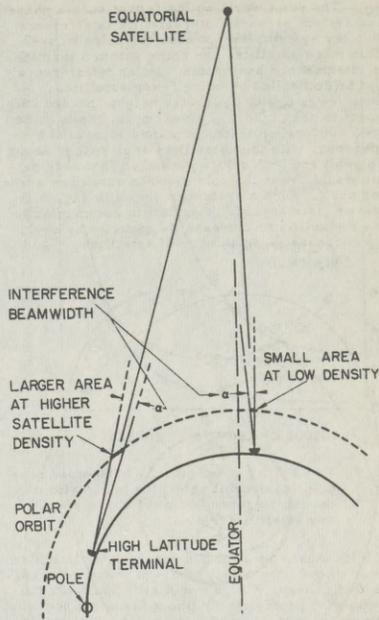


Fig. 8. Interference geometry for polar and equatorial orbit systems.

The orbit planes are assumed to be equally separated, but each satellite is randomly located in its orbit. The results plotted in Fig. 9 show that here the lowest interference probability is 0.035 percent, for 1-degree interference beamwidth at an equatorial location, and this increases to 0.1 percent at the heavily populated latitude of 41 degrees. It is debatable whether such an interference probability could be tolerated, but no unnecessary interference should be permitted.

The same geometry and method apply with any circular equatorial orbit and a lower random polar-orbit system and would lead to minimum interference probability at the equator.

RANDOM INCLINED-ORBIT SYSTEMS

Such systems are similar to the polar-orbit systems previously discussed, except that the loci of their sub-satellite traces do not exceed some limiting latitude. Hence, the satellite density would

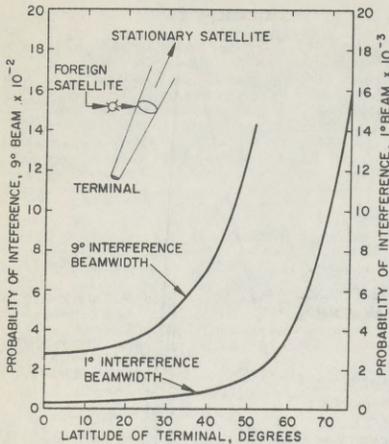


Fig. 9. Probability of one of fifty 6000-mile random polar orbit satellites being within the interference beamwidth of a stationary satellite terminal.

reach its maximum over the two limiting latitudes instead of over the poles, where it would be zero. With this change, Fig. 8 would still illustrate the interference geometry. Without further discussion it is evident that interference probabilities would be just as high over the equator for equal satellite density there and would increase more rapidly with latitude.

THE POLAR COVERAGE PROBLEM

Since an equatorial satellite system cannot serve the poles, and since a polar satellite system can have interference with an equatorial one, how can global coverage be obtained without intersystem interference? Three answers will be suggested.

First, and least satisfactory, the question can be parried by observing that satellite communication to polar regions is primarily of military interest and that such military systems might operate at a different frequency.

Second, polar coverage can be obtained from a synchronous inclined-orbit system, as in Fig. 10. Such a system has the same 24-hour period as the stationary orbit. Its satellites would cross through a vacant point in the stationary orbit twice each period. Such an inclined synchronous orbit should have sufficient phased satellites and be sufficiently inclined that one or more of its satellites always would be at a useful elevation from all latitudes above the coverage of the stationary satellites. Terminals working with these

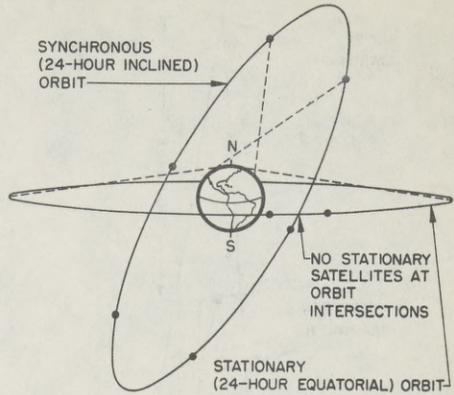


Fig. 10. Use of 24-hour (synchronous) inclined orbit for polar coverage.

synchronous satellites would need limited antenna-tracking capability.

The third solution would be to use an auxiliary system of lower polar-orbit satellites, as in Fig. 11, activated only at the high latitudes at which they need be used. For example, these polar satellites could carry a deactivate-command receiver which was responsive to a control signal beamed from the stationary satellites or perhaps from certain earth-control terminals.

CONCLUSIONS

It has been shown that there would be real dangers of interference between independent co-channel satellite communication systems, especially if they employed orbits which would permit satellites of two or more systems to be within a terminal's interference beamwidth. Thus, adopting a multisatellite random-orbit system could delay or even prevent the subsequent inauguration of an equatorial orbit system, particularly a stationary system. Prior to major commitments toward a specific satellite communication system ample study should be made of the relative long-term advantages of various orbit systems, and of the interference problems which could accompany the introduction of, or gradual changeover to, a second orbit system.

Two or more independent systems can operate without intersatellite interference if their satellites are accurately and adequately phased apart around the same orbit. It would be difficult to phase these satellites to minimum noninterfering separation around a nonstationary orbit in which each satellite could be tracked only intermittently. The stationary orbit permits continuous observation, thus facilitating this phasing. In fact, putting

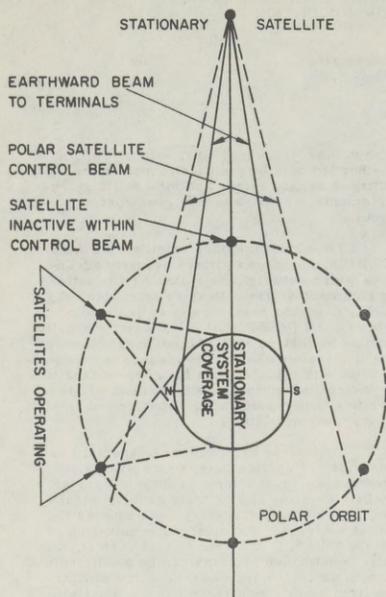


Fig. 11. Polar coverage via phased polar-orbit satellites which are inactivated at low latitudes.

and keeping a satellite "on station" in this orbit, within any specified tolerances, assures that it is phased to within these tolerances. Hence, the stationary orbit lends itself naturally to simultaneous occupancy by independent satellite systems.

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TWELVE ADVANTAGES OF STATIONARY SATELLITE SYSTEM
FOR POINT-TO-POINT COMMUNICATION

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Summary

With the exception of those systems which are intended to satisfy special military requirements, passive satellite communication systems will not be economically competitive with high-capacity, active satellite systems because of greater terminal costs. There are twelve reasons why stationary orbit systems should become the backbone of future global communications, and these are discussed in detail. Seven of these are based on economic and system advantages, while the remaining five arise from interference coordination advantages in frequency sharing among satellite systems and with surface services. Stationary satellites present space technology and propagation delay problems, but these are rapidly being overcome. It is therefore recommended that more planning and regulatory emphasis be focused on stationary satellite communication systems, since nonstationary, nonmilitary systems will only be interim or supplementary systems.

Introduction

In 1945, Arthur Clarke¹ prophetically described a stationary-orbit global satellite communication system. Since Sputnik, many engineers studying early possibilities of satellite communication have recognized the technological difficulties as well as the advantages of stationary satellites. Although this probably would become the "eventual" system, they asked: "How could its difficulties be side-stepped in order to start satellite communication sooner and more easily?" From efforts to achieve this objective came SCORE, ECHO, COURIER, STEER, RELAY, and early phases of ADVENT, not to mention other systems proposed by industry. As a consequence, there is now more confusion and indecision concerning the "eventual" system than was evident just three years ago. At that time we saw a beautiful but distant forest of global communication capability. Having now reached the edge of this forest, we are becoming confused in finding our way through the first trees. Perhaps we should look at the entire forest again.

Exclusion of Military Requirement Systems

One major, though infrequently recognized, method of classifying satellite communication systems is based on whether the system would be economically competitive for point-to-point communication and acceptable from an

international frequency-utilization viewpoint or whether it would be justified primarily by its ability to satisfy unique and vital military requirements, regardless of higher cost per circuit.

Low-orbit memory satellites such as COURIER may have military security advantages which outweigh their obvious limitations for commercial use. Passive satellites, e.g., ECHO, carry no receivers to be jammed. Orbital chaff (NEEDLES) would seem virtually immune to destruction. Active nonstationary satellite systems have been planned for communication with vehicles, via high power densities (or the equivalent in correlation coding), at a sacrifice in communication capacity and frequency-sharing ability.

This study excludes these special purpose military applications, concentrates on commercial, high-volume, common-carrier satellite systems and on their governmental point-to-point counterparts, and assumes the goal of achieving "the most communication per system dollar." The evolution of such economically constrained systems can be predicted with reasonable accuracy, whereas a new military requirement or a new technique for satisfying military requirements can invalidate predictions of an ultimate military satellite communication system.

Elimination of Passive

The passive satellite merely reflects signals, whereas the active satellite employs electronics to receive, amplify, process, and retransmit them. Some workers still extol the passive satellite and claim that it will be the ultimate winner, because of reliability, unlimited bandwidth, and low satellite costs.

Immunity to electronic failure is an undeniable advantage of passive satellites, but it is an advantage that is easily overemphasized. Active satellite systems can be competitive with present transoceanic cables, even if satellites are replaced on an average of once a year. Bell Telephone Laboratories is designing a satellite traveling-wave tube with an 18-year life expectancy. Submarine cable repeaters have demonstrated these life expectancies, with no tube failures thus far reported. It should be noted here that during the 1928-31 period, Bell Telephone Laboratories planned a passive

(nonrepeated) transatlantic submarine telephone cable. At that time, deep-sea repeaters appeared less practicable than satellite repeaters do today, but the nonrepeated cable would have cost many millions for just one telephone channel. Passive satellite systems will be seen to face the analogous problem of excessive system cost per circuit.

The desire for long-life satellites stems largely from their present expendability, or irreparability. Although better reliability is always desirable, to the extent we can afford, the trade-offs for reliability will change as space technology advances and satellite repeaters become more complex. Eventually, the far-future "exchanges in orbit" will be manned or at least will be visited periodically by maintenance technicians. Adequate electronic reliability can be achieved with properly directed effort, as was true for submarine cables. Diverting such efforts to passive satellites would be a negative solution to electronic reliability.

There are those who still extol the spherical passive satellite because its unlimited bandwidth provides "the most communication capacity per dollar in orbit." Unfortunately, this over-simplification is grossly misleading. The measure of economic competitiveness is system cost per voice circuit or per other unit of information rate, and the system is composed of terminals plus satellites. All foreseeable passive systems shift the electronic burden from the satellite to its terminals and then compromise on lower orbits and fewer voice circuits. The passive satellites' lack of repeater gain is only partially compensated by its area gain. Were the passive satellite to be interchangeable with its active counterpart it would need to intercept enough power from the transmitting terminal to reflect a signal strength equal to that of the active satellite.

To make this argument more specific, Fig. 1 shows power-level comparisons between illustrative active and passive systems at 2.0 and 6.5 kMc. The stationary and 3000-mile active systems are of 600-channel capacity with 60-foot antennas. The passive system with a 100-foot sataloon in a 1000-mile orbit carries only 60 channels even though it requires very expensive 150-foot steerable antennas. All systems were assumed to use 30°K masers in terminal receivers.

Attempts to use this 100-foot sataloon in higher orbits with the same antennas and receiver would call for the transmitter powers shown in Table 1.

The potential cost of megawatts at these frequencies is prohibitive. Of course, one would not use a 100-foot spherical reflector in the stationary orbit, in view of these power costs. One would balance and reduce costs by using a better reflector than a simple 100-foot sphere; one larger and flatter requiring attitude control, or a sphere covered with reflectors and lenses as

TABLE 1

Circular Orbit, Miles	Max. (10 degrees) Path, Miles		At 2.0 Gc		At 6.5 Gc	
1000	2390		42 dbw + 16.6 kw		32 dbw + 1.66 kw	
2000	3840		50.2 + 102 kw		40.2 + 10.2 kw	
3000	5100		55.1 + 324 kw		45.1 + 32.4 kw	
5000	7400		61.6 + 1.45 Mw		51.6 + 145 kw	
10,000	12,700		71.0 + 12.6 Mw		61.0 + 1.26 Mw	
22,100 (stationary)	25,100		83.0 + 200 Mw		73.0 + 20 Mw	

proposed by Stahler and Johnson.² Such techniques would be difficult and expensive, and even if they permitted a 20-db power reduction, stationary passive satellite systems would remain noncompetitive.

As to NEEDLES, little can be said except that it may have military usefulness but it does not appear competitive for commercial service.

Before disposing of passive satellite systems as being noncompetitive, one must admit the very unlikely possibility of creating a highly reflective complete shell around the earth, i.e., an artificial but more ideal ionosphere.

Generalizations Relative to Satellite Orbits and Systems

The stationary orbit is a special-case orbit having unique properties, whereas there can be a limitless number of possible nonstationary orbit systems. Therefore, one cannot argue that all possible nonstationary systems lack any of the advantages of the stationary systems. For example, a circular equatorial system of a dozen nonstationary satellites phased equally apart could be used with limited repetitive tracking by

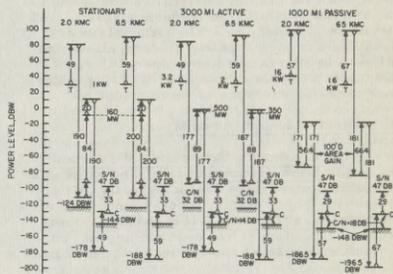


Fig. 1. Power-level diagrams of reference satellite systems.

its terminal antennas. Terminal sites for such a system would have a similar advantage to those for a stationary system in that they do not require a low horizon except over a limited tracking arc. There are other cases in which a specific nonstationary system has some advantage claimed for stationary systems, but it is the collective advantages of stationary systems which make them so compelling.

Some advantages of stationary systems may not be important initially, but they will acquire increasing importance as system capabilities are more fully exploited. Although two incompatible systems could be separated in frequency, today, mounting traffic will increase system bandwidth and force systems to share the spectrum. Ideally, incompatibilities could best be avoided by having a single worldwide internationally cooperative system in which satellites could be added to increase traffic capacity. Realistically, there will be pressure for many satellite communication systems. The United States will at least have separate common-carrier and government systems, possibly several, and other nations certainly will want their own independent systems. Consequently, system advantages should be assessed on the basis of approaching full utilization of the communication capability offered by satellite technology, with the traffic shared among independent but compatible and coordinated systems. The reader may find it difficult to acquire this long-range view of satellite communication because of preoccupation with the possibilities and limitations of today's technology. It is so difficult to get today's primitive systems into operation and to achieve even 600-channel capacity that one still rebels at thinking of six-million-channel systems and their problems.

Advantages of Stationary Satellite Systems

The major potential advantages of stationary satellites fall into two classes: those concerned with system capabilities and economics, and those relating to frequency sharing and interference protection. The latter class of advantage has been less widely recognized, but will assume increasing importance. Certain advantages are relative or have differing importance for different types of communication.

Economic and System Advantages

1. Continuous Coverage and Freedom from Discontinuities: The value of a communication service depends greatly on its continuity. For example, moon-bounce circuits are useful less than one-half of each day; therefore they cannot be relied upon for urgent communication. At least two accurately phased non-

stationary satellites* are required for continuous coverage of limited areas, with three or more required for better coverage. In random orbits, about 50 satellites are required for an acceptable probability of having communication whenever needed. An exception is that some orbital belts of needles could provide continuous communication near the poles or equator.

As a corollary advantage from its continuous coverage, the stationary satellite system has no circuit hand-over problems. All nonstationary systems require a circuit hand-over to the antenna tracking the descending satellite to that tracking the ascending one. The propagation path via this new satellite may be somewhat shorter or longer, with a corresponding delay difference. Consequently, there can be missed bits or repeated bits in a digital message stream at the instant of hand-over. These bit errors can disrupt synchronization and cause multiple errors in crypto or teletype systems. The bit stream can be matched, of course, by a delay adjustment just prior to hand-over, but this introduces an undesirable complication.

2. Freedom from Doppler Frequency Shift: The propagation path between fixed terminals via a stationary satellite is of constant length, so there is no Doppler frequency shift.

Doppler frequency shift has introduced well-known problems even in communication with supersonic aircraft. This shift amounts to approximately 1 cycle/Mc/Mach number. Using 30 Mc to a Mach-3 aircraft thus results in a 90-cycle shift, enough to impair single-sideband communication. A low satellite can attain Mach 23 (25,300 ft/sec). If approaching or receding from both terminals, the propagation path can change at nearly twice this velocity, or at over Mach 40. Hence, in this extreme case, Doppler shift at 10 Gc could exceed 0.4 Mc. This might or might not present serious problems, depending on the modulation system used. However, with a truly stationary satellite and fixed terminals, there would be no Doppler shift. Even with early quasi-stationary satellites, Doppler shift should be negligible.

* Two satellites accurately phased apart in a highly elliptical orbit with a northern apogee could always have one satellite visible from high northern latitudes, but an elliptical polar orbit does not have a stable line of apsides, because of the earth's oblateness. A 63° 24' inclination of the orbit plane stabilizes the apogee to first order oblateness perturbation, but this reduces the continuous coverage area to the near-arctic region.

3. Large Coverage per Satellite: From 22,300 miles, the stationary satellite sees the earth's horizon at $81\frac{1}{4}$ degrees from its equatorial point. If its earth terminals have minimum antenna elevations of 10 degrees, the useful coverage is 68.4×10^6 square miles, or approximately one-third of the earth's area, and may include several continents (see Fig. 2). In contrast, a satellite at 1000 miles has only a 11.8×10^6 square-mile coverage with 10-degree antennas, which corresponds to only 17.3 percent of the stationary satellite's coverage area. Actually, the useful coverage is even less, because this is a rapidly moving area.

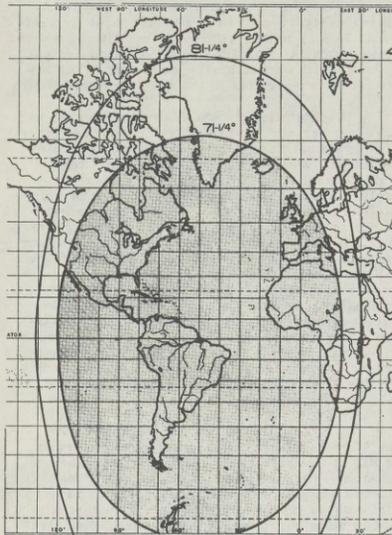


Fig. 2. Coverage from stationary satellite at 50° W longitude.

4. Multiterminal Capability: A major advantage of the stationary satellite is its potential ability to interconnect many earth terminals simultaneously, much as if it were an "exchange in orbit,"^{3,4} as shown conceptually in Fig. 3. This will permit direct and rapid interconnection of parties in different continents. These long circuits no longer need be patched together from radio links, cables, and long lines. Furthermore, such a multiterminal system can have flexibility of traffic loading because of its terminal diversity. The bandwidth of channels between any two of its terminals need not remain

fixed; it can be adjusted to best suit changing traffic loads, thus utilizing the satellite capacity more fully.

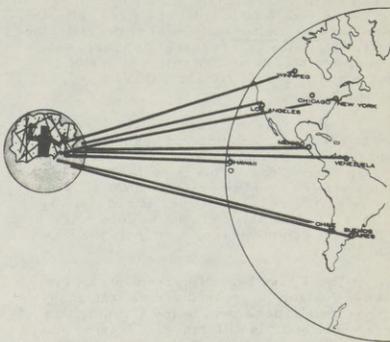


Fig. 3. The exchange-in-orbit concept. Interconnection of many terminals through stationary satellite.

Multiterminal operation also may be possible to some extent with certain nonstationary satellite systems, such as a phased circular equatorial system at medium altitude. Such operation seems impracticable with a multi-satellite random orbit system. A terminal of such a system would reach other distant terminals through satellites visible from both. Hence, this terminal would need several sets of antennas to track these several satellites for distant communication in several directions. Additional antennas would be needed for pretracking and switch-over, and these antenna costs would become prohibitive. This conclusion seems to be supported by the AT&T disclosure of plans for a 50-satellite system with 13 pairs of terminals.⁵ Each satellite would link one pair at a time. Consequently, such a system would provide just 13 long two-terminal circuits similar to wide-band cables. These would be patched together as required for longer circuits, much as must be done with present long circuits.

5. Less Expensive Terminal Antennas: A terminal for a nonstationary satellite requires large steerable antennas. Except for terminals at certain latitudes, or for certain nonstationary orbits, these antennas must be fully steerable to minimum elevation at all azimuths. Additional expensive facilities are required for satellite acquisition and accurate tracking. To maintain continuity of communication, a second set of

antennas is needed to locate and start tracking an ascending satellite prior to switch-over from the descending satellite.

The first stationary satellites may only be "stationary" within a few degrees. Nonetheless, they could be tracked more simply by moving just the antenna feed in front of a fixed reflector, or perhaps by limited movement of the reflector itself. The later generations of stationary satellites should stay on station within tenths of a degree and so should remain within a fixed antenna beam.

Some argue that excellent tracking always will be needed for orbiting and positioning stationary satellites and for subsequent station-keeping corrections. This is perhaps true, but such a service could be performed for all stationary satellites by a few specialized tracking stations. It definitely need not be done by each of the many communication terminals per satellite.

There have been disagreements on the relative costs of large fixed versus tracking antenna installations, with some claiming that there would be little difference. Clearly, this is absurd. There are twice the number of tracking antennas, plus probable spares because they are less rugged and reliable. Tracking mounts are large and expensive, as balanced against their large dishes being light and expensive, with the additional expense of the electrical and electronic tracking equipment, probably controlled by expensively computed tapes. In contrast, the stationary antennas often could be excavated and lined to achieve their paraboloidal contour, eventually at costs more comparable to California swimming pools!

Finally, suitable sites for fixed antennas often may be acquired and developed at lower cost than those for random-tracking antennas (see Advantage 10, Terminal Site Protection).

6. **Low System Costs:** Minimizing the cost of a satellite communication system requires balancing (not necessarily equating) surface and satellite costs. Satellite costs can be increased to reduce total surface costs, or vice versa, whichever reduces the system total. In general, a nonstationary system shifts the cost burden to the terminals, in tracking and associated costs, to reduce the unit cost of its many satellites. For example, Mapes⁵ has estimated the cost of a 50-satellite random-orbit system with 13 pairs of 600-channel terminals at \$115,000,000, with \$1,000,000 satellites and \$2,500,000 terminals. The satellite-to-terminal cost ratio was 0.77, reasonably near unity; however, antennas and tracking equipment accounted for 68 percent of the terminal costs.

Stationary satellites will be more expensive than equivalent lower altitude ones because of their higher orbit energy, need for orbital (station keeping) adjustment, and greater space

attenuation. The energy is only about 16 percent more than that for a 6000-mile circular orbit, or 38 percent more than that for a 2000-mile orbit. Station keeping may use cold gas jets, thereby adding little weight. Antenna directivity will overcome some or all of the additional space attenuation, probably requiring attitude control or at least beam-steering from a spin-stabilized satellite. Purely as an estimate, a large-bandwidth stationary satellite might be equal in orbital cost (after development) to three simple low satellites of equal bandwidth or to two such satellites with gas jets for orbital phasing.

A system, serving a third of the earth continuously, can start with one stationary satellite, rather than 3 to 50 simpler ones. A global stationary system would have at least three, or preferably five or more, stationary satellites, whose total cost might thus approach that of equivalent coverage with nonstationary satellites. The important difference lies in the relative earth costs.

Each stationary satellite should serve at least four terminals, probably 20 or more; therefore, low-cost fixed terminal antennas become important. Moreover, cheaper transmitters might be used by dividing the total power per satellite among its terminals. The cost of more satellite power might be offset by cheaper parametric receivers, although this is not yet promising. In addition, the stationary system's many terminals would be distributed in relation to their traffic sources, whereas a paired-terminal random-orbit system tends toward "gateway" terminal placement. In order to serve underdeveloped continents which have inadequate surface communications to such gateways, stationary terminals could be located to minimize new surface communication cost. This and other flexibilities of stationary systems should enhance their revenue-earning capability.

7. **Mild Radiation Environment:** The Van Allen radiation belts constitute a hazard to the life of transistors, solar cells, and other radiation-sensitive parts of active satellites. This radiation is of solar and/or cosmic ray origin and is trapped by the earth's magnetic field in belts surrounding the magnetic equator.⁶ The inner belt, of hard (high energy proton) radiation, has negligible intensity below approximately 500 miles, reaches a maximum and probably intolerable intensity about 3000 miles above the magnetic equator, and then dies out beyond 4000 miles. The outer belt is variable, less well defined, and generally contains the less severe "soft" (electron) radiation of solar origin. Characteristically, its maximum intensity occurs near 10,000 miles, but is less severe by 10^{-4} than radiation at the heart of the inner belt. Outer belt radiation normally falls to a tenth of its maximum value below 8,000 miles or beyond 20,000 miles above the magnetic equator. The "slot" between the belts is relatively free of radiation.

In terms of satellite orbits, one which stayed below the inner radiation belt (below 500

miles) would be too low for good communication coverage. At the opposite extreme, the stationary orbit lies beyond the normally intense portion of the outer belt, in a relatively mild radiation environment which does not present problems. Admittedly, any orbit which stays near the minimum of the "slot" between belts, such as a 6000-mile equatorial orbit, may have an even milder radiation environment. This, however, would not be a significant advantage unless stationary satellites experience radiation problems. Inclined elliptical orbits are apt to pass periodically through these radiation belts; nevertheless they would be much better than one which remained near the heart of the lower belt.

Interference Coordination Advantages

The following advantages of stationary satellite systems relate to ease of frequency sharing and interference coordination. Similarly, they relate to multiplicity of spectrum use by independent satellite systems, and hence to the eventual capacity of this communication medium. All of these advantages are consequences of the satellites remaining in fixed, known positions.

8. Frequency Sharing by Many Satellites:

With multiple co-channel satellites, interference will result whenever two or more operating satellites are within the interference cone of a terminal's antenna. Glaser⁷ has reported that single sideband modulation requires 60-db interference suppression, compared with 30 db for wide-deviation FM, and that a 3600 square-foot horn antenna should have the following interference cones:

Frequency	1.0 Gc	4-6 Gc
Single Sideband	35°	9°
Wide Deviation FM	4°	1°

The corresponding interference cones of 60-foot paraboloids probably are larger.

With multiple orbits, there must be earth areas in which a terminal can have a second satellite within the interference cone of its antenna. For example, multiple polar orbits cross over each other at the poles, with interference most probable near the poles. Near-equatorial terminals could have interference from satellites in different equatorial orbits. With multiple inclined orbits, the areas of potential interference may be bounded by high latitudes.

At first these interorbit interferences may be tolerably brief and infrequent, but more satellites will increase their seriousness and require coordination. With knowledge of all satellite orbits, these interorbit interferences can be forecast in time to track and switch to a

better satellite. McMillan⁸ has shown that a very high degree of coordination between terminals would be required in tracking satellites of the random-orbit system proposed by Mapes. With only the loose coordination that is probable between independent systems, directional or geographical restrictions would be needed to prevent (if possible) directing terminal antennas near satellites of a different system. Such restrictions may limit communication capability, much as would frequency separation of the systems.

Interorbit and intersystem interference can be avoided by use of a single orbit of phased satellites, with adjacent satellites belonging to different systems. For global coverage to acceptably high latitudes, this orbit must be equatorial, circular, and at least 5000 miles high. Maintaining accurate phasing between satellites of different systems certainly could be difficult if the orbits were nonstationary. However, when a stationary satellite is held on station, it is thereby phased into the stationary orbit. Hence, the stationary satellite has this natural advantage toward multisystem interference coordination.

With wide FM and above 4 Gc, up to 360 co-channel satellites can share the stationary orbit. Though only 40 satellites using SSB modulation could share this orbit (with 9 degrees separation), they could carry four to five times as many channels within the same bandwidth.

The possible intersystem coordination difficulties constitute an argument for caution in embarking on nonstationary satellite system programs.

9. Protection from Beamed Surface Interference: From any latitude

there are, at most, two horizontal directions which intersect the stationary orbit, as shown in Fig. 4. The high-gain horizontally directive antennas of microwave or troposcatter terminals can be beamed in all directions, except close to these two directions, without their antenna gain contributing to interference to or from any satellite around the stationary orbit. As much can be said for any circular equatorial orbit, of course, provided that all systems share this same orbit. However, the beamed (tangential) interference belt of a stationary satellite is itself stationary. This is the narrow belt of earth at the satellite's horizon from which horizontal antenna beams (microwave, troposcatter, etc.) can strike the satellite and augment interference by their antenna gain. All antenna azimuths being equally probable (see Fig. 5), only the beamwidth fraction of the stations within this belt could have the satellite within their antenna beams. The EIA studies⁹ (see Fig. 5) have shown that the beamed interference from these few microwave stations in a satellite's tangential interference belt would be at a higher level than the total nondirected interference from all other such stations to which the satellite is exposed. When this belt is stationary, it might be possible to locate and correct these few stations. Furthermore, certain stationary orbit locations

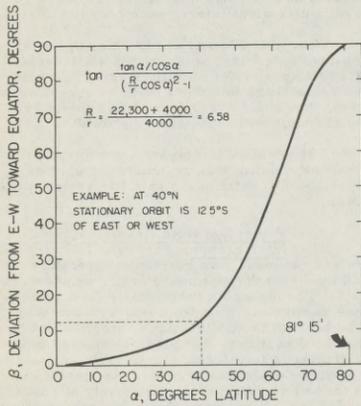
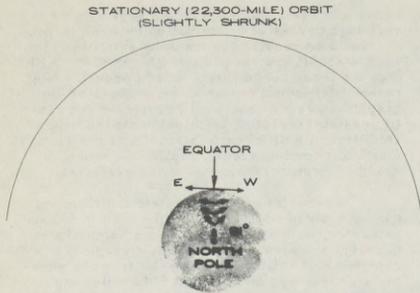


Fig. 4. Horizontal directions to stationary orbit.

(such as 100°W, shown in Fig. 6) have interference belts which miss all populous land. However, a nonstationary satellite has a moving interference belt which must sweep over any high-interference regions.

When the world cooperates in protecting the stationary orbit (or perhaps some other circular equatorial orbit) by restricting the antenna direc-

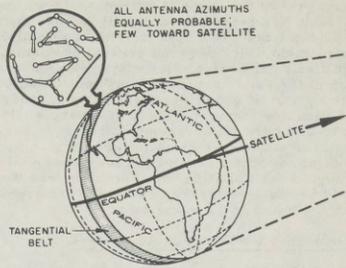


Fig. 5. Horizontally beamed interference belts.

tions of future surface stations from intersecting this orbit, surface services can be greatly expanded without interference with satellites in this orbit.

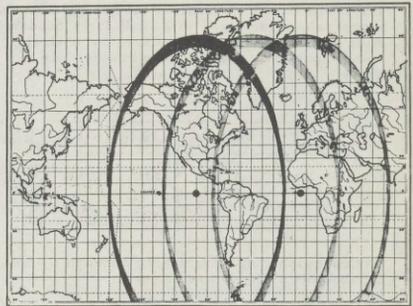


Fig. 6. Interference belts of 5, 50, and 100°W satellites.

10. Terminal Site Protection: Filings on FCC Dockets 11866 and 13522 agreed that there is a potential problem in coordination between earth terminals on smooth earth and nearby surface services. Interference to co-channel a microwave receiver could occur if it is within 60 miles, even with the microwave antenna directed away from the terminal. Clearly, full advantage should be taken of terrain shielding to reduce these

minimum separations. A terminal for a stationary satellite could even be located in a deep canyon having high horizon angles in all directions, except the angle toward the satellite. In contrast, the terminal for a random-orbit satellite system can only be located in a shallow valley having horizon angles in all directions which are safely below the minimum satellite elevation. Such a terminal cannot be protected from surface interference as well.

As previously mentioned, the fixed terminal antenna reflectors for stationary satellites may be excavated. Such antennas would have no back radiation.

When only a smooth earth terminal site is possible, the stationary antenna can be set in a pit; Fig. 7 shows such an antenna pit having steep sides except in the satellite's direction.¹⁰ A large tracking antenna for use with random non-stationary satellites would require a pit with gradually sloping sides (about 5 degrees) in all directions and with a depth of perhaps 70 feet. Such an excavation would be much more expensive.

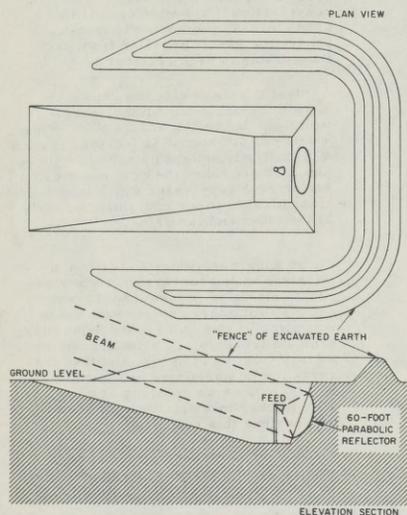


Fig. 7. Pit protection of earth terminal antenna for stationary satellite.

11. **Multiterminal Sites:** A glance far into the future reveals that population centers such as Los Angeles may need terminals for many independent satellite systems, domestic and foreign, which can be seen by analogy to the L. A. International Airport as the terminal for many independent airlines. These communication terminals will need to transmit and receive within the same frequency band, much the same as aircraft land and take off from the same airport. Establishing separate low-interference sites for each of these systems could entail real estate costs comparable to those of separate airports for each airline. Clearly, all transmitting terminals should share one site, with all receiving terminals sharing another. However, if the terminals antennas at these sites have to track nonstationary satellites to minimum elevation in any direction, including directions to other antennas, the large antenna separations would make these multiterminal sites difficult to locate and develop. For example, 60 feet subtends 5 degrees at 690 feet, nearly one-eighth of a mile.

The separation and low-horizon problems would be greatly reduced if all antennas at a multiple site tracked only satellites in a common circular equatorial orbit such that each satellite followed the same arc and need be tracked only within a limited sector. These problems would be minimized, however, with stationary satellite systems. Here, one can readily conceive of a common antenna structure with multiple fixed beams.

12. **Multiple Beams from Satellite:** Another far-future advantage is that large stationary satellites may multiply their traffic capacity by using several pencil beams to several regions of the earth (see Fig. 8), with each beam sharing the frequency band. These narrow antenna beams would have correspondingly higher gain and would therefore conserve power that otherwise would be wasted on oceans or underdeveloped areas. Such tight beams would also make jamming more difficult.

The low-altitude satellite would have prohibitive difficulty with multiple beam operation. The beams from such a satellite would have to track the desired earth areas as they passed beneath the satellite. Moreover, the beam shape and antenna gain would have to change as each desired area first appeared on the horizon, spread beneath the satellite, and then shrank as it receded.

Disadvantages of Stationary Satellites

Advantages seem always to bring disadvantages or problems, and those of stationary satellite systems are of two kinds — temporary or lasting. In the temporary category, the problems of orbiting, station keeping, attitude control, primary power, extended life, etc., have discouraged and delayed the use of stationary satellites in favor of easier orbits. These are problems which are and will be solved through space research programs aimed toward other objectives, programs receiving high priority and billions of dollars.

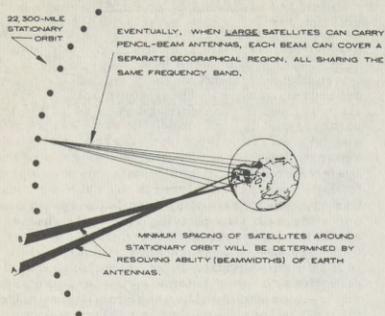


Fig. 8. Selection of satellites and geographical areas by antenna beams.

Many of these problems could be sidestepped to achieve uninterrupted single satellite communication sooner and at reasonable cost. "Stopping" a satellite at a desired point on the stationary orbit would require precision of three velocity vectors and three position coordinates. However, cumulative error or drift results only from equatorial velocity error (as interrelated with altitude); other errors cause periodic motions. These motions can be tracked and tolerated if the satellite stays within, say, 5 degrees of its desired station. It is primarily the drift-producing velocity error which must be kept corrected by command control of cold gas jets, or by similar means.

Some investigators believe that inadequate electrical power will handicap the stationary satellite. If the possible power requirements for attitude control and sun-tracking are neglected, the stationary satellite need not radiate more r-f power than a lower-orbit satellite using omnidirectional or doughnut pattern antennas.

Even attitude control is not essential. The Hughes Communication Satellite,¹¹ developed by Dr. H. A. Rosen, uses only spin stabilization, although it is intended for the stationary orbit. Its initial version employed a doughnut antenna pattern, yet required the satellite to radiate only 2.5 watts for good television transmission. A later version employed an electronically steered beam directed to earth from the spinning satellite. Its gain approaches that attainable from an attitude controlled satellite.

Additionally, there are "temporary" communication system problems, such as how best to achieve multiterminal operation. Conceptually this is simple, but many of the practical aspects are not.

As to the "lasting" class of problems, decisions must be based on their seriousness and on means for sidestepping them. Solar noise is this kind of problem. Whenever the sun is within a terminal's receiving antenna beam, its thermal noise will jam reception or at least degrade it. Although any system may encounter solar noise interruptions, low-orbit satellites have rapid apparent motion (ECHO, for example) and negligibly brief and infrequent solar interruptions. The interruptions to stationary satellite reception could occur on several successive days, twice a year, with objectionable duration. An equatorial terminal, for example, would have these interruptions around the equinoxes, each with an approximate duration of three minutes* and all highly predictable. At these times, sufficiently important traffic could be rerouted. Consequently, the solar interference problem is relatively unimportant and can be avoided when necessary.

Another lasting problem arises from the propagation delay via the distant stationary orbit. Quoting Pierce¹² on this problem:

"The stationary repeater has a disadvantage for telephonic communication. The propagation time to and from the repeater is about 0.3 second. Thus, a speaker cannot receive a reply to a remark for about 0.6 second. Tests indicate that this delay does not interfere with a telephone conversation if a 4-wire circuit is used, that is, if completely independent paths are provided from each transmitter to each receiver.

"Actual telephone circuits, however, always include 2-wire links, over which one both talks and listens. When a delay of 0.6 second is included in such a circuit, an intolerable echo precludes use. To get rid of the echo one must use an echo suppressor which interrupts transmission at one end while the party at the other end is talking.

"Echo suppressors do not seriously interfere with a conversation when the round trip delay is less than 0.1 second. Preliminary experiments show that circuits with 0.6 second delay and echo suppressors are objectionable to a large fraction of users, and that conversation is sometimes brought to a halt by both users speaking at once. Only further investigation will show how serious this really is.

"It has been proposed that one might talk to the antipodes by sending a signal to one stationary satellite, back to the

* Based on a 0.53 degree solar angle, plus 0.2 degree beamwidth of a 60-foot paraboloid at 6 Gc. The radio noise temperature of the quiet sun is about 9×10^4 K at 2 Gc and considerably higher during solar disturbances.

ground, to another stationary satellite, and thence to the antipodes. This involves a round-trip delay of over a second. Preliminary experiments indicate that such delay is nearly intolerable."

Recently, Parks and others of the Stanford Research Institute have conducted such investigations by making numerous telephone calls through a satellite delay simulation circuit introducing 0.8 second delay with echo suppression at the Stanford terminal. The writer conversed over this circuit for several minutes without realizing that it was a delayed circuit.

These investigations are being continued by General Telephone and Electronics Corporation (Palo Alto) with improved echo suppressors. Most people who have tried the G. T. & E. test circuit report that it does not significantly impede normal conversation. The delay is noticeable in rapid reply situations, such as in checking a list of numbers, but it is not intolerable.

Other tests doubtless will be performed elsewhere, and doubtless there will be contradictory results or conclusions. Such tests are difficult and can be biased, even unintentionally, toward a preconceived or desired conclusion. Although this delay problem arises only with voice communication, it is a pivotal problem which must be resolved promptly and permanently, and in proper relation to the advantages of stationary satellites.

Conclusion

The evolution of satellite communication may be analogous in some respects to the evolution of television, with which many engineers are still painfully familiar. Today's satellite communication experiments or demonstrations seem impressive, as did some of the crude television demonstrations of the 1925-30 era. Some experimental short-wave television licenses were issued during the early 1930's, and there could have been an expensive short-lived boom in low-definition television broadcasting. Fortunately, level-headed engineers recognized that there could be good and lasting television service. Now it is our responsibility to approach satellite communication from a similarly mature engineering viewpoint and to guide its evolution by helping to establish intelligent regulations and standards.

Unless the stationary satellites delay effects on conversation are found to be unacceptable, the enumerated advantages of stationary satellite systems will become compelling, perhaps as compelling as those of the kinescope over the scanning disk and neon tube. Granting this, we may agree that nonstationary satellites eventually will decrease in their importance, providing auxiliary coverage of polar regions or meeting certain other limited requirements, without competing or necessarily conflicting with the stationary systems which would carry the bulk of the world's traffic. When (and if) we can suppress the distracting aspects of the myriad possible nonstationary active and passive systems and consider such systems only in their eventual minor roles, then perhaps we can concentrate more effectively on

the simplified problems of standardization and regulation for stationary orbit systems and their probable auxiliary nonstationary systems. In contrast, if we fail to think and work along reasonably parallel lines and only continue promulgating today's orbital and system confusion, we cannot be as helpful toward establishing agreements, regulations, and standards which can survive the test of time.

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9. W. L. Firestone, S. G. Lutz, and Jack Smith, "Control of Interference Between Surface Microwave and Satellite Communication Systems," Research Report No. 173, Hughes Research Laboratories, Malibu, Calif., pp. 37-46; December, 1960.
10. S. G. Lutz and D. D. Willmans, "Fit Protection of Satellite Communication Terminal Antennas from Surface Radio Interference," SRS-420, Hughes Aircraft Company, Culver City, Calif., February 1, 1961.
11. Barry Miller, "Hughes communication satellite detailed," *Aviation Week*, vol. 73; December 12, 1960.
12. AT & T filing, p. 22 (July 8, 1960); testimony of J. R. Pierce.

Mr. MURPHY. There is a point that we would like to make, which we think is very important.

Dr. Adler has touched on the fact that we can share frequencies with terrestrial microwaves without interference, and that is described in here [indicating].

I mentioned also that we felt we could have satellites at least as close as 10° around the Equator.

There is a third and very important point.

Our Syncom Mark II system is based upon using a type of transmission which is called single side-band, suppressed carrier, frequency diversity transmission.

I won't try to explain what that is. [Laughter.]

If we are successful in using this type of transmission from the ground to the satellite, we will be able to get through a given number of megacycles many more telephone channels.

The nature of this kind of transmission not only gives the multiple access we talked about, but it gives us much denser use of the frequency spectrum, which is a priceless ingredient; there is just so much spectrum, and we must use it as efficiently as we can.

You talked about later generations of communication satellites, Mr. Boone, and I think one of the first things we will be able to do in a follow-on program is to also use single side-band modulation from the satellite to the ground.

It will be more economical both of dollars and also the frequency spectrum, and we will be able to do that as soon as we have inexpensive nuclear power supplies and traveling wave tubes with capacity for that kind of transmission.

They should certainly be available by the time that Dr. Dryden mentioned.

Mr. BOONE. Inherent in this is the problem of the multiple access. Is there something unique about the synchronous orbit that allows this, whereas the medium altitude orbit does not?

Dr. ADLER. Yes. With a stationary system you have no, or essentially no, doppler shift, which is a shift in frequency caused by relative motion of the ground stations and the satellite.

If you have to contend with doppler shift you have a number of problems which are such that you generally cannot use multiple-access and you cannot use single side-band operation. Single side-band operation, of course, is very desirable from the point of view of conserving spectrum.

The other thing that is inherent in the multiple-access capability is the mutual visibility, and this mutual visibility over a large fraction of the Earth you only get with a stationary satellite and you do not get, to a usable degree at least, with a lower altitude system.

Mr. BOONE. In all of our discussion here, we have been talking about worldwide communication.

How about from the east coast to the west coast?

Have you thought about this?

Dr. ADLER. We have thought about it a little bit. We can certainly visualize, for example, a stationary satellite which is stationed over the Equator just below the United States for the express purpose of tying together, let us say, all the major cities of the United States. In this manner Seattle could talk to Washington, to New York, and so on.

Once you have this kind of a system up it is just as cheap to talk from, let's say, Los Angeles, to, let's say, Japan, as it is from Los Angeles to some point closer in the United States.

In other words, the distance here does not make any difference in the cost of a call. So this system would be perfectly feasible then, and also, we believe, very economical for intracontinental communications.

To introduce it I think you would have to be careful about the existing long lines, existing traffic structure, existing investments of present common carriers in these long lines and of their profit picture. Or, to put it more explicitly, this kind of system would be in direct competition with the existing long lines.

There is, of course, a minimum distance where it is certainly cheaper to go over the ground. Certainly you would not call Baltimore from Washington via satellite.

But it may be more economical to call someplace in Maine from Washington via satellite than to go through ground lines all the way. We have not made a detailed study of what this breakeven or cross-over distance is.

Certainly coast to coast it would be more economical to talk via satellite.

Mr. BOONE. Do you have some idea of what the relative cable capacity is across the Atlantic, say, compared to satellite?

Dr. ADLER. I believe there are 36 channels. The actual capacity can be increased to the equivalent of about 80 using a time-sharing technique called TASI.

Mr. BOONE. You haven't discussed very much your cooperation with the military in your development.

Would you like to comment on this?

Are they playing any part at all in cooperating with the ground facilities?

Mr. MURPHY. Yes, the Syncom program is based upon a joint DOD-NASA effort. NASA is the lead agency and is responsible for the development of the satellite, the launching itself, and control of the satellite in orbit.

The communications equipment that will be used for the communications experiments will be supplied by the Department of Defense, the executive agency is the Army and in particular the organization that used to be called the Advent Management Agency, I believe now is called the Satellite Communications Agency of the U.S. Army.

They are supplying a number of stations to us. The Fort Dix station is capable of talking to our satellite. One air transportable station is being built and will be used initially at Lakehurst, N.J., to communicate with the satellite. That can later be moved to Europe or other places as desired.

Finally, a ship will be outfitted—the U.S.S. *Kingport* is under modification at Philadelphia Navy Yard to act as both the communications station and also the prime satellite control station.

This ship will be taken to a harbor in Nigeria, it is my understanding, and from there we will control the satellite and will talk to the two stations in New Jersey. We will use the ship to conduct our communication experiments.

So we are completely dependent, if you will, on DOD ground stations for the communication portion of the system.

Mr. HECHLER. The ship would be used both for commercial and defense purposes?

Mr. MURPHY. It is not my understanding that it will be but perhaps it could be.

Mr. HECHLER. Yes.

Mr. BOONE. The Defense Department is fully aware of your program, then, and has your estimate of the operational capability resulting from the use of Syncom; is that correct?

Mr. MURPHY. They are very aware of the Syncom I part of it since they are an integral part of that program.

I have continuously pointed out to them the applicability of Syncom I to some of their earlier needs.

Mr. HECHLER. Have they talked to you about any possible contracts?

Mr. MURPHY. We have talked to the Air Force, which is the new executive agency for the satellite portion of the military system—about the applicability of Syncom to the military program.

We have recently submitted to them a three-phase proposal for how the Syncom technology and developments can be economically and quickly brought to bear on the military requirements.

This program, I understand, is now under evaluation by the Air Force Systems Command.

We have not yet heard what their desires are with respect to proceeding with those developments.

Mr. HECHLER. Any further questions?

If not, I want to thank you, Dr. Adler, and Mr. Murphy, for appearing before the committee. I think your testimony has been clear, forceful, confident, and in the American competitive spirit.

We will follow developments with sympathetic interest.

The committee stands adjourned until tomorrow morning at 10 o'clock.

(Whereupon, at 11:50 a.m., the committee was adjourned, to reconvene at 10 a.m., Wednesday, September 19, 1962.)

COMMERCIAL COMMUNICATIONS SATELLITES

WEDNESDAY, SEPTEMBER 19, 1962

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON APPLICATIONS,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
Washington, D.C.

The subcommittee met at 10 a.m., Hon. Ken Hechler (chairman) presiding.

Mr. HECHLER. The committee will come to order.

This morning we are continuing our hearings on the development of communications satellites and we have a representative of the National Aeronautics and Space Administration, Mr. Leonard Jaffe, Director of Communications Systems of the National Aeronautics and Space Administration, to discuss Syncom, Relay, and Echo, which are being funded by NASA.

Mr. Jaffe, it is a pleasure to have you with us this morning, and you may proceed with your prepared statement.

STATEMENT OF LEONARD JAFFE, DIRECTOR OF COMMUNICATIONS SYSTEMS, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. JAFFE. Thank you, sir.

Mr. Chairman, members of the subcommittee, I am happy to have this opportunity to outline for you the current NASA program of research and development in the area of communications satellites.

This program was reviewed before Subcommittee No. 4 of the Committee on Science and Astronautics of the House of Representatives by Mr. Morton J. Stoller on March 6, 1962. The program has not changed substantially since that time; however, significant progress has been made. It will, therefore, be my purpose here today to review the elements of the NASA program and bring you up to date on the progress which we have made since January.

On July 10, 1962, the great potential afforded by the uses of artificial earth satellites to provide worldwide communications was again demonstrated. Although not the first communications satellite (S. P. Brown, "Project Score: Signal Communication by Orbiting Relay Equipment," IRE Trans. Military Electronics, July 1960, vol. MIL-4 No. 2-3, pp. 624-630. G. F. Senn and P. W. Siglin, "Courier Satellite Communications Systems," IRE Trans. Military Electronics, October 1960, vol. MIL-4 pp. 407-413. W. C. Jakes et al, Project Echo, "The Bell System Technical Journal," July 1960, vol. XL, No. 4.) Telstar, an active repeater satellite with wideband capabilities, dramatically transmitted television programs in both directions across the Atlantic Ocean.

In the eyes of many, Telstar inaugurated operational communications satellites. This is not the case.

Telstar's many accomplishments, to date, are not to be minimized, but it should be recognized that it is an experimental communications satellite. Other experimental satellites will soon follow Telstar and from all of these experiments will come the answers to many questions, and the technology from which operational communications satellite systems can be built.

Before we discuss the experimental program, it is desirable that a few words be said about the need for communications satellites. Less than 6 years after the installation of the first transatlantic telephone cable we have come to the realization that undersea cables would not supply the growing demand for intercontinental communications in just a few years. Each new undersea cable has been used to capacity within weeks of inauguration into service.

In addition to this, the high frequency radio-telephone circuits have never been abandoned with the establishment of cables, but rather continue to augment the cables.

This luxury of the capacity afforded by high frequency radio-telephony will be reduced considerably in the coming years due to the upcoming minimum in the 11-year cycle for solar activity. (George Jacobs and Edgar T. Martin, the "Dwindling High Frequency Spectrum," presented at the IRE convention, March 21, 1961, reproduced in the Convention Record, pt. 8, pp. 179-195.)

This minimum will result in a lowering of the upper bound to useful frequencies for long-distance communications and, consequently, a reduction in the bandwidth available in this means of communications.

Although undersea cable installation is, and should be, continuing at a rapid pace, the installation rate cannot keep up with the demand, nor can economic cables supply the bandwidth required of modern technology—that required for television and high-speed data communication.

Microwave repeater systems, in use throughout the world, are capable of supplying the appropriate bandwidths, but are presently limited to line-of-sight distances on the earth's surface.

If microwave repeaters can be elevated, large distances above the earth's surface, the line-of-sight distances which can be spanned by such a communications system would extend beyond the oceans. Thus it is by means of artificial earth's satellites that we plan to raise microwave repeaters to high altitudes.

Technical and economic studies which have already been undertaken indicate that communications satellites can provide services comparable in performance to those of undersea cables, at lower costs per channel of capacity.

It would be a mistake to minimize the technical problems of establishing a communications satellite system. As we shall see, they are many and great, but equally great are the rewards and incentives to get the job done.

While the usefulness of the communications satellite and its importance in worldwide communications is undisputed, it is not immediately apparent which of the technical approaches to the problem will turn out to be the most rewarding in arriving at the design of the operational systems of the future.

Accordingly, NASA is endeavoring to assist in determining as rapidly as possible which of the various system designs which have been proposed should be used in the establishment of operational communications satellite systems.

To do this we must first determine which technique has the greatest promise of reliability and economy of operation, so that the development of the commercial system can be pushed forward as rapidly as possible.

On the first chart (F 62-30) there are indicated the three major communications satellites systems which offer sufficient promise to warrant continued detailed investigation.

The first of these is the system using low or intermediate altitude passive reflectors. The second uses low or intermediate altitude repeaters, and the third depends on high altitude, synchronous, active repeaters.

Perhaps at this point I should remind you that the passive or reflector satellite does not carry with it any power supply, receiver, or transmitter. It is in effect a radio mirror in the sky, and it is used simply to reflect the radio energy from one terminal of the communications satellite system to another.

Active repeaters draw their name from the fact that they carry receivers, transmitters, and sufficient power supply so that the message to be transmitted is received, amplified, and retransmitted to the far terminal.

By low or intermediate altitudes, we mean from several thousand miles to as much as 12,000 or so miles (20,000 or so kilometers). By high altitude, synchronous, is meant the 22,300 mile (35,900 kms.) orbital condition in which the satellite apparently remains fixed over a point on the earth's equator.

The next chart (F 62-31) shows pictorially the elements of a low altitude active communications satellite system. It is characterized by terminal stations with large antennas located, for example, on the European and the American continents, and by a number of satellites orbiting at low altitude. The reason for the large number of satellites indicated on the chart is that the time that any one of these satellites is visible to both of the terminal stations is limited, when the satellites are in orbit at low altitude.

Consequently, to get continuity of transmission between the two terminals, a number of satellites must be put into orbit, and these must be so distributed in space that at all times at least one can be used as a communication link between the terminal stations.

A realistic appraisal indicates that unless fairly complex provisions are included for controlling the position of the individual satellite in its orbit, it must be expected that the satellites will come after a period of time to an essentially random set of spacings.

Estimates of the number of satellites required for substantially continuous service between terminal points are, therefore, generally made on the assumption that the satellites are distributed in a random manner in orbit.

An example of the results of calculations on the number of satellites that are required for the maintenance of communications at several orbital altitudes is given in the next curve (F 62-32).

Here we see how many satellites are needed for substantially continuous service between ground terminals located some 3,000 miles (5,000 kms.) apart.

Note that if we were to orbit the satellites at an altitude of only 1,000 miles (1,600 kms.) that as many as 400 randomly distributed satellites would be required. If we plan to use the 5,000 (8,000 kms.) altitude range, then we can immediately cut the number of satellites required to 40.

Satellites are not inexpensive, and launch vehicle costs are at least comparable if not higher.

Consequently, even 40 satellites in orbit will represent a considerable investment for the communications satellite system. If fewer satellites can be used, we can cut the initial costs somewhat and keep the replacement charges down.

Suppose we plan on using the 22,300 mile (35,900 kms.) altitude, which is about as high as we would wish to go for reasons which I will mention in a moment. Nineteen satellites are shown to be required by the analysis, which assumes that the satellites are randomly distributed in orbit.

In actuality, if we were to orbit the satellites at 22,300 miles (35,900 kms.) and it were possible to exert effective precision control of their orbital velocity, we would not use randomly distributed satellites at all, but would establish what is known as a synchronous satellite system.

The synchronous satellite system is illustrated on this chart (F 62-33). It is of great interest in communications work, because at the 22,300 mile (35,900 kms.) altitude, the spacecraft will remain fixed over a point on the equator and it is only necessary theoretically to have three units up to provide for basic worldwide coverage.

At this altitude a satellite will continuously see one-third or more of the earth's surface. Consequently, if we can put a satellite up at such a longitude that it is visible to both American and Europe, continuous communications can take place between the two continents through just a single satellite.

Similarly, the establishment of another satellite further to the west will permit us to establish communications between the American continent and Japan, Australia, and the Far East.

A third satellite would round out the coverage for messages between the Far East and the European and African nations. To realize this type of system, the problems of providing a satisfactory attitude and position control system for the satellite must be met.

As it is by no means certain how long it will take to arrive at a control configuration of adequate reliability and precision, research on the synchronous system is being conducted parallel with that on low altitude systems.

I might interject here that I included the word "theoretically" in my statement about three satellites taking care or providing for complete global coverage.

The low altitude system by the very virtue of numbers of satellites provides a certain amount of redundancy, so that if there is a satellite failure we do not lose complete communication.

This is not the case in the high altitude system. If a satellite fails you lose the coverage over that portion of the earth that the satellite

was serving, so that we must think in terms of more than three in an operational system.

Mr. HECHLER. Mr. Boone?

Mr. BOONE. Are you suggesting that we would need possibly a standby for each of these three satellites, if we were able to control them?

Mr. HECHLER. Or are you suggesting that we put four up to make sure of the complete coverage if one fails?

Mr. JAFFE. The number is between four and six.

I am not sure that it takes a standby for each of the three satellites. It may be that a single standby could be maneuvered fast enough to repair the damage done by the loss of one. This, of course, must be the result of continued investigation, studies and experiments with being able to maneuver these satellites once they have been placed into the 24-hour orbit.

Certainly an operational system would not be satisfactory unless such backup provisions were provided in the event of failure of one of the satellites.

Mr. ROUSH. Mr. Chairman?

Mr. HECHLER. Mr. Roush.

Mr. ROUSH. May I ask, you can have an operational system with just one satellite, can't you?

What I am thinking is: There are portions of the world which perhaps are not as ready to receive this type of thing as other portions.

The Far East is not near as ready as Europe. I can conceive of us having an operational system which will really be progressive with just one or two, perhaps delaying for a few years the third, when those portions of the world which are more remote are more ready to receive this type of thing.

Mr. JAFFE. Certainly you are correct, that one satellite position would serve that area of the world covered by that satellite. A position over the Atlantic would serve the Atlantic traffic operationally.

My point is that it would be difficult and perhaps disastrous to rely on a single satellite in that position for an operational system which must handle the traffic on a detailed and routine basis. One would want to back this up in some way.

I have already mentioned that a communications system with the satellites at low altitude will require a number of satellites in orbit simultaneously, and that spacecraft and launching costs are likely to accumulate rapidly with such a system. We are studying techniques whereby we can launch a number of satellites into orbit from a single booster vehicle and have initiated work in this area which we expect will lead to a flight experiment within the next few years.

Having discussed some of the reasons for the different orbital configurations proposed for communications satellites, let me now review the satellites themselves. Basically, the simplest of all the communications satellite techniques is the passive reflector—the radio mirror in the sky. The passive reflector can take many forms and over the years a number of specific configurations have been suggested.

At the present time NASA is investigating four of these configurations, as they appear to have the most promise for immediate application. These four are shown on this chart (F 62-35). The first is the simple reflecting sphere. This, of course, has been tried already, in Project Echo, of which I will say more in a few moments.

As a follow on to the simple sphere with a continuous surface, there are two varieties of surface structure which promise better overall performance so far as the passive reflector communications system is concerned.

One of these is a sphere which has been lightened by etching holes in the metallic foil which constitutes the reflecting surface. This reduces the weight and makes it possible to orbit a larger satellite, which will have correspondingly improved performance, with the same launch vehicle.

An alternative method of reducing the weight of the sphere is to make the sphere of an appropriately sized wire mesh. We are not sure at this time which of the two techniques for lightening the sphere will actually prove to be the more effective. As we wish to make the sphere very much larger insofar as its reflection characteristics are concerned, we are also looking into the possibilities of effectively accomplishing this without actually orbiting the whole sphere.

In normal circumstances only the bottom face of the sphere, the portion facing the Earth, is actually used in reflecting the signal from one station to another. For this reason it seems rather unnecessary to orbit the upper portion, which serves no purpose in the communications satellite system.

The problem then becomes one of erecting, and then stabilizing, the spherical segment that is placed in orbit. With a complete sphere, regardless of stabilization, there is always a lower surface available to act as a reflector, while the spherical segment, shown over on the right of the chart, if not provided with stabilization, very often would not face in the proper direction.

Mr. ROUSH. Is this project which involves the orbiting of needles considered a form of communication, passive communication satellite?

Mr. JAFFE. Yes, it is.

Mr. ROUSH. Is it a project which is going ahead, or is it one that we have abandoned?

Mr. JAFFE. This is a DOD project, not a NASA project.

It is a project which, it is my understanding, will be carried through a small experimental phase to determine the desirability of this kind of communication satellite system.

I am not sure of the current status of that project.

Mr. ROUSH. Thank you.

Mr. JAFFE. As a result, the reflecting area that the antenna on the ground would see would often be very small, just as if you were looking at a shallow bowl, edge on, and it would not be possible to establish an effective transmission path. Therefore, to use the spherical segment, it is necessary that we add a stabilization device, which will hold the reflecting face toward the Earth.

Studies of the spherical segment reflector and of the stabilizer will therefore be carried on together, because without the second, the first is of little use.

NASA's passive satellite program includes several flight tests. The properties of the sphere as a communications reflector are being evaluated in these flight tests. The first of these tests was the Echo I project. Most of you have probably seen Echo moving across the sky and may be interested to learn that we are continuing to measure its

reflection characteristics to see if any more significant changes in its shape or surface conditions occur.

To refresh your memory, the left side of the next chart (F 62-36) shows that Echo was 100 feet (30.5 meters) in diameter, weighed 135 pounds (61.5 kgm.), and was constructed of mylar plastic film 5 ten-thousandths of an inch (1 one-hundredth of a millimeter) in thickness.

This is approximately 500 millionths of an inch in thickness, about one-quarter of the thickness of a human hair. The mylar film was made reflective to radio waves by evaporating an aluminum film on to the plastic in a vacuum chamber.

The aluminum was therefore extremely thin and contributed no structural strength to the sphere. After the Echo sphere had been in orbit for some time, it exhibited a certain amount of wrinkling, and there were small changes in its shape which are associated with the loss of the original volume of inflation gas.

As the sphere wrinkled, it became less acceptable as a communications reflector, as a smooth surface is the best reflector.

Accordingly, we have now built a new version, Echo II, which is shown on the right, a sphere which will maintain a fairly smooth surface characteristic. In designing this reflector, we took advantage of the availability of a large booster vehicle to make the sphere larger. It will now be 135 feet (41.5 meters) in diameter, and will weigh about 500 pounds (227 kgm.).

In this case the sphere is made of a laminate, a combination of two layers of aluminum foil, and one of mylar, as is indicated on the chart. The total thickness will be 750 millionths of an inch (0.015 millimeter). This is 50 percent thicker than Echo I, but is appreciably stiffer because of the presence of the two layers of aluminum foil.

When this sphere is inflated and somewhat overpressured, it takes on a permanent set, and does not tend to resume its earlier wrinkled condition when the gas pressure drops.

Consequently, it is our hope that even though the inflation gas will not remain within the sphere for an appreciable period of time, as a result of the punctures which will occur from micrometeorites, that the fairly smooth surface that is shown on the next chart (F 62-37) will be maintained for quite some time, and the effectiveness of the reflector will be demonstrable over a long period. The major objective of the Echo II project is to show that a rigidized structure of this type is a practical one as a passive reflector.

Mr. HECHLER. Could you read into the record some of the technical details of the passive repeaters, and give us your conclusions on what you feel their operational value is?

Mr. JAFFE. Sir, I might do this at this time.

We still feel that the passive satellite can be provided in space with a great deal of assurance to live for a long period of time. There is nothing within the satellite basically that can go bad, other than the structure itself. So it is the purpose of the NASA research program to determine what kind of structural integrity is required of these satellites to maintain these surfaces in the space environment.

There is no doubt that for commercial systems, the active satellite, if it could be provided with the reliability to make it economically viable, will provide more capacity for a given dollar, or a given-sized ground facility, than the passive satellite.

The big question still remains the life and, therefore, the economic situation. The life of the satellite strongly determines the economic factors, costs, initial costs, and the sustaining costs in an operational system.

Mr. HECHLER. This is essentially an interim system until the perfection of the active system; is that not correct?

Mr. JAFFE. It would be either an interim system or a system which could provide long-term service, should we run into difficulties in the space environment, which we do not recognize at this time, and which would preclude active satellite systems.

Mr. HECHLER. Therefore, you would recommend continued research and development and testing of the passive systems?

Mr. JAFFE. That is right. We feel that the research must continue. We are not advocating the establishment of an operational system. I might add that the research and the development of this technology of erecting inflatable structures in space is of interest to us not only from the passive communications satellite standpoint, but from the standpoint of erecting large structures for other purposes in space, such as solar collectors, large space stations, reflective surfaces for other purposes.

So this area of technology is one that has justification in other areas other than just the passive communications satellite.

Mr. HECHLER. Would you expand for just a minute on what you have just observed, on the other concrete advantages?

Mr. JAFFE. I am not sure that I understand the question, sir.

Mr. HECHLER. Would you expand on what you have just said, in listing the other things that we can learn?

Mr. JAFFE. Well, what I just said was that the technology of erecting, via an inflatable technique, large area structures in space, we feel will be useful to us in areas other than passive communications reflectors.

We can use large area structures for solar collection, collection of solar energy for radiation of power into space, for the erection of large space stations, so this is an area of technology which will provide us with a technique for putting large surface area structures or large control structures into space with small payload weight constraints.

I don't know whether this answered your question, but this is what I meant to convey.

Mr. HECHLER. What I was seeking was a more concrete illustration. If you cannot expand further at this time you may continue.

Mr. BOONE. Doesn't this offer, for example, different and more economical modulation methods?

Isn't there inherent in this an anti-jamming capability?

Mr. JAFFE. There is.

Mr. BOONE. Or such other factors that are not obvious?

I assume these are the areas you are looking into?

Mr. JAFFE. My remarks, with regard to the passive satellite, were restricted to a consideration of a communications satellite for commercial services.

There are some advantages to passive satellites from an antijam standpoint for military application, possible advantages, which may be of interest to the military.

Mr. BOONE. In that regard, aren't the civilian users or operators interested in antijam capability also?

It seems to me that current HF communications utilizes garbling methods, and so forth, for their oversea communication.

Don't you have to consider the same thing for commercial uses?

Mr. JAFFE. I think that the commercial interests are interested in preserving a certain amount of privacy on the communication services. This is a good deal different from providing antijam capabilities. There is a difference in the degree to which one goes to provide a measure of privacy as opposed to complete jamming protection.

I have not heard the commercial interests express a desire to provide systems which were jam-free.

Mr. BOONE. Thank you.

Mr. JAFFE. I will return to the statement.

Mr. HECHLER. Would you continue with a discussion of the active repeater program?

Mr. JAFFE. Would you like me to move to the active repeater program?

Mr. HECHLER. Put into the record the technical details.

Mr. JAFFE. Certainly.

Mr. HECHLER. Pick up on page 15 at the bottom.

(The portions of Mr. Jaffe's statement which were not read are as follows:)

In the next chart (F 62-38) we show the very interesting procedure which is followed in testing the Echo II sphere.

You may remember that in developing Echo I a number of ballistic flight tests were made to prove out the packing and inflation techniques for the sphere. In the course of these tests we learned a great deal about the details of the techniques required to build the canister containing the sphere, how to inflate it, and how to make sure that it was not damaged in the inflation process.

Our experience with Echo I convinced us that similar procedures must be followed with Echo II.

The first of the Echo II tests was conducted on January 15 and the second on July 18 of this year. The sphere ruptured during the first test, but the second test was completely successful. Right after I describe the test sequence outlined on the chart, I will show some of the films obtained from these tests. In the case of Echo II, because the sphere alone without its container weighs about 500 pounds (227 kgm.), a large rocket vehicle is needed to get the sphere to the proper altitude for inflation. A Thor rocket is used and launched at the Cape Canaveral range. At 147 seconds after liftoff, as shown on the chart, the shroud at the nose end of the vehicle is ejected, and at 161 seconds the canister containing the sphere is freed from the booster. At 186 seconds the canister is opened by an explosive device and the sphere, which has been folded within the container, starts to inflate as the solid gas generating material within it begins to evaporate.

As it inflates, we observe in detail how the process progresses. For example, we want to know whether or not the loose metallic parts which are in the vicinity after the separation of the canister halves interfere with the unfolding of the sphere or perhaps even puncture it. The unfolding and inflation take place at an altitude of over 200 miles (322 kms.).

It is obvious that it is not going to be possible to make the detailed observations with optical instruments on the surface of the earth. Accordingly, we made provision for the installation in the Thor

vehicle of a television observation system and a camera observation system.

Both of these devices record continuously as the canister is ejected and opened and as the sphere inflates. The chart indicates that observations from the Thor vehicle continue as the sphere rapidly reaches full inflation and then follows a ballistic trajectory to a peak altitude of 950 miles (1,570 kms.) and then drops back to the terminal atmospheric reentry.

Both the Thor and the sphere are outside the atmosphere in this phase, and they will maintain their relative positions as they move along the trajectory. Before the vehicle gets too far back into the atmosphere on reentry, a data capsule is ejected. This capsule contains the data recording camera and recovery aids, and is lowered by parachute to the predicted impact area where a recovery team is waiting.

At the same time the TV camera mounted in the Thor has been transmitting data to the Cape, so that if by any chance we lose the data capsule, we will not lose all the information from the test flight. The film which follows shows first the result of the television transmission, then the sphere, as observed from the camera in the Thor. The same sequence of television pictures and film camera pictures are then shown for the second successful test.

Mr. JAFFE. Turning now to the active repeater program, the general configuration of an active repeater is shown on the next chart (F 62-39). The satellite contains storage batteries which are kept charged by the external solar cells. These are used to power the receiver and the transmitter. An antenna system consisting of two units, one for the earth-to-satellite link and a second for the return link, is also necessary.

Ground terminals with steerable, high-gain antennas and associated transmitters and receivers are needed to complete a point-to-point channel. With this statement of the general concept of the active repeater, let us look at the specific versions in the experimental flight program.

It might be desirable to review quickly the Telstar satellite, although, by now, it is familiar to many of you.

The Telstar satellite shown in the chart (FC-1) was built by the Bell Telephone Laboratories and launched by the National Aeronautics and Space Administration under a cooperative agreement with the American Telephone & Telegraph Co. Under this agreement A.T. & T. provided the satellite and reimbursed NASA for all identifiable additional costs involved in launching the satellite.

Mr. HECHLER. How much was that?

Mr. JAFFE. The reimbursable cost to NASA has not been finally determined because we are still providing a service. However, it is in the order of about \$3 million.

Mr. DAVIS. Mr. Chairman?

Mr. HECHLER. Mr. Davis.

Mr. DAVIS. I happened to read this morning an account to the effect that this radiation which resulted from our high-altitude atomic explosion was not affecting Telstar on account of the sapphire covering and in the future you would have to have a sapphire covering to guarantee the radioactivity of the atomic explosions would not impair its ability to operate.

How much does that add to the cost of a satellite, the sapphire covering?

Is that a major portion of the cost?

Mr. JAFFE. It is a fair portion of the cost.

However, I would like to correct one impression here. All of our communications satellites have been designed with protection over the solar cells. A.T. & T. chose to put sapphire, actually aluminum oxide, on the surface of the solar cells.

In other cases we are using quartz glass. It is not necessary that the particular material be sapphire, it could be glass. It is a question of how much weight you really place in front of the solar cells.

It was recognized at the outset of the programs that high energy protons rather than electrons would be the worst enemy of solar cells at the altitudes that we are interested in for communications satellites. This Telstar has borne out. It has been the proton damage which has been observed rather than electron damage, and the reason is obvious, that the quartz, or sapphire, in this case, has protected the solar cells against electron damage.

Mr. DAVIS. Well, now, in discussing the relative cost of the sapphire as compared to the rest of the satellite, is it half, would that covering represent half the cost?

Mr. JAFFE. No.

Mr. DAVIS. Is this quartz much cheaper than sapphire?

Mr. JAFFE. Not really. The costs are mostly those of fabricating and mounting the glass, or sapphire, to the solar cells, rather than the cost of material per se.

I don't know at this time how to separate the costs of the protective cover from the costs of solar cells.

The solar cells are by and large the most expensive portion of this unit.

These are very expensive.

Mr. DAVIS. One further question.

Is it likely you would need that protective covering regardless of whether or not we had set off that high altitude atomic explosion?

Mr. JAFFE. Yes. The necessity for protection against electrons was recognized before this event.

Mr. DAVIS. And protons, too, I guess?

Mr. JAFFE. And the necessity for protecting against protons was also recognized.

The Telstar is a spin-stabilized spacecraft. The two rows of slots make up the microwave transmitting and receiving antennas which have very nearly omnidirectional radiation patterns. The antenna at the top is a VHF telemetry and command control antenna.

I brought this up to indicate some of the relative differences between this and some of the other satellites.

Telstar carries a single transponder. That is, one chain for receiving the signal from the ground, amplifying it, and retransmitting it back to the ground.

These (FC-2) are some of the details of this transponder chain. The interesting information is the fact they use 6,000 megacycles for the link from the ground to the satellite and 4,000 megacycles from the satellite to the ground.

These are the Telstar characteristics (FC-3).

Approximately 170 pounds. I won't go through the details. There are 3,600 solar cells and some batteries in the power supply.

It is these 3,600 solar cells that we were talking about being protected by sapphire covers.

The Telstar satellite was placed in elliptical orbit with the parameters shown in the next chart (FC-4).

The Relay satellite, shown on the next chart (FC-5), is somewhat different.

Although designed to experiment in much the same region of space, it carries a bit more power than the Telstar satellite and, in order to provide this greater power supply, the surface is much more thoroughly covered with solar cells than the Telstar.

Mr. HECHLER. What is the launching date?

Mr. JAFFE. The launching date is now the end of this year or first of next year.

Substantially as reported originally in March.

May I have the next slide?

The Relay spacecraft block diagram is shown here (FC-6).

The point I make with this chart is that there are really two complete sets of receivers, transmitters, and amplifiers within the spacecraft.

The upper portion of that chart shows the detail block of one set of transponders, the lower part, that says "Transponder No. 2 same as above," shows a complete duplicate set of equipment within the satellite.

There are some other differences in technique demonstrated by this chart for the handling of the signal within the satellite, and these are important differences from a technological standpoint.

From the standpoint of external users, the Relay satellite, will radiate 10 watts of power, as opposed to roughly $2\frac{1}{4}$ watts for Telstar.

Mr. HECHLER. What will it do that Telstar won't do?

Mr. JAFFE. They both have the capability for transmitting approximately 3 or 4 megacycles worth of band width. This is equivalent to a television band width. Both satellites have a capability for transmitting a nominal amount of two-way telephony, in the order of 12 or so channels, in both directions at the same time.

They will both do approximately the same thing. By virtue of the power in Relay it places much less stringent requirements on the ground systems that would work with the satellite as opposed to those that would work with the Telstar satellite if they were both placed in the same orbit.

Mr. HECHLER. Do I gather by that, that Relay is superior to Telstar and could replace Telstar?

Mr. JAFFE. They are both experiments. It is difficult to say which one is superior. At this stage of the game Telstar is performing beautifully in orbit—beyond expectations. Relay is only superior from the standpoint of more power. The detailed differences of how this will be accomplished internally within the satellite are technological differences and it remains to be determined which of these are really superior. This is one of the purposes of the flight program.

Only from the standpoint of power output is the Relay satellite superior in the user sense.

In the next chart (FC-7) we see some of the spacecraft details.

Again we are very much interested in the radiation environment.

Both Telstar and Relay are carrying radiation damage experiments. We have indicated here the kind of radiation measurements. Both protons and electrons are being measured.

On the bottom we have some pertinent details on the spacecraft. The same attitude correction system, using a magnetic coil. Weight is approximately the same, about 170 pounds. We have a good many more solar cells. About 8,400 solar cells on Relay as opposed to 3,600 on Telstar.

In both Relay and Telstar programs a goodly number of ground systems have been developed and are devoting time to these programs. In the next chart (F 62-46) we see a picture of the A.T. & T. facility at Andover, the large horn, with which we are all familiar, which was used for Telstar experiments.

This will also be used in the Relay experiments.

The interest in communication satellites is international. By its very nature, the communications satellite is an international communications medium, and many countries have indicated an interest in taking part in the program.

We have indicated on this next chart (F62-61) the total number of stations which are currently involved in Relay, but they are also taking part in Telstar as they become available.

Mr. HECHLER. Have these all been completed?

Mr. JAFFE. No. I will run down the list.

The station in Maine is the A.T. & T. facility, currently completed. NASA is providing a smaller facility in the Mojave desert in California, currently under construction.

In Nutley, N.J., I.T. & T. is providing a 40-foot antenna to take part in the program. This is complete.

Brazil is providing a transportable 30-foot antenna, built in this country by the International Telephone & Telegraph Co.

It is complete and virtually ready for shipment to Brazil.

The English facility is a large 85-foot antenna and is complete. It is currently taking part in the Telstar experiments.

I would like to turn to the French facility. This is a facility very similar, almost identical, to the Maine-Andover A.T. & T. facility; is complete, and has been taking part in the Telstar experiments.

Germany is planning construction of an 85-foot antenna, a large facility, and the situation there is that it is currently on paper, although the construction contracts have already been let.

However, no ground has been turned at this stage. It is expected to be completed the end of next year.

Italy is building a small facility, a 30-foot diameter dish. The ground installation has been started, the site is virtually complete, ready to accept the electronics and hardware, and it is scheduled to be completed by the end of the year.

These are all facilities which are different. They are all intended for the experimental program, and the very fact that they are different will shed a great deal of light on the kind of ground facility that ought to be best employed with communications satellites.

Mr. HECHLER. Mr. Jaffe, what do you think of constructing all these ground stations for medium altitude communications satellites if the decision should be made to move to a synchronous system which necessitates less ground stations?

Would not this be a tremendous waste of investment?

Mr. JAFFE. Sir, these facilities which are underway or have been constructed are, again, experimental facilities and fully recognized as experimental facilities.

It was recognized at the outset by all of these participants that there is the possibility of high altitude and low altitude systems. These facilities were so constructed that they would be capable of taking part in programs of investigation into both kinds of satellite systems. They would be useful with both kinds of satellites.

It was also recognized that an operational system may make use of ground installations that are different and perhaps simpler, eventually.

However, in the initial phases of the program it was recognized that facilities must be built capable of working with all of these satellites, and the experimental nature of the program was recognized by all of the participants before they started out to build these facilities.

I hope I made this point clear: Both kinds of satellites can be used with these facilities.

May I have the next chart—

Mr. HECHLER. Before you leave this: Are there any Advent ground stations that could be utilized?

Mr. JAFFE. There are Advent ground stations. There are two Advent ground stations currently being constructed.

Mr. HECHLER. To be utilized by other medium-altitude systems, such as Relay and Telstar?

Mr. JAFFE. I have no knowledge of their being utilized with the medium-altitude systems.

Mr. HECHLER. Can they be used?

Mr. JAFFE. They—can they be?

Mr. HECHLER. Yes.

Mr. JAFFE. I would have to get a detailed answer on this, but my impression is yes, with one exception. That is, that the frequencies for which these facilities were designed and the electronics to implement for these frequencies, were different for the Advent program, therefore modifications would have to be made to utilize them with the current satellites in the medium low altitude programs.

Mr. HECHLER. I am just trying to save a little money.

Mr. JAFFE. Basically the antenna, which is the major cost item, is capable of working with these lower altitude satellites. The antenna size, the surfaces, are good. The rates at which the antenna can be moved are such that they could be used.

Mr. HECHLER. Mr. Boone?

Mr. BOONE. Has the military participated with you in the Relay program in any way?

Mr. JAFFE. Participated directly; no. They have participated—

Mr. BOONE. They have a stated requirement as of hearings of several weeks ago and they apparently are going down a reoriented Advent program to provide a medium altitude satellite, and it seems that they should have—or might have wanted to—participate with you in the Relay program.

Mr. JAFFE. They have not participated with us in the sense of being a partner in the Relay or the Telstar programs to date.

However, they have been fully informed and are fully aware of all of the details and results of these programs.

There is a great deal of liaison between ourselves and the DOD.

I understand that there is some thinking currently, and perhaps a program has been established, but we had better check this point, for possible experimentation with the current Telstar satellite with some DOD facilities.

Mr. BOONE. Namely, the Advent facilities?

Mr. JAFFE. I don't believe they are the Advent facilities.

I will check on this point and insert it into the record.

(The item referred to follows:)

The type of facilities which the DOD could use for this purpose is described in a Department of Defense release dated September 14, 1962, as follows:

"Two transportable ground communications stations, leased by the Air Force from the International Telephone & Telegraph Corp. are expected to provide valuable experience in space communications to the military communications community well in advance of the development of a military communications satellite system.

"Using these mobile transmitter-receiving stations, military communications men will learn to exchange messages via experimental communications.

"The Department of Defense authorized this program in order to satisfy, at minimum expense, a need for operational experience in the communications satellite field. This new program, will provide valuable data on the practical problems of using satellites for communications support.

"Initially, one of the transportable terminals will be located at Nutley, N.J. The other terminal will be located, initially, at an undisclosed site in the Caribbean area.

"The contract with ITT's American Cable & Radio Corp. for lease of the stations amounts to approximately \$1 million.

"The terminals were designed and engineered by ITT's Federal Laboratories, at Nutley. Each unit is a completely self-contained communications center capable of carrying up to 11 simultaneous telephone conversations and an additional 24 teleprinter or several high-speed data circuits.

"Each ground terminal is housed in four mobile vans which can be transported by air, ship, rail, or road to anywhere in the world. At its destination the station can be assembled by the operating and maintenance personnel in a single workday.

"Heart of each transportable space terminal is a steerable 30-foot parabolic-antenna, and the radio frequency portions of the transmitter and receivers mounted behind the antenna. A 30-foot equipment and operations van contains the 10-kilowatt FM transmitter power supply and control and other radio equipment."

Mr. HECHLER. You may proceed, Mr. Jaffe.

Mr. JAFFE. Well, to go on with these ground stations, I thought it would be interesting for you to see what some of these looked like. These are very large, very expensive.

This (FC-10) is the English facility at Goonhilly, England, 85-foot antenna, currently participating in Telstar experiments.

The next slide (FC-11) is the French facility at Pleumeur-Bollou in Brittany, currently completed and participating in the program. It looks very much like the Andover, Maine, A.T. & T. facility.

Next (FC-12) we see the International Telephone & Telegraph Co. 40-foot dish in Nutley, N.J.

Next (FC-13) we see the transportable 30-foot antenna which will be supplied to Brazil. We are much interested in this kind of facility. One, because of its portable nature, and secondly, we are extremely interested in what might be done with the satellites by using minimal type ground installations.

We turn now to the Syncom program—

Mr. HECHLER. Before you get into the Syncom program, I would like to point out that the Hughes Aircraft Co. testified yesterday. Dr.

Adler testified, and testified on the technical aspects of the system and the launching, and I wondered if you could direct your remarks toward an appraisal of the reliability of the system.

I think the Hughes Aircraft representatives showed great confidence and bold and vigorous imagination in their presentation.

I would be interested in NASA's appraisal of the problems of injection into orbit and the reliability of the system as appraised by Hughes Aircraft.

Mr. JAFFE. Perhaps, with your permission, I will just leave the text and insert it into the record, because you did hear pretty much a description of the—

Mr. HECHLER. Unless there are any particular charts that you wish to use to illustrate your remarks.

I think we already have most of the details, technical details, of the system.

Mr. JAFFE. Yes.

Of the launch sequence.

Mr. HECHLER. We are interested in what you think of it, and what you think of the booster capabilities and the technical problem of injection into orbit, and the reliability of the system.

Mr. JAFFE. Very good.

Mr. HECHLER. What you are doing about it.

(The remainder of Mr. Jaffe's statement, and the charts referred to are as follows:)

As shown in block diagram (FC-2), the satellite carries a single transponder which receives the signal from the ground at 7.390 gigacycles, and converts it to a 90-megacycle intermediate frequency for amplification. The signal is then upconverted to 4.170 gigacycles, and further amplified in a traveling wave tube capable of delivering about 2 watts to the transmitting antenna. A 4.080-gigacycle beacon is also transmitted to assist in tracking the satellite with the ground antennas. The pertinent details on the Telstar spacecraft are given in chart (FC-3).

Telstar was placed in an elliptical orbit with the parameters shown in chart (FC-4). The launching vehicle was the three-stage Delta.

The Relay satellite is being developed for NASA by the Radio Corporation of America, and is shown in chart (FC-5). Relay is also a spin-stabilized satellite, and will go into an orbit very similar to that of Telstar. The microwave receiving and transmitting antennas are on the extended post, and also provide very nearly omnidirectional radiation patterns. The telemetry and command control antennas are short wires extending from the base of the satellite. The shape of Relay was chosen to take maximum advantage of the volume permitted inside the Delta vehicle's protective satellite shroud.

Both Relay and Telstar carry a magnetic torquing coil which can be energized, on command, to adjust the orientation of the satellite's spin axis, if necessary.

The Relay transponder is somewhat different and its block diagram is shown in chart (FC-6). Relay carries two complete transponders, either one of which can be selected by command. Both transponders cannot be turned on simultaneously. Each transponder has three channels through it. When used for one-way wide band transmission, a 1.725-gigacycle signal transmitted to it from the ground is received and converted to a 70-megacycle intermediate frequency. The fre-

quency is then tripled to increase the frequency deviation of the FM signal. This signal is then up-converted to 4.170 gigacycles, for amplification by the traveling wave tube output stage, which is capable of supplying 10 watts to the transmitting antenna.

When the satellite is used to transmit narrow bandwidths in two directions at the same time (as for two-way telephony) the lower two channels are used. The incoming frequencies are separated, as shown, and the signals fed through their respective channels where they are individually limited and the frequency is multiplied. The signals are then combined for retransmission to the ground. Other pertinent facts on Relay are given in chart (FC-7).

Both Relay and Telstar carry a great deal of telemetry, both to indicate the condition of the transponder, and to measure the radiation encountered in orbit and the effect of this radiation on the life of solar cells, transistors, and diodes. Since these satellites are orbiting in the heart of the Van Allen radiation belt, accelerated and severe radiation damage experiments can be made.

The effect of the radiation environment will have a large influence on the orbital altitude for operational systems, and may determine whether active satellites are feasible altogether.

The Telephone Company has built, at Andover, Maine, a very interesting facility as an earth terminal for the Telstar communications satellite. This chart (F 62-46) gives an artist's view of the facility which is now complete at that location. This is the facility which is used in the Telstar experiment. You will note that a large horn-type antenna is contained within a flexible radome. The radome is to be 210 feet (64 meters) in diameter. NASA will use this facility on a contract basis for its Relay program. NASA will also provide, for its own purposes, a 40-foot (12-meter) parabolic antenna and ground communication stations which will be used in checking out the Relay system performance. This will be located at the Goldstone Facility in the Mojave Desert of California.

Both Relay and Telstar have given rise to a great deal of international interest, and NASA has entered into agreements for joint experimental testing of the Relay satellite with Great Britain, France, Germany, Italy, and Brazil. Discussions with Japan and other countries have taken place, and it is expected that additional agreements will result. At present, the stations which are preparing for Relay operations are shown on the chart (F 62-61). Those in Maine, England, and France are taking part now in Telstar tests. Photographs of the ground stations at Goonhilly, England, and Pleumeur-Bodou, France, are shown in charts FC-10 and FC-11. In addition, the next two charts (FC-12 and FC-13) show the ground stations for Relay which will be operated at Nutley, New Jersey, United States of America, and Rio de Janeiro, Brazil.

The third active satellite project in our present program is Syncom, which is being built by the Hughes Aircraft Co. This is NASA's initial effort directed to the development of the synchronous satellite. Its objectives are to provide experience in using communications satellites in a 24-hour orbit at the earliest possible time; to develop the capability of launching satellites into the 24-hour orbit, using existing launch vehicles plus additional "apogee kick" rockets and to test the life of communications satellites components at the 24-hour orbit altitude.

The spacecraft itself is shown, partly completed, here (FC-14). The part protruding at the upper right is the apogee rocket motor. A traveling wave tube is used in the transmitter of all three active satellites because of its wide bandwidth and high frequency.

Now, with the help of the charts which follow, I will try to outline for you the way in which it is intended to get the Syncom satellite into a synchronous orbit at an altitude of 22,300 miles (35,900 kms.) (chart F 62-50). The initial injection of the satellite will be from the Cape into a very highly elliptic orbit, using the three-stage Delta vehicle. The planned apogee of this elliptic orbit will be at 22,300 miles (35,900 kms.). As a result when the satellite reaches the apogee altitude, it will be at the desired altitude for synchronous rotation with the earth. However, it will not have had enough energy imparted to it to stay at that point, and the internal apogee rocket must be fired to add the energy required.

Since the launching will take place from the Cape, we can launch directly only into an inclined orbit, as a launch into an equatorial orbit would require an extra velocity impulse at an angle to the original direction of motion. This is one of the constraints resulting from limited vehicle performance which we must accept at this time. When the satellite is separated from the lower stages of the Delta launch vehicle, it is spun about its axis and so it is rotating much as a gyroscope would rotate, as it comes up to altitude. The gyroscopic effect holds the axis of the satellite in the attitude with which it was separated from the Delta booster, so that when, through either ground control or by proper timing, the apogee rocket is fired, the satellite will be injected into a circular orbit. At this time the attitude control jet in the end of the satellite can be actuated by ground control to provide a force to turn the satellite. The result of this operation is indicated in this view. The satellite then appears to be rotating on its axis like a wheel as it moves in its orbit.

On the next chart (F 62-51) we see the satellite in its orbit above the earth. I have already remarked that the orbit is inclined. It is more than likely that the satellite's speed in orbit will be somewhat too fast or too slow for an exact match with the earth's rotation and it will tend to progress or retrogress around the earth.

A result of the inclination of the orbit is to make the point below the satellite trace a path resembling a series of connected figure eights as shown here. An additional element of ground control is then available. Data from the solar sensor is transmitted to the ground and there a control signal is computed which would activate the positioning gas jet in the side of the satellite.

This force will slow the satellite down or speed it up in its orbit, depending upon the direction in which the jet is pointed when it is operated. This controllable jet can be used to reposition the satellite from its original injection point close to the African coast, to the location somewhere over the Atlantic Ocean, where we would like to have it for communications experiments.

The next chart indicates the final position of the Syncom satellite (F 62-52). It will still be rotating about its axis and will be moving back and forth in a figure-8 pattern about 30° above and below the Equator.

The antenna pattern of Syncom is indicated on the right-hand portion of the chart. It resembles that of Relay in that it is uniform around the satellite axis and so the rotation of the satellite will not affect its performance.

With this antenna pattern, providing about 6 decibels gain, we should achieve effective coverage of almost all that portion of the hemisphere which can be seen from the satellite.

Snycom carries redundant transponders, as does Relay. The block diagram is shown in chart (FC-8). It is a straight transponder which receives the signal from the ground in the eight gigacycle region and retransmits the signal to the ground in the two gigacycle region.

Further details on the Syncom satellite are given in chart FC-9.

These are the experiments in the current approved flight program. They will investigate elements of the various methods of using artificial earth satellites to accomplish global communications, and they will explore the environment in various regions of space. From these experiments and others which will follow, we will obtain engineering data upon which to base operational system designs.

Studies, of course, have been under way for some time and are continuing on follow-on flight programs in the intermediate altitude and stationary altitude active satellites.

Although we have not begun the fabrication of flight hardware for these follow-on flight programs in the intermediate altitude and stationary altitude active satellites.

Although we have not begun the fabrication of flight hardware for these follow-on experiments and will not until early results of the first phases of our program can be analyzed, the development of long leadtime critical components is being carried forth now and proceeding at a very rapid pace.

It is felt that this procedure will minimize the time and costs of this important research program designed to assist in hastening the day when communications satellites will be used operationally on a routine basis.

Operational satellite systems will be larger and will require larger boosters than the Delta rocket to place them in desired orbits. They will almost certainly be more costly to establish.

When Arthur C. Clarke, a British science writer, first proposed the use of satellites for communications in *The Wireless World* in 1945, 12 years before Sputnik I, he hypothesized the use of manned space stations for this purpose.

If, indeed, it were possible to rely upon man to keep communications satellites working, many of our current problems would vanish. We cannot rely on man to repair failures in space. The satellites of the near future must be designed to exhibit reliability and dependability, unattended in the space environment for many years if we are to have economically visible communications satellite systems.

This is the problem and as I said earlier, it should not be underestimated, for the rewards are great.

We have seen demonstrations of transatlantic television and telephone via satellite this year.

But there is still much to be done. It takes time to develop systems which can survive unattended for years in the somewhat hostile environment of space, of which we still have much to discover.

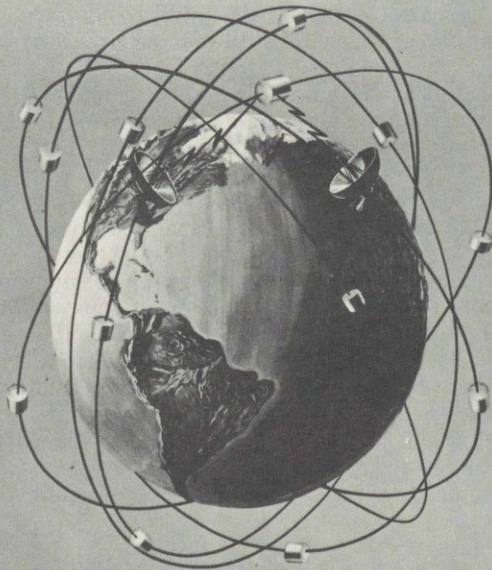
(The charts attached to Mr. Jaffe's statement are as follows:)

TYPES OF COMMUNICATIONS SATELLITE SYSTEMS

- LOW OR INTERMEDIATE ALTITUDE PASSIVE REFLECTORS
- LOW OR INTERMEDIATE ALTITUDE ACTIVE REPEATERS
- HIGH ALTITUDE, SYNCHRONOUS, ACTIVE REPEATERS

F 62-30

ACTIVE COMMUNICATIONS SATELLITES LOW ALTITUDE ORBITS

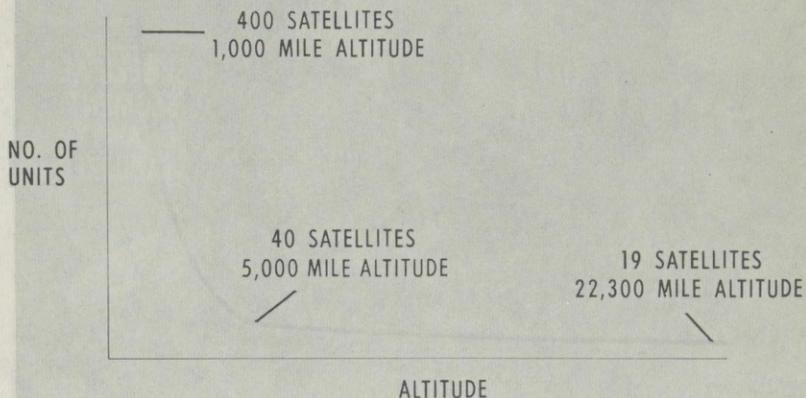


F 62-31

COMMUNICATION SATELLITES

RANDOMLY SPACED

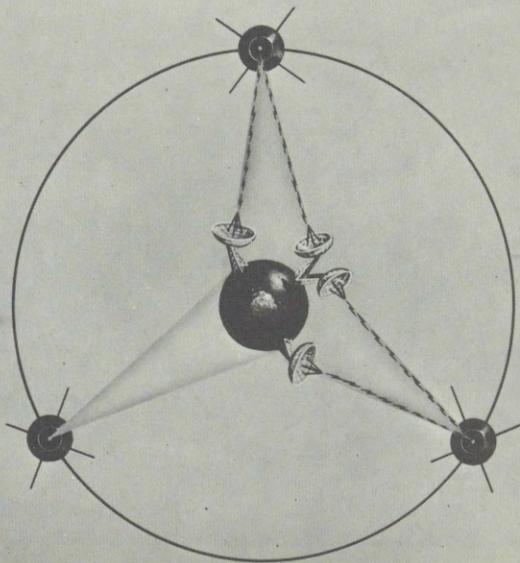
SUBSTANTIALLY CONTINUOUS SERVICE BETWEEN
GROUND TERMINALS 3000 MILES APART



F 62-32

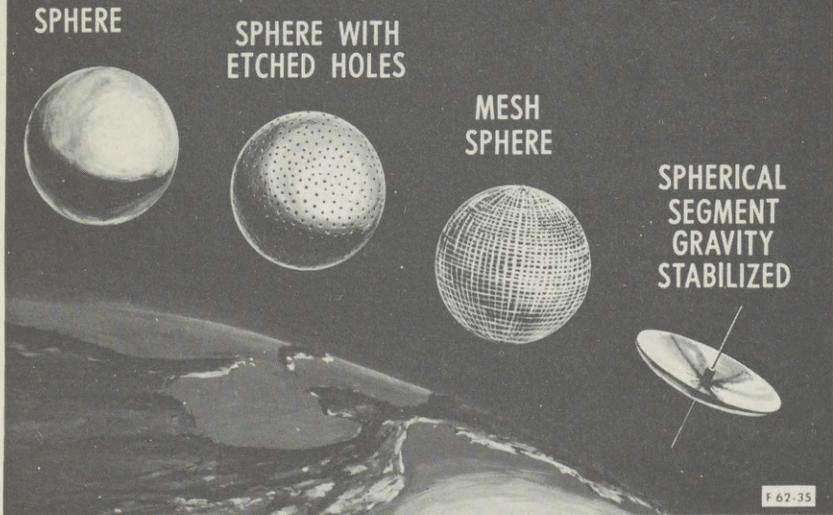
ACTIVE COMMUNICATIONS SATELLITES

SYNCHRONOUS ORBIT

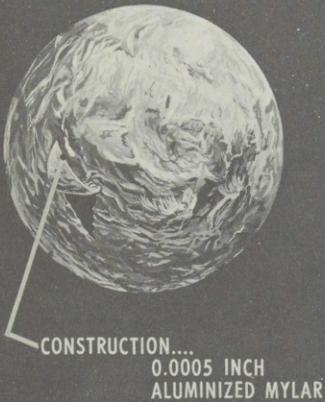


F 62-33

FORMS OF PASSIVE COMMUNICATION SATELLITES

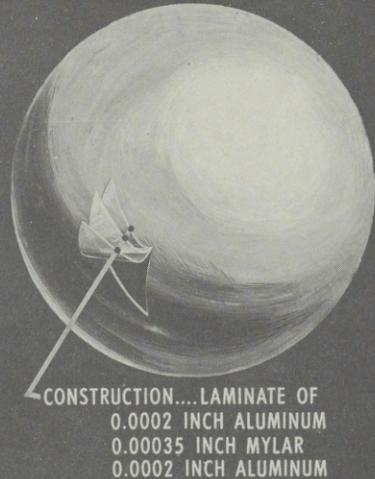


ECHO I



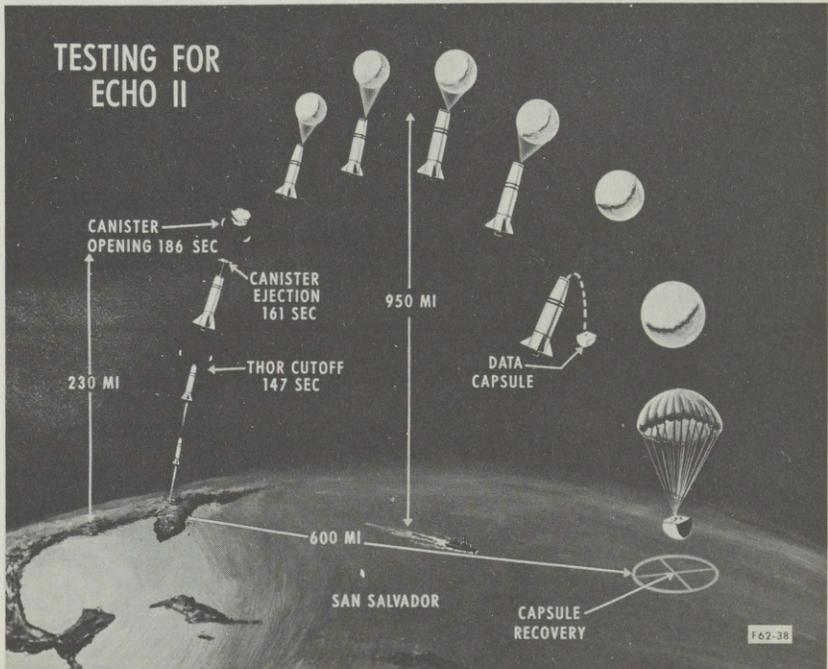
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WEIGHT 135 LBS.

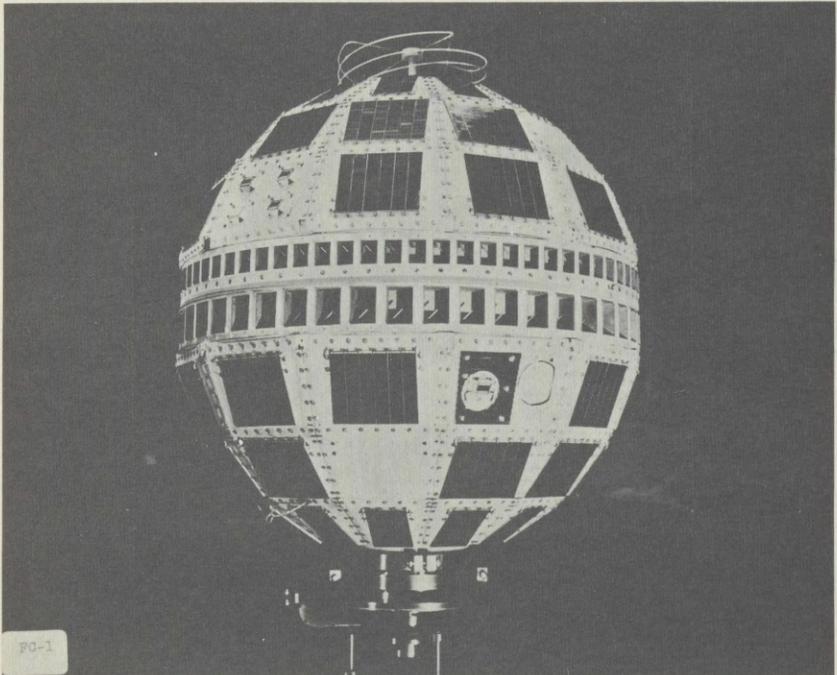
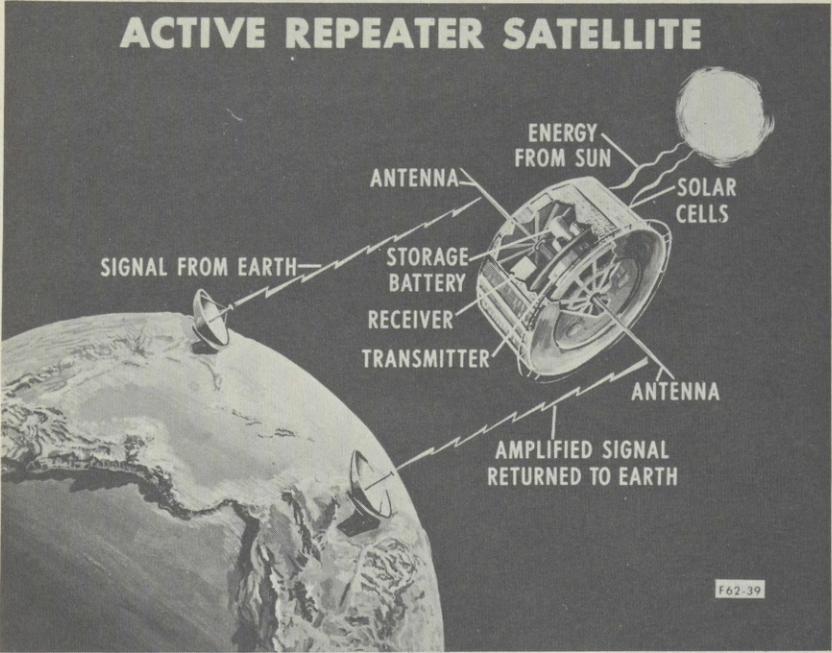
ECHO II



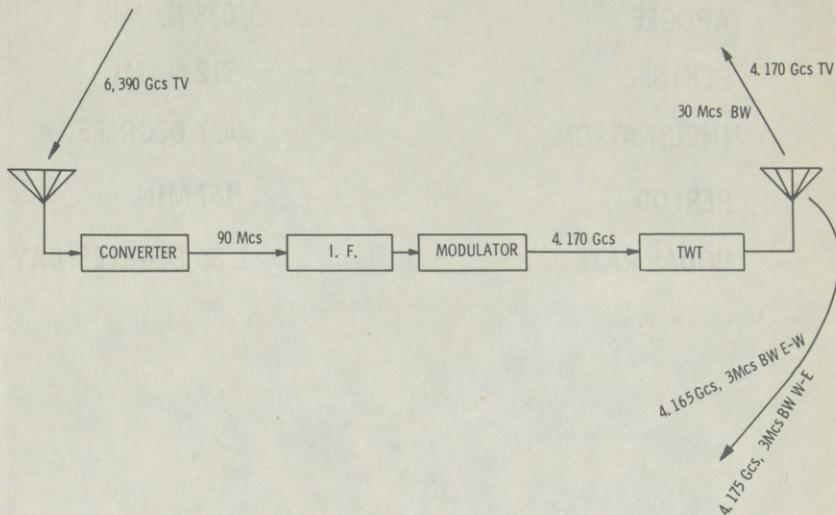
DIAMETER 135 FT.
WEIGHT 500 LBS.

F 62-36



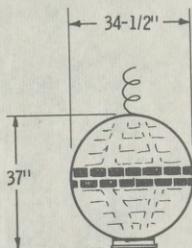


TELSTAR BLOCK DIAGRAM



FC-2

TELSTAR CHARACTERISTICS



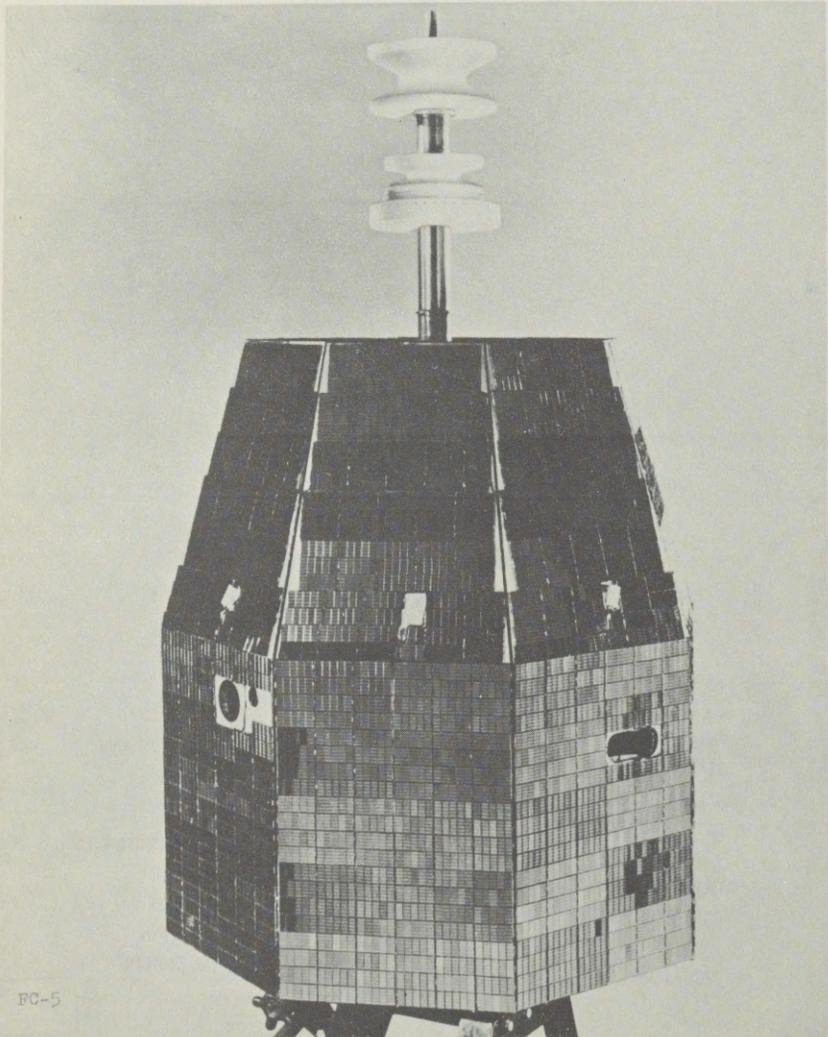
- | | |
|------------------------------|--|
| WEIGHT | - 170 POUNDS (77.5 kgm) |
| STABILIZATION | - SPIN - 180 rpm |
| ATTITUDE CONTROL | - MAGNETIC COIL |
| TWT OUTPUT POWER | - 2.25 WATTS |
| POWER SUPPLY | - 3600 SOLAR CELLS PLUS NICAD BATTERIES |
| TELEMETRY FREQUENCY | - 136.05 Mcs |
| RADIATION MEASUREMENTS | - ELECTRONS - 0.2 to 1.25 Mev |
| | - PROTONS - 2 to 2.5 Mev |
| RADIATION DAMAGE EXPERIMENTS | - 3 SOLAR CELLS, 6 SPECIAL SILICON TRANSISTORS |

FC-3

TELSTAR ORBITAL CHARACTERISTICS

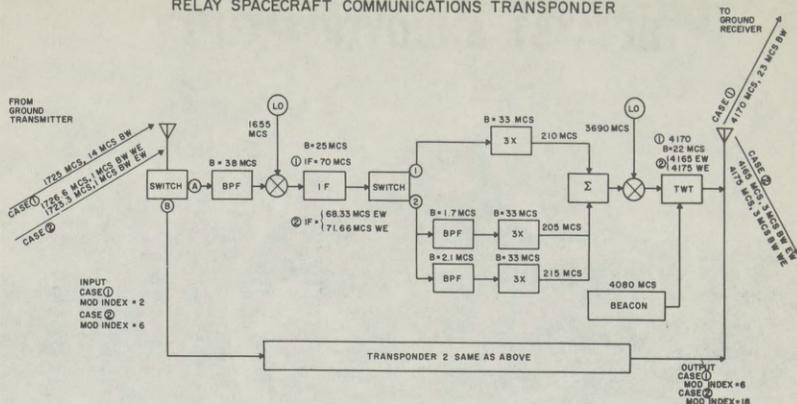
APOGEE	-	3,038 N. MI.
PERIGEE	-	512 N. MI.
INCLINATION	-	44.7 DEGREES
PERIOD	-	157 MIN.
NODAL RATE	-	1.86 DEGREES/DAY

FC-4



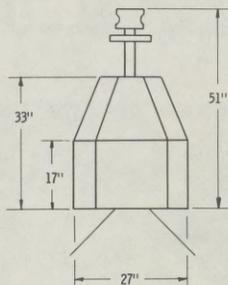
FC-5

RELAY SPACECRAFT COMMUNICATIONS TRANSPONDER



FC-6

RELAY SPACECRAFT DETAILS



RADIATION DAMAGE EXPERIMENT -
 30 SOLAR CELLS SILICON, n/p, p/n, REVERSE CELLS WITH QUARTZ COVER.
 THICKNESS 0, .030, .060, INCHES (0, 0.76, 1.52 mm)
 SIX SILICON DIODES

RADIATION MEASUREMENTS -

PROTONS -	OMNIDIRECTIONAL -	35-300 Mev
	DIRECTIONAL -	1-8.1 Mev
		15-60 Mev
		2.5-25 Mev
ELECTRONS -	DIRECTIONAL -	0.5-1.2 Mev
		0.25-1.0 Mev

STABILIZATION - SPIN 150 RPM
 ATTITUDE CONTROL - MAGNETIC COIL (1 DEGREE/DAY)
 BEACON FREQUENCY - 136.6 Mcs
 TELEMETRY FREQUENCY - 136.1 Mcs

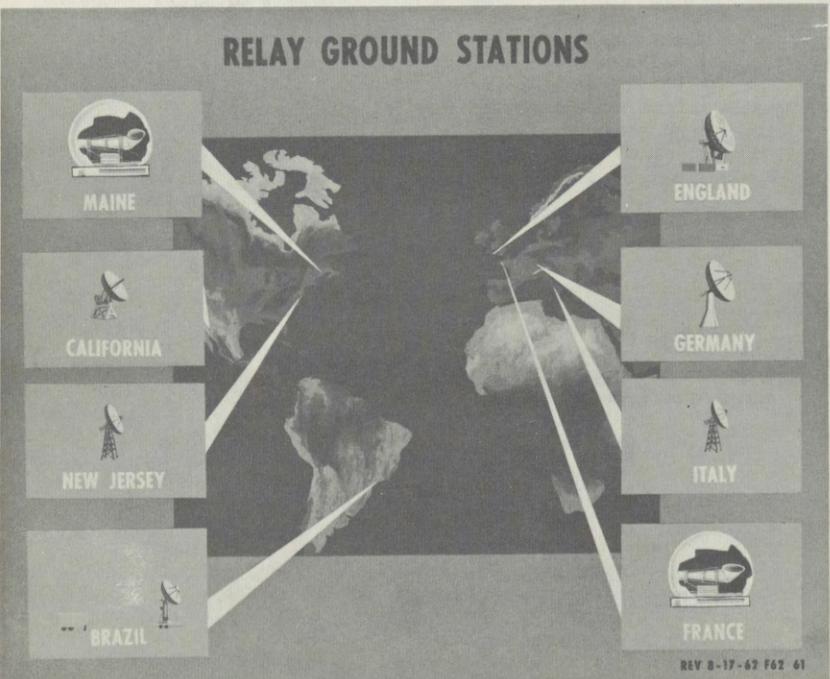
DIAMETER - 29 INCHES (73.7 cm)
 WEIGHT - 168 POUNDS (76.5 kgm)
 POWER SUPPLY - 8400 SOLAR CELLS PLUS NICAD BATTERIES
 TWT OUTPUT POWER - 11 WATTS

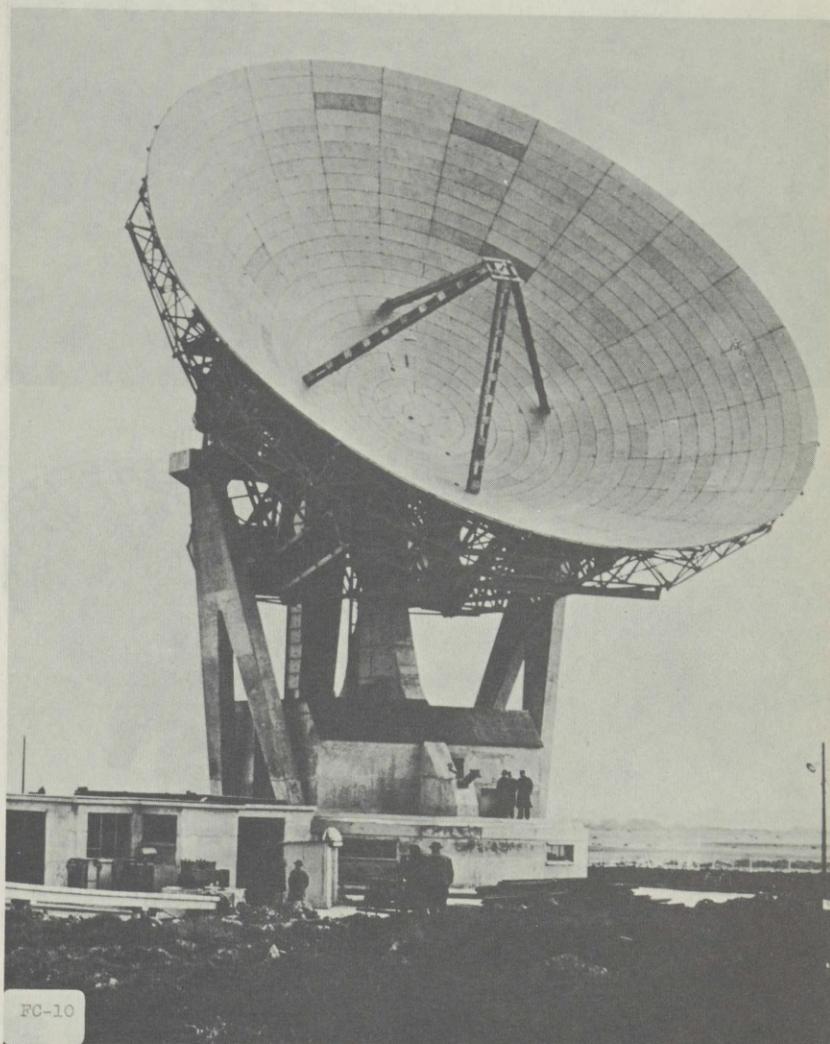
FC-7

THE AT&T ANDOVER FACILITY

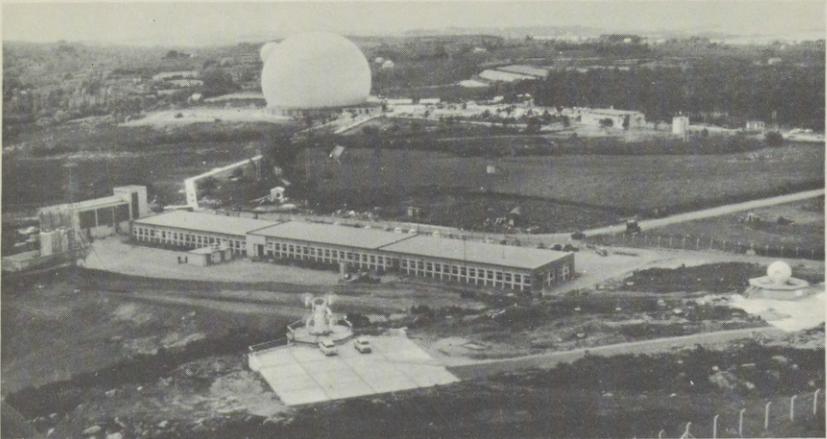


RELAY GROUND STATIONS

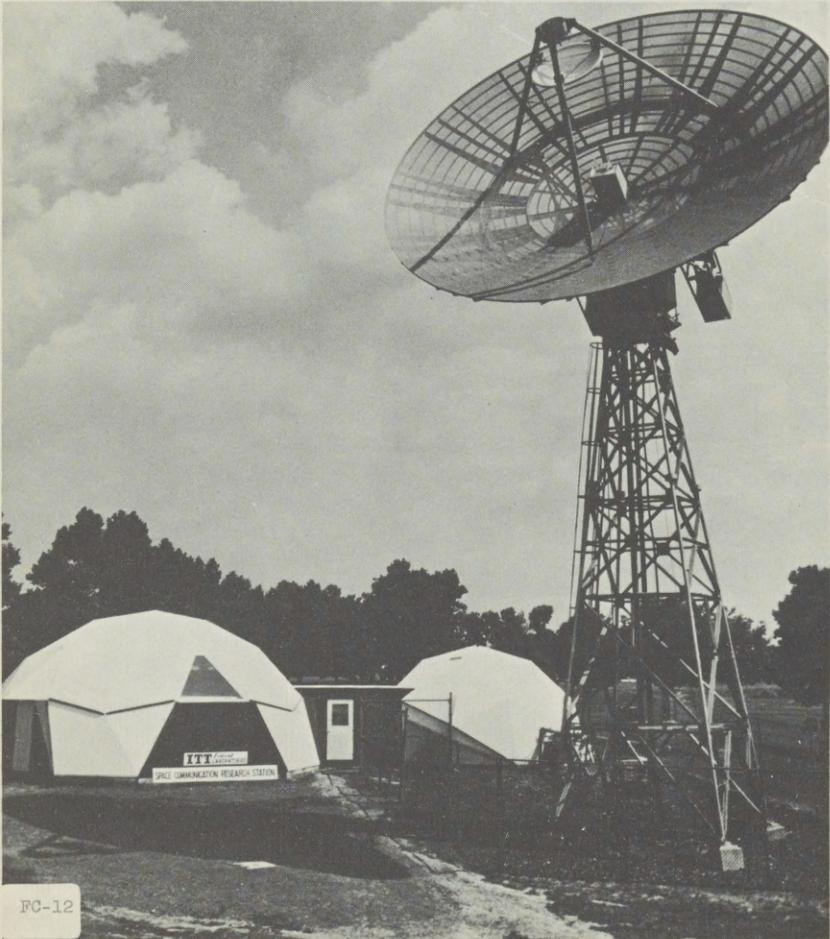




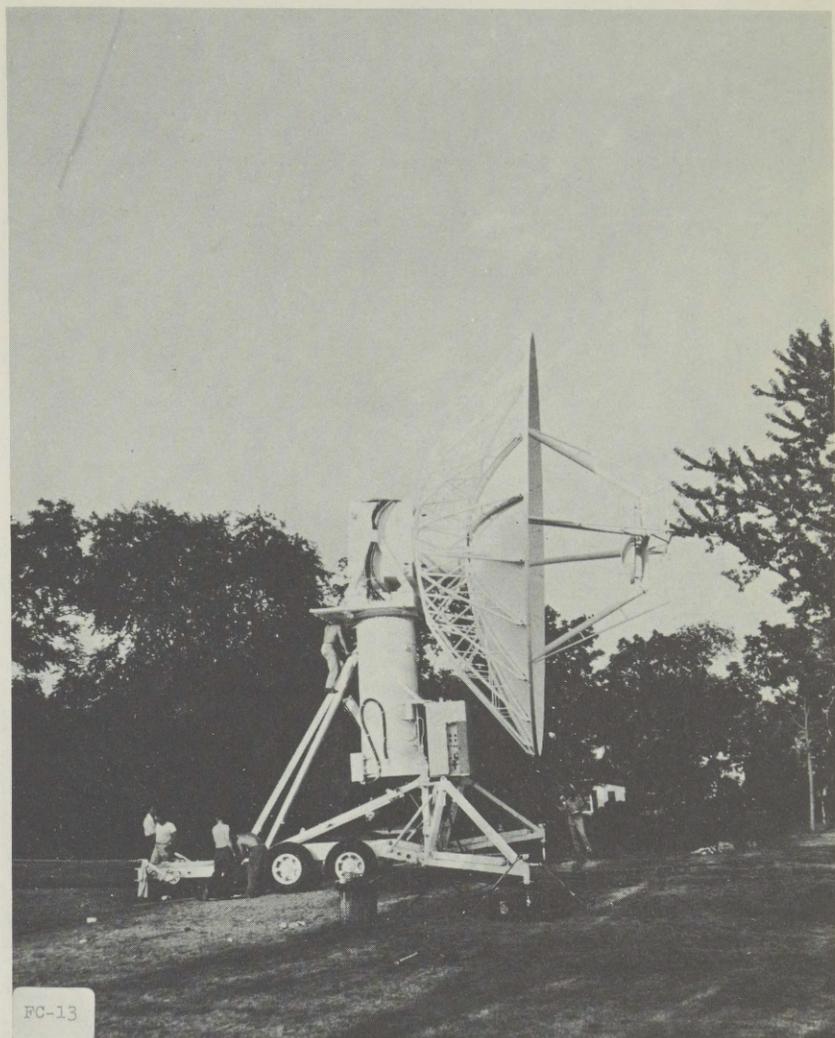
FC-10

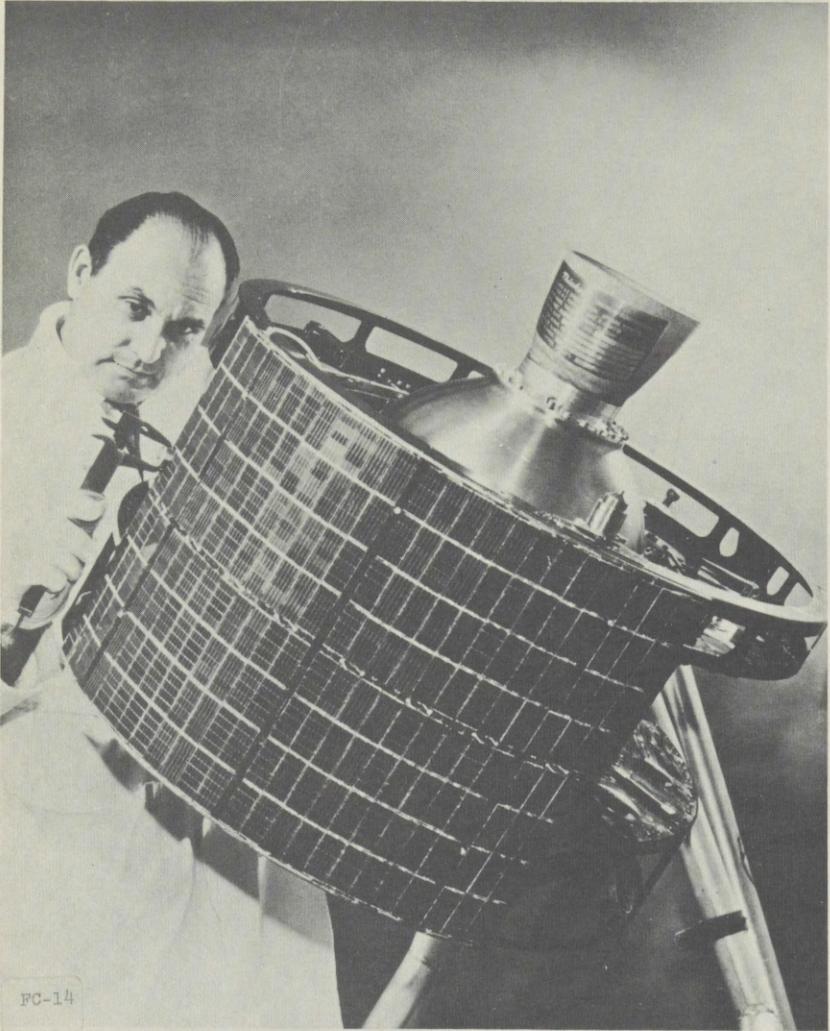


FC-11

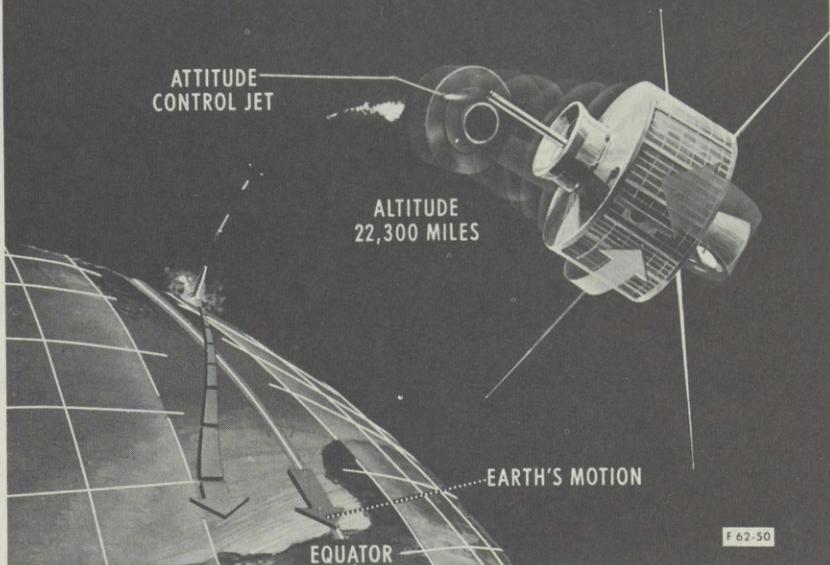


FC-12

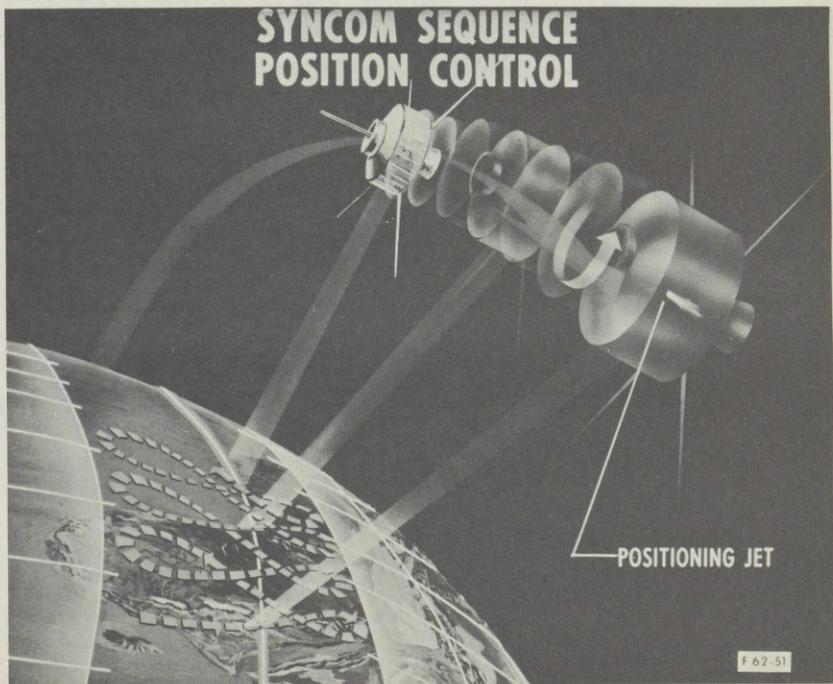


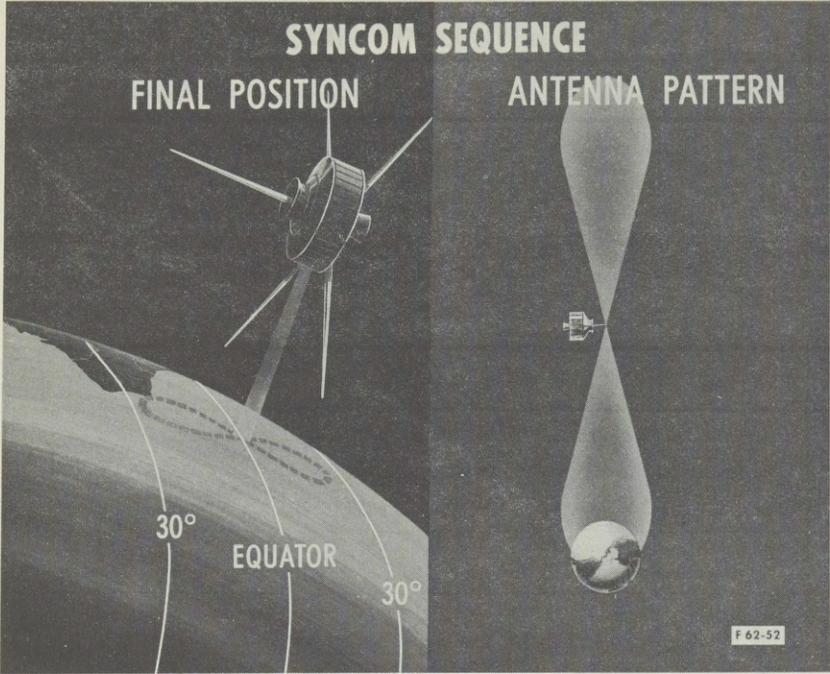


SYNCOM SEQUENCE LAUNCH & ATTITUDE CONTROL

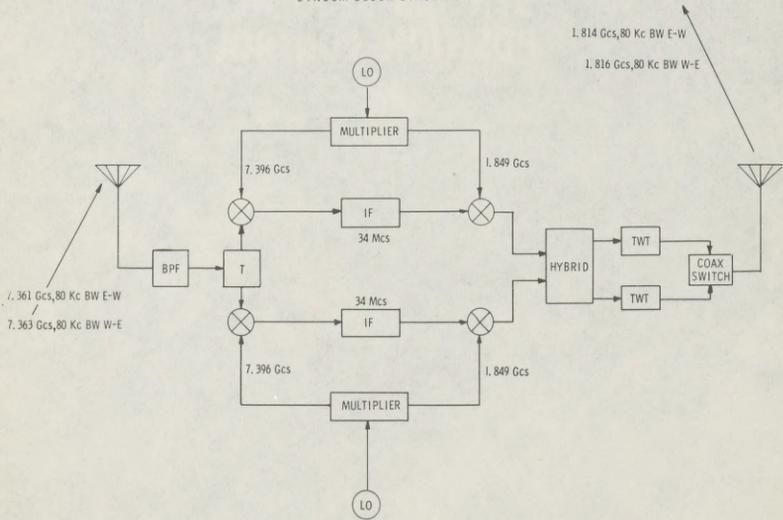


SYNCOM SEQUENCE POSITION CONTROL

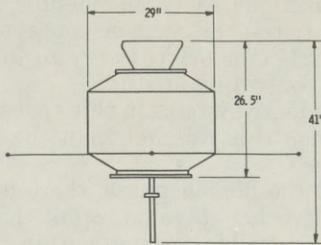




SYNCOM BLOCK DIAGRAM



SYNCOM DATA



WEIGHT	-	142 POUNDS (64.5 Kg)
WEIGHT OF SOLID FUEL	-	61 POUNDS (27.5 Kg)
WEIGHT OF CONTROL GAS	-	N = 2.5 (L 16 Kg) ; H ₂ O ₂ = 4.9 POUNDS (2.2 Kg)
COMMUNICATIONS CAPABILITY	-	1 FULL DUPLEX VOICE CHANNEL
STABILIZATION	-	SPIN 160 RPM
ATTITUDE & VERNIER POSITION CONTROL	-	COLD GAS, PULSED IN RELATIONSHIP TO SUN LINE SENSOR
COARSE POSITION CONTROL	-	H ₂ O ₂ JETS
TWT POWER	-	2 WATTS
POWER SUPPLY	-	3840 SILICON CELLS PLUS NICAD BATTERIES
BEACON FREQUENCY	-	136 Mcs
COMMAND FREQUENCY	-	148 Mcs
SATELLITE POSITION DETERMINATION	-	RANGE AND RANGE RATE MEASUREMENT THROUGH SATELLITE TRANSPONDER
GROUND STATIONS	-	ONE SHIP MOUNTED, ONE TRANSPORTABLE 30 FOOT (9.2 METERS) PARABOLOIDS, PARAMETRIC AMPLIFIER RECEIVERS, 20 KW TRANSMITTERS

Mr. JAFFE. First, let me start with Syncom, which is the only flight program that we currently have in this area.

I did not read the Hughes testimony. I will qualify my remarks that way, so I may repeat some of the things they said.

The Syncom I is basically an experiment, again.

It is a very small spacecraft. The actual communications portion weights only about 55 pounds. Because of this limitation we could build into it only a very small communications capability.

With rather small ground installations, of the 30-foot antenna size, we will have a capability with Syncom of about one two-way telephone channel.

So that it has a very small communications capacity.

Basically the purpose of Syncom is to, first of all, get into the 24-hour environment as early as possible, test components in this environment, and to test the Syncom concept of using a spin stabilized spacecraft in the 24-hour orbit, to try to inject it, control its period in this orbit, and control its attitude.

There are many more systems in this spacecraft which must work in order to accomplish this mission than there are in any of the low-altitude systems.

With regard to the launch phase, there is an additional rocket involved, additional rocket stage on top of the Delta vehicle. There is an additional gas propellant system within the spacecraft which must work during the launch phase in order to get it into the approximate vicinity of the 24-hour orbit, and there is another gas propellant system in order to control its attitude and its velocity over long periods of time.

All of these systems, all of these propulsion systems, must work.

Technically, there is no reason why it cannot work, otherwise we would have not undertaken the program. We do feel that the technique has merit, we feel that it must be developed.

The question in our mind is how long is it going to take to develop it to the point where you can rely on it.

I don't know how to answer it other than to say that it is a complicated venture, there are many systems, many more systems in this spacecraft which must work than there are in many of our other spacecraft—certainly in the low-altitude spacecraft.

These systems are going to be called upon, in an operational system, to work over a period of many years.

We have not had any experience with these systems in space over a period of years. Therefore, we must be somewhat hesitant about expressing a lot of optimism about when, in time, such a system might come into being.

We feel that the results of the Syncom tests will certainly give us a good feeling for how much of a problem this really is.

A great deal has been done in the way of reliability of these components, and a great deal will continue to be done. However, it is a very complicated mission. We feel that Syncom will be launched in the early part of 1963 and the next phase of a program to further develop the Syncom concept must await the outcome of the Syncom experiment.

Mr. HECHLER. If it is successful, would you think at that point that we could put more emphasis on the synchronous system?

Mr. JAFFE. If it is successful, and if it demonstrates an ability to live for long enough periods of time, then I am sure that it would be time then to place more emphasis on the 24-hour type of a satellite, or on the Syncom approach. I will qualify this in one other way. We are not sitting still on possible future programs with the Syncom approach.

We have undertaken a program of advanced technical development on those critical components of a followon version of a Syncom type of spacecraft which must necessarily be developed to fully utilize this concept.

There are several of these which are critical and these too must come along before one makes a decision to rely on this kind of a concept for operational systems, or before, even, one undertakes the next phase of the Syncom program.

I hope it was made clear to you yesterday that the Syncom spacecraft while spinning generates a sort of doughnut shaped antenna pattern.

Much of the energy is wasted by going out into space from this antenna pattern.

We feel that it is not proper, not desirable, to waste this energy, we must direct this radio energy back toward the Earth.

One of the important developments which must come into being and which must be demonstrated prior to fully developing the Syncom concept, is the ability to direct energy back to the Earth from a rotating or spinning spacecraft. Based on a proposal submitted, we have awarded a contract to the Hughes Corp. to develop a technique in this area.

We feel that this must be demonstrated.

We also want to look at the complexities of the solution that they come up with in providing this—we call it electronically steerable—as opposed to other techniques which might be used in a 24-hour spacecraft.

These must be weighed.

There is development of an additional rocket stage. Hughes is talking about a 500-pound spacecraft. This we think is an appropriate size.

We are moving ahead with the design study of this rocket phase.

There are some other details on components which are long leadtime items which we feel are critical items which must necessarily be in hand, or at least the solutions to these development problems be in hand, before one commits himself to a flight program of this magnitude.

Mr. HECHLER. I think it was a very, very sound decision that NASA made to participate with the A.T. & T. in launching the Telstar, because if we sit around and wait until absolute perfection, we may never get anything done.

I certainly commend NASA for moving forward with this program and at the same time looking toward the future in the development of the synchronous system that may eventually be utilized.

Do you believe that if Syncom I in its experiment works out well, and Syncom II also does, do you think this will replace the medium altitude systems that are currently under test?

Mr. JAFFE. This depends on one very critical question, the question of what the permissible time delay will be in two-way telephone conversations.

There is an international standard existent today. It happens to be 250 milliseconds—a quarter of a second—the delay in a 24-hour altitude system is in excess of this.

Mr. HECHLER. Six-tenths of a second?

Mr. JAFFE. It would be six-tenths of a second for one satellite link.

Mr. HECHLER. Yes.

Mr. JAFFE. This has been studied by many people. Many people in this country have come to the conclusion that this six-tenths of a second delay is not objectionable. This is currently under review by international groups, such as the International Telecommunication Union, and their technical support organizations.

One of the criticisms, and it may be a valid criticism, of the U.S. evaluation efforts in this area, is that they have largely been carried on between people speaking the same language.

This is felt not to be a valid objective—or subjective—test, and therefore this may be a valid criticism; I don't know.

I feel this question must be answered by an international standard group. It is currently being studied and considered.

If it is not an acceptable time delay, if the six-tenths of a second is too long, then we will probably be restricted in somewhat lower altitudes to provide the telephony service.

There is certainly no question but that the 24-hour altitude is perfectly good for the other services such as television and data transmission. It would be a far more acceptable system from the standpoint of complexity, complexity of ground terminals, if the satellite technology does not prove too difficult.

Mr. HECHLER. How soon do you think this could be perfected, this system?

Mr. JAFFE. The synchronous system?

Mr. HECHLER. Yes.

Mr. JAFFE. I can indicate only the time scale which we see things happening here. Syncom, as I said, we will launch early next year. We have been moving ahead with the critical components of the second phase. Should it be desirable to initiate a second-phase program here, it would be done after some initial experience with Syncom.

It is difficult at this stage of the game to tell you whether it is 1 month's, 2 months', or 6 months' worth of experience. It depends on the nature of the program and what kind of difficulties we encounter.

I will say this: the second phase, or the contemplated second step in the Syncom program, contemplating a 500-pound spacecraft to be launched on an Atlas-Agena, is a large mission, very difficult development, and it is NASA's opinion that this development, from the letting of a contract to a flight, is a minimum of 2 years.

To a first flight, that is.

Mr. HECHLER. Does this mean that you could have an operational synchronous system by the middle of 1964?

Mr. JAFFE. Well, it certainly does not mean that, if the operational system is based on what has been called Syncom II. In actuality, NASA does not officially have a Syncom II project. We refer to it as the advanced synchronous communications satellite.

Mr. HECHLER. Yes, that is what I mean, Syncom II.

Mr. JAFFE. My own opinion is that if the so-called Syncom II is started, that is, the flight hardware, is begun, early next year, beginning of 1963, it would be early 1965, or very best, late 1964, before a first flight of such a spacecraft.

Now, this is, again, a first unit. If one is willing to say on the event of success of that first unit we have an operational system, well, fine. I think it takes a few more than one before we can say that it is operational.

Mr. HECHLER. What was the date you gave?

Mr. JAFFE. I gave late 1964 or 1965.

Mr. HECHLER. It is too bad you could not have gotten the thrill of hearing the testimony of the Hughes Aircraft people, who confidently predicted this could be done by mid-1964, and one of the reasons I was interested in having you talk about your appraisal of what Hughes had predicted, was to indicate what you felt some of the difficulties might be that would cause a lag beyond what the contractor was predicting.

Mr. JAFFE. Well, again, I think we are not wasting any time.

We have under development those critical items which must be developed before one can undertake the development of the flight article of the next satellite.

One must know whether or not we have a solution to this antenna pointing problem and how complex it is.

One must know what this additional rocket stage will look like before one can design the satellite around it.

These things are proceeding.

We feel that the solutions to these will not be forthcoming before Syncom gets off the ground.

So that there is a compatibility in the timing of these programs that we will, hopefully, have some experience with Syncom in the same time scale so that we can make an appropriate decision on the advanced satellite.

Mr. HECHLER. On page 4 of your statement, there is the sentence—

Accordingly, NASA is endeavoring to assist in determining as rapidly as possible which of the various system designs which have been proposed should be used in the establishment of operational communications satellite systems.

By that, do I take it that it is your decision rather than the corporation's as to which of these systems to utilize?

Mr. JAFFE. No, sir; I do not mean that.

Those words were fairly carefully chosen. We will assist in helping to determine what kind of a system should be used.

Our mission is not to develop operational units nor even operational prototypes, but to provide units which will carry the kind of research programs from which such systems can be built.

This is why I qualified my answer to your question about whether or not we would have an operational system with the advanced synchronous satellite. This satellite, again, will be an experimental spacecraft and will carry many experimental devices. It will carry, certainly, radiation monitoring devices, which are of much concern to us, but not of concern to an operational system.

So there are many things that would be carried aboard a first experiment of this nature at these altitudes that would not be carried in an operational system once the engineering parameters are known.

Mr. HECHLER. Mr. Davis?

Mr. DAVIS. Mr. Chairman, I have one question.

It was said yesterday by the witnesses from the Hughes Aircraft Co. that the guidance systems which were used on the Ranger shot and also on the Venus shot met with success and showed a critical ability in excess of the requirements of Syncom.

Do you agree with that, that the test that the guidance systems were put to on the Moon and Venus shot called for an accuracy even greater than would be required in a Syncom satellite—or in a synchronous satellite, rather?

Mr. JAFFE. I am not clear what the reference was here. If they are talking about the accuracy required of the Atlas vehicle during that portion of a flight the answer is "Yes," that the Atlas probably performed as well as would be required for the advanced mission.

Mr. DAVIS. The framework in which that statement was made was this: it was pointed out that the satellite would be launched at an angle to the equatorial plane and it would have to be redirected and placed in the equatorial plane and then would have to be kept right over a particular spot on the earth at all times.

The statement was made that the—I suppose it is a bottled gas technique, of positioning the satellite, but that was not specifically said, but I judge that is what was meant, that that was sufficient and that the requirements in getting a spacecraft to the Moon, or near Venus, are even more exacting than that of getting a satellite in synchronous orbit.

Mr. JAFFE. Well, I cannot answer you specifically.

I don't know what the relative accuracy requirements are. I don't think we have any strong doubts about the accuracy requirements of this kind of a mission, or that they can be accomplished.

Our major questions are with regard to the long term vulnerability to failure of this kind of a system, or the reliability. This must work for a longer period of time.

Mr. DAVIS. You spoke of economic viability.

I usually think of that as meaning that it would be a good investment from the standpoint of a stockholder, but in the case of a Government-sponsored proposition, what determines whether or not it is economically viable, what is your yardstick there?

Mr. JAFFE. Our research is based on things which would be useful to commerce.

Mr. DAVIS. Do you use something comparable to the cost-ratio basis which the Corps of Engineers uses on a hydroelectric project, for example?

Mr. JAFFE. The output of research is very difficult to evaluate. I don't know, I don't claim to be an expert on how one evaluates research output.

Mr. DAVIS. When you use the term "economic viability" it is simply a relative term?

Mr. JAFFE. My reference was for the operational system. This is a very finite thing.

In other words, the satellites, the satellite system, must be capable of supporting the costs; the revenues must be capable of supporting the cost, and the revenues must be such that they are not in excess of doing it any other way.

Mr. DAVIS. That puts it something similar to the cost beneficial ratio, doesn't it?

The benefit should bear a favorable ratio to the cost?

Mr. JAFFE. Right.

Mr. DAVIS. What is that ratio, in your testimony?

Would you say 1 to 1, or something like that?

Mr. JAFFE. I must make it clear that I am not an economic expert. We have had studies which indicate that satellites systems definitely can be provided which would show economic benefit over and above other forms of communications.

It is very difficult to do a definitive evaluation at this time, for two reasons: One is that the satellite system is uniquely different from most other communication systems. One usually talks about a cost per channel-mile of service, how much it costs you to get a given amount of communications from over a mile of line.

The satellite system is not that kind of a system. A satellite will serve just as well a situation with two terminals a hundred miles apart as one a thousand miles apart. So the cost per mile concept does not fit.

Secondly, the satellite not only serves one link as would be served by a cable, between two terminals, but serves many stations, so again the cost per mile does not follow.

The other factor, which is a very difficult one to assess at this time, is the lifetime that one can assign to a given satellite system. This strongly determines the operating costs.

It makes a big difference if one assigns a 1-year life or 5-year life to satellites.

But enough of an economic study has been done to show that even with the pessimistic numbers inserted, that satellites still can provide a service which shows economic advantages over cables, let's say.

Mr. DAVIS. In summary, the economic viability cannot be precisely measured; is that not true, and nearly everything depends on the life of the satellite?

Mr. JAFFE. That is correct.

I could qualify it only one way: the economic viability can be measured for a given set of circumstances.

One has to specify those circumstances—

Mr. DAVIS. Or assume them?

Mr. JAFFE. Or assume them.

Mr. WAGGONNER. I think you could measure the potential, but you do not know the reliability yet?

Mr. JAFFE. That is right.

Mr. WAGGONNER. So it would be impossible to come up with anything really accurate.

Mr. DAVIS. Thank you. That is all.

Mr. BECHLER. Mr. Waggonner, any questions?

Mr. WAGGONNER. No.

Mr. HECHLER. On the statement that Mr. Davis was making about guidance, with reference to what we have now in our Mariner shot, I quote from what Hughes said, so we have it.

Dr. Adler testifying yesterday indicated:

We rely on the Atlas-Agena guidance system to give us about one degree of accuracy, which is within the state of the art.

We can allow a total inaccuracy of about two degrees of direction of thrust, or in the direction of final velocity vector. We can also allow about 1½ percent variation in the impulse from this motor, which is, again, within the state of the art.

Then we have calculated that the worst error that we then will have to correct is about the equivalent of 300 feet per second, so we have allowed this much correction capability in our satellite design for initial alinement of the satellite, very accurate alinement, to make it truly stationary initially—300 feet per second.

Incidentally, we have also looked at the accuracy at which the recent Ranger IV shot, which landed on the backside of the Moon, and the recent Mariner, now on the way to Venus, had been launched.

These have been launched using the Atlas-Agena guidance system also.

If we could have the equivalent accuracy in this launch, then we would only need actually 50 feet per second of correction capability rather than 9,300 feet per second, which we have actually supplied.

So we have been quite pessimistic in our assumptions regarding the accuracy of the Atlas-Agena guidance system, at least as demonstrated in these two flights that I mentioned.

Mr. JAFFE. I think, sir, that this sort of corroborates my opinion, that they were referring to the Atlas performance, Atlas-Agena performance, and certainly the Atlas-Agena performance in the recent Ranger mission, was very good.

We have no doubts about this portion of the advanced satellite flight mission. It is more with regard to the additional equipments that would go on top of the Atlas and in the satellite that we are concerned.

Mr. HECHLER. Yes.

Mr. Boone?

Mr. BOONE. Do you intend to place in orbit the three Syncoms that are going to be delivered to you? Will you do this as quickly as possible?

Mr. JAFFE. Well, we have a tentative schedule which shows something like 2 or 3 months between launches. Obviously this is something that one considers at the time.

After the first launch, depending on the results, we would make a decision with regard to how rapidly to fire the second one. It is our intent to put at least two of the three in orbit.

The third is considered a sort of backup.

Mr. BOONE. Doesn't the Syncom I, or would it not, offer you some limited capability?

I think most of the time schedules have been based on development of Syncom II satellite. Why not put Syncom I in orbit for a limited operation capability?

Mr. JAFFE. You mean additional Syncoms, if they are successful?

Mr. BOONE. I would like to go to the single station and at least have one station operating, as suggested earlier by Mr. Roush.

Mr. JAFFE. If one is satisfied with the minimal capability that exists in Syncom, certainly, if successful, there is no reason why it could not be used in an interim way, if there is an operational requirement.

Mr. BOONE. If you had to put a satellite in operation today, what scheme would you go to?

Mr. JAFFE. If somebody ordered me to put a satellite system in orbit today, that had to work, the only satellites that I know of are either Telstar or Echo.

These we have put in orbit. These have worked.

Beyond that it is conjecture. We have developments underway, but the two I mentioned are the only proven things.

Mr. BOONE. From the point of view of reliability, Echo must be higher on the list, is that right?

Mr. JAFFE. No. A month or two ago, I would have said "Yes." But Telstar has shown a remarkable survivability rate at this stage of the game. It is very premature to say this. I hope that this will not—

Mr. HECHLER. Reliability as well as survivability?

Mr. JAFFE. That is right. It is much too early in the life of Telstar to really be very definitive about how well it is going to perform over a long period of time. However, it is performing as predicted in every respect, and we have no reason, at this stage of the game, to believe that it would not live for the prescribed time, which, hopefully, is 2 years.

Therefore, at this stage of the game, I would say Telstar is probably a very good bet, if one had to bet right now.

Mr. HECHLER. Mr. Davis?

Mr. DAVIS. Dr. Jaffe, I notice from the testimony yesterday that—well, our chairman quoted Dr. Dryden as having said that he doubted that a synchronous satellite system could be put into operation in less than about 10 years.

Now that varied from the testimony of the Hughes witnesses on yesterday, who gave a prediction, or estimate, very substantially in accordance with your own, which was approximately 2 years from now.

As I got it from Dr. Dryden's testimony, he seemed to have misgivings about the system of storing energy in spacecraft in the form of gas under pressure and using it to kick the satellite back into position every time it drifted out of position, and I wondered if you would care to say which you think is the best estimate, Dr. Dryden's—I should not have to discuss that—you have stated you thought it could be done in about 2 years yourself.

Mr. JAFFE. May I comment?

Mr. DAVIS. Yes.

Mr. JAFFE. I hope I make this clear. My opinion is not at variance with Dr. Dryden's. As a matter of fact, it is quite consistent with his. I said it would be a minimum of 2 years from the time of contract to the first launch of an advanced synchronous communications spacecraft.

The contract is not let. Therefore, the first launch of an advanced spacecraft, if we were to undertake that kind of a mission, would be somewhere around early 1965.

Now, it is both Dr. Dryden's opinion and my opinion that it will take several satellites of an experimental nature, followed by several satellites of an operational prototype nature, before one establishes an operational system.

One does not put up an experimental satellite, and, if successful, say we have an operational system.

So, if I recall Dr. Dryden's testimony correctly, he said certainly we will see demonstrations, we will see limited operational uses of an interim nature with experimental spacecraft, we are seeing some of this today with Telstar, but before one says he has an operational sys-

tem that is used on a detailed basis, in a routine manner, that one can rely on, he said it would be about 5 years.

I think this is pretty close to right. Before we have an operational system, which is run as an operational system, not involving experimental spacecraft, it will be about 5 years.

Mr. DAVIS. I might be wrong, but as I recall the part of his testimony which our chairman quoted yesterday, he used the figure of 10 years from this time until the time of an operational system.

Not that that makes any difference, because I am sure he did not intend it as any hard-and-fast prediction.

I did not really mean to get into that, and I am not trying to establish there is any conflict in the testimony. What I am really trying to get into is this: Is there any practical method of storing energy in a spacecraft that can be used to keep it in position, which would have to be done in the event of a synchronous system, other than the concept of bottled gas?

Is there any other method?

Mr. JAFFE. Yes; there are many concepts.

We feel the bottled gas is probably the simplest and the one that could be used earliest.

This is one of the reasons it is being pursued.

But there are many, many systems proposed and many very exotic, involving radioactive supplies, involving solar energy.

I would have to go back and look at some of these.

Mr. DAVIS. Solid fuels, maybe.

Mr. JAFFE. Solid fuel rockets can, of course, be used. There are many types of propulsion systems that can be employed—that may be employed in the future.

It is just at this point it is felt that the gas systems are more immediately available to us.

Mr. WAGGONNER. What is considered to be the ultimate life of the bottled gas system to maintain position of a synchronous communication satellite in orbit as compared to some of these systems you refer to as being exotic?

Mr. JAFFE. Well, the life of a gas system is based on two things: One, how much correction does one have to supply over a given amount of time?

Secondly, how much weight are you willing to carry in the way of gas on board the satellite?

I believe that the Hughes proposal talks about gas life times, or gas supplies, capable of operating for as long as 5 years.

This is based on the theoretical errors in obtaining orbit in the first place, moving the satellite around, for which you will have to correct, and the assumption we can carry this amount of material and do not have any leakage in the system from which we lose gas.

Gas systems can be provided to live for virtually any amount of time if you are willing to carry along enough gas, is what it amounts to.

The leakage problem is one that is not to be minimized. I don't know whether we have valves today that would prevent leakage over a long period of time. If the gas leaks out one does not have gas to correct the orbit any more.

Mr. WAGGONNER. The telephone people tell me that they estimate they must have for satisfactory performance and for economic feasi-

bility, a life somewhere in the vicinity of 5 years of a communication satellite to ever supplant the underseas cable and make it a workable program.

Do you agree with that proposal, or, that estimate?

Mr. JAFFE. I think it is in my opinion somewhat conservative. I think the number is more like 3 years.

The studies which I have seen have varied anywhere from 1 to as high as 10 years as being the requirement.

Again, this is based on the use factor to which the satellite system is put and the lifetime that one prescribes to the various components of the system.

Our own thinking is that something in the order of 3 years would provide an economic situation.

Mr. DAVIS. You are speaking in terms of a low altitude satellite there, are you not?

Mr. JAFFE. Speaking in terms of either.

Mr. DAVIS. Either one?

Mr. JAFFE. I think that the economics are not that far different from the standpoint of launch costs and sustaining costs.

Mr. WAGGONNER. What are the relative merits of ship-based ground stations as compared to actual ground based ground stations?

Mr. JAFFE. Between the two systems?

Mr. WAGGONNER. Yes.

Mr. JAFFE. There is no doubt that a fixed point in space to look to from a moving ground station would be a desirable thing. It would be much easier to operate with a synchronous satellite system to moving ground stations.

Mr. WAGGONNER. And that is the reason then for the use of the ship in this program?

Mr. JAFFE. Not entirely.

The reason for the use of the ship is that the ship was being proposed for the Advent program, could be utilized or be proposed for the Syncom program in the time scale that we needed it, and it seemed to be the most expeditious way of getting the station where we wanted it.

Mr. WAGGONNER. It was a matter of utilizing that which was available at the least cost, which ultimately might not be the case once a system becomes fully operational?

Mr. JAFFE. That is correct. This happened to be the one that was available. It was a question of the station in the particular location.

Mr. HECHLER. Mr. Boone?

Mr. BOONE. You mentioned the directive antenna.

Do you think that ultimately we will go to some three-axis stabilization scheme?

Mr. JAFFE. Ultimately, yes.

Mr. BOONE. It would be preferred over the spin stabilized satellite?

Mr. JAFFE. Well, this again depends on the application. I think these will be applications which will require the three-axis stabilized technique, or the three-axis stabilized satellite.

This does not mean that, perhaps, a spin-stabilized satellite won't satisfy the civilian communications requirement for intercontinental communications for a long time.

But it may be desirable from the standpoint of communicating with smaller stations on the ground, or mobile stations, to be able to direct

the energy from the satellite much more precisely than one can from a spinning spacecraft to particular areas.

You may want to illuminate only a quarter of the Earth instead of half, or smaller areas in order to get more energy back to the given spot on the Earth.

This would require—

Mr. BOONE. For a particular application?

Mr. JAFFE. For a particular application, that is right. This would require the completely stabilized platform.

Mr. BOONE. But the spin stabilized method would be suitable to put something in orbit immediately?

Mr. JAFFE. The spin stabilized platform would be suitable for immediate application. It may be suitable from a long-term standpoint in the general case of intercontinental communications.

Mr. BOONE. Do you think then that based on Syncom I we could have an operational system in 2 years?

Mr. JAFFE. My answer is still "No," we cannot have an operational system in 2 years based on Syncom.

Mr. BOONE. I wanted to ask, do you intend to proceed with the Relay development?

Mr. JAFFE. We are proceeding with Relay as it exists.

Mr. BOONE. I mean to continue it beyond the current plans?

Mr. JAFFE. We have—

Mr. BOONE. Is it not a duplication, for example, of the Telstar, in a sense, and what more can you learn?

Mr. JAFFE. Relay is not really a duplication of Telstar. I tried to point out there are significant differences, that we want to determine at this time the results of these differences.

Our current effort in a follow-on program to Relay at this stage of the game is that of a study phase.

We are looking at what kind of a satellite and what kinds of things ought to be determined during the next phase of the program.

Where should one go with operational systems if one is going to use the intermediate altitude system?

We formed certain opinions and we have laid out a program, which has not been approved by the NASA Administrator yet, for the direction of such a flight program.

I think that whether or not we will undertake this program depends, first of all, on the results of the Relay program, final results of the Telstar program, and the other programs that exist throughout the country at the time we have to make the decision, if there are such.

I am speaking mainly of the existence of a program of the corporation which has not been formed yet, and we must look at the kind of a program that they will come up with before we make some of these decisions, if the corporation does indeed come up with an experimental program in this time scale.

Mr. HECHLER. Mr. Jaffe, how much does NASA have funded for communication satellites now, and how does this generally compare with the past years?

Can you give us an idea of the trend in relation to the total NASA budget?

If you would like those figures may be submitted for the record.

Mr. JAFFE. I will submit those figures and insert them.

I believe it has leveled off this year.

(The table referred to follows:)

R. & D. obligations including launch vehicles for communications satellite program and overall NASA programs from inception through fiscal year 1963

[In millions of dollars]

Fiscal year	Communica- tions obligations	Cumulative	Overall NASA obligations	Cumulative
1959.....	3.3	3.3	175.7	175.7
1960.....	3.0	6.3	307.9	483.6
1961.....	28.9	35.2	644.2	1,127.8
1962.....	33.2	68.4	1,261.3	2,389.1
1963 (estimated).....	60.1	128.5	3,109.5	5,498.6

Mr. HECHLER. Does this indicate any diminution of interest?

Mr. JAFFE. No, sir. It merely indicates that the rate at which the program developed and was undertaken was very steep at the outset, and that the rate at which expenditures had to be made were quite large.

Mr. HECHLER. You do not feel at all inhibited by lack of funds?

Mr. JAFFE. No, sir.

Mr. HECHLER. Any further questions?

If not, we want to thank you for appearing this morning.

It may be that the committee will meet tomorrow to hear a representative of the Department of Defense but that is at the present time uncertain.

Mr. WAGGONNER. Mr. Chairman?

Mr. HECHLER. Mr. Waggonner?

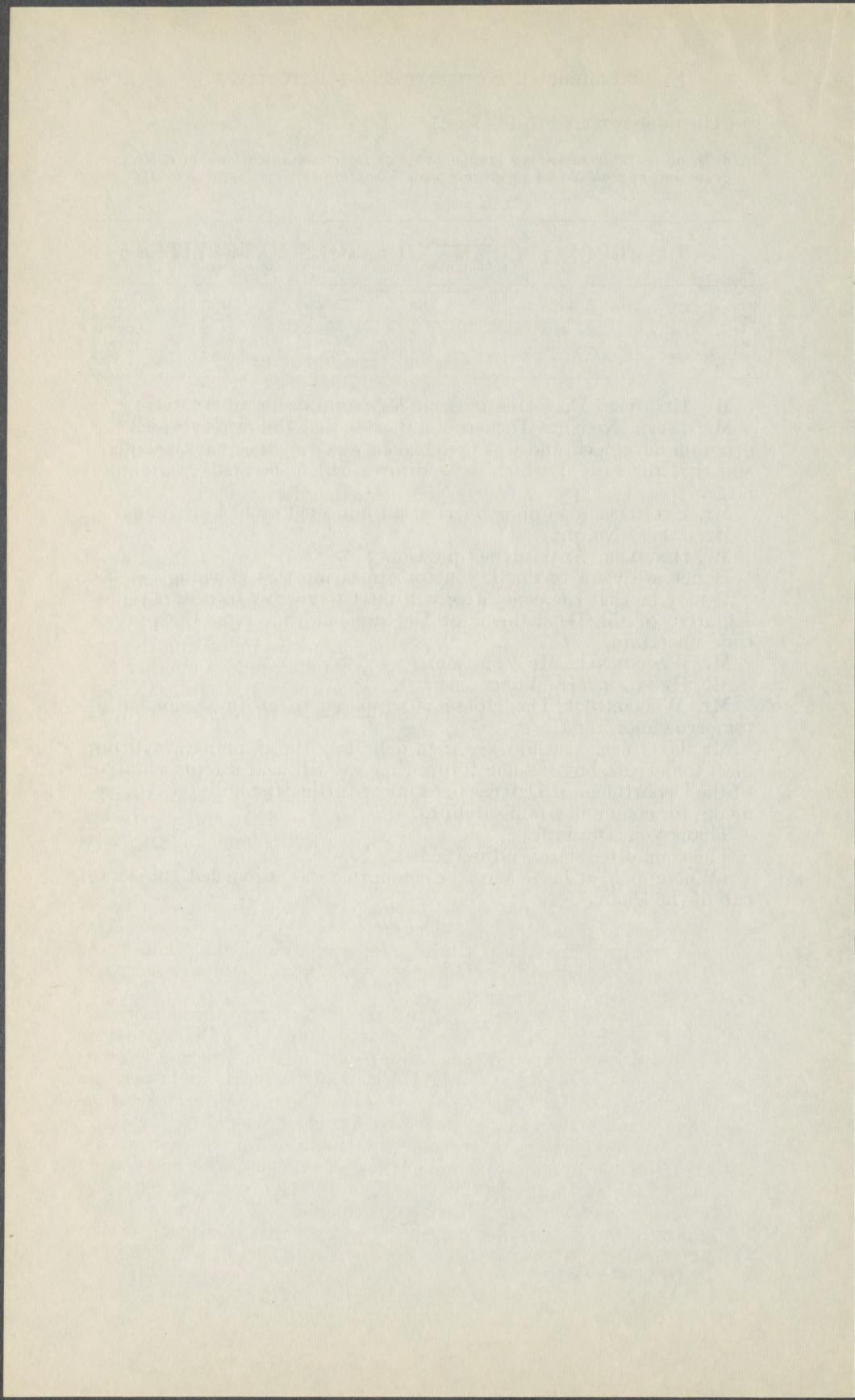
Mr. WAGGONNER. The House is supposed to go in session at 10 tomorrow morning.

Mr. HECHLER. I would say then definitely the committee will not meet tomorrow, but at some future time we will hear a representative of the Department of Defense to examine further the military requirements for communication satellites.

Thank you, Dr. Jaffe.

The committee stands adjourned.

(Whereupon, at 11:45 a.m., the committee was adjourned, subject to call of the Chair.)



COMMERCIAL COMMUNICATIONS SATELLITES

FRIDAY, SEPTEMBER 21, 1962

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON APPLICATIONS,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
Washington, D.C.

The subcommittee met at 9:30 a.m., Hon. Ken Hechler (chairman) presiding.

Mr. HECHLER. The committee will come to order.

This morning we continue our hearings on the development of communications satellites.

Our witnesses will be Dr. Eugene G. Fubini, Deputy Director of Defense Research and Engineering (Research and Information Systems), and Mr. Ralph L. Clark, Assistant Director of Defense Research and Engineering (Communications and Data Processing).

There has been testimony before this committee indicating the possibility that a synchronous orbit system might produce another first in space for the United States in communications satellites. There has also been testimony that it is possible that a synchronous orbit system might be achieved at a lower cost.

There are certain other advantages of a multiple access, high-altitude orbiting communications satellite system. It would require a minimum number of ground station facilities. There are advantages for meeting military and other requirements for security and survivability, and the area of coverage also far outweighs the immediate installation of a medium-altitude system.

Previous testimony by Department of Defense witnesses last month before a subcommittee headed by Hon. Joseph Karth of Minnesota indicated that the Department of Defense contemplates initiating a new medium-altitude satellite development. The stated requirement by the military is that such a system be operational within 2 years.

The best advice we have received from the National Aeronautics and Space Administration witnesses is that it is highly unlikely that an operational system of any type could be attained in a period as short as 2 years. Although the military system at the start would presumably be a medium-altitude system, there has been no direct participation by the military in the Telstar or Relay developments.

Since the first firing of Syncom I is scheduled for the first quarter of 1963, the question arises whether the Department of Defense might not logically await the initial results of the Syncom, and assess its potential to meet overall military requirements.

I am not satisfied in my own mind yet with the reasons given by Department of Defense witnesses for their rejection of a system with

the capabilities of Syncom. This is an area this subcommittee would like to explore.

This subcommittee is interested in pushing forward the development of communications satellites which will fulfill both military and commercial requirements, at the cheapest cost, and at the earliest practicable time.

If the United States can develop a low-cost system at an early date, it will be a tremendous breakthrough and constitute another first in the space race.

Dr. Fubini, it is a great pleasure to have you and Mr. Clark before our subcommittee.

Do you have a statement that you would like to make, prepared or otherwise?

STATEMENT OF DR. EUGENE G. FUBINI, DEPUTY DIRECTOR OF DEFENSE RESEARCH AND ENGINEERING (RESEARCH AND INFORMATION SYSTEMS), ACCOMPANIED BY RALPH L. CLARK, ASSISTANT DIRECTOR OF DEFENSE RESEARCH AND ENGINEERING (COMMUNICATIONS AND DATA PROCESSING)

Dr. FUBINI. Sir, I have no prepared statement. But I would like, if I may, to ad lib one.

Let me refer first to your remarks.

As you indicated, it is intended to initiate both a medium altitude satellite system and a synchronous type.

We may start with the first. But we intend to do both.

As you know very well, we have participated actively and in close cooperation with NASA in the development of Syncom I, and we are as anxiously awaiting the results of that test as NASA.

I am saying this to establish the fact that we have not rejected the system with the capability of Syncom.

We have cooperated with the establishment of Syncom I and intend to go ahead with the exploration of the synchronous satellite system.

I would like now to add a few more technical remarks, if I may, regarding these problems.

I have read the testimony given by the members of the Hughes Co. to this subcommittee, and have decided that if I go back to industry I will try to hire Gordon Murphy as my salesman.

The problem as we see it, sir, is really inherently a difference between the word "experiment" and the word "system." And if I may, I would like to take some time to explain how in my mind there is a difference between the two.

Unless we have this clear understanding, I am afraid that we will have trouble.

Let me assume that we will have one synchronous satellite up and working. We can start using it right then and there.

We will call it an experiment, but the public they will say "Why is that an experiment?"

And I would like to show you how we look at the problem, when we consider it as a system.

To start with, we want global coverage. For instance, we want to talk to Alaska.

Alaska is not only a State of the Union, but from our point of view is the site of one of the BMEWS sites, the DEW line. And we also would like to talk to Thule, which is also another site of BMEWS.

This has a very strong military importance.

Now it happens that the synchronous satellite will essentially have limited or no coverage to Alaska or to the northern latitudes. And that is not their fault. It is just the fault of geometry.

The satellite will either not be on the horizon or very low on the horizon, so low anyway that the absorption of the atmosphere will severely interfere with the use of the satellite.

It does not cover all of Alaska anyway, but even the part which is in the twilight region is going to be marginal at best.

For this reason, we must remember that three equatorial satellites do not cover the world, statements to the contrary notwithstanding.

Unless I be misunderstood, I want to say this: We are very happy to see a company like Hughes, with the drive, the spunk, the leadership that they are showing.

The fact that they are selling their wares I think is only proper.

The fact that we cannot go along with them in all the details of their claim is also proper.

Now to cover the world, if we need to, we need at least some extra satellites over those three. And we think that three high altitude polar satellites will just about do the job.

And that will make it six.

Unfortunately from our point of view, the problem does not end there.

We have to see what happens if one fails. We cannot avoid looking at that problem.

And let me ask you to stay with me for a moment and see what happens if one fails.

Let me stipulate that we have a launching pad, an Atlas launching pad, which is all ours. We control it and we control the blockhouse and it is all ours and nobody touches it.

Today, we turn around an Atlas pad, if nothing happens, once every 6 weeks. And we hope that we are going to have a standard Atlas which will turn around once every 4 weeks.

If the satellite booster burns on the pad, then the number of days is very much longer.

Now, if one fails, we have to put another one up.

The total time to go in orbit is only 6 hours, and that would not be so bad—it would be pretty bad, actually 6 hours interruption.

I guess we could live with it.

The problem is that we just do not have usually one which is counted down to zero time. And it is very difficult to keep one counted down that closely. We have to refuel it anyway. So we will have 24 hours delay at the very best before we have another one up.

And that is not really the bad part yet.

This is a little like having a flat tire and putting a spare on. If it happens that you have another flat, you have no spare. Usually you take care of this by going to the service station and having it fixed.

In this particular case, however, we go 6 weeks empty in which, if we have another flat, we have no substitute.

We can solve the problem in two ways. We can put another launching pad up, and then we have to control it all the time. Or we have to

have more satellites up ready to take over in case this problem occurs.

And may I say this occurs quite frequently. Because if one satellite lives for 1 year, 6 weeks are about 10 percent of its life.

When you make a computation now of how many satellites you really need to have 95-percent reliability—and now I mean 95-percent reliability this way, that at any point in the world whenever you want to communicate, it does not matter when, you have 95-percent chance to be able to communicate.

This is not the same thing as saying what is the percentage of downtime.

The two things are substantially different, in this case.

The computation says that for 95-percent reliability four satellites are required at each spot. This means 4 times 3, or 12, around the equator.

But his assumes a turn-around time on the Atlas pad of 6 weeks. And as I told you before, we think we can do it in 4 weeks eventually.

We just have given money to improve the Atlas situation, just so we can turn it around in 4 weeks.

So let's say three per each will do the job. So that makes three times three, or nine.

And then let me remind you that we had just put in three high altitude satellites in a polar orbit to cover the north, and maybe in some cases the south.

And those can fail, too.

But you see, now, in these, the problem is very much easier because we can stand a loss of one of those, because the others will come back. We know how long the loss is. We can schedule it. And so I don't think we should put too many up. And I think one more will do just reasonably well. We will have a hole, but we will know how long the hole is. And this is a hole only in the northern regions.

So in my computation I will say 3 times 3 is 9, plus 4 is 13.

I need then to have 13 satellites up. This gives me a global coverage.

May I say this gives me a global coverage but only if I use high-altitude satellites.

Unfortunately, our reliability of launching intervenes—now I am not talking about how good the Hughes equipment is, or anybody's equipment. It is just a fact that a combination of circumstances has indicated that in easy orbits we do 50 percent and in difficult orbits we do 30 percent. After we learn we do better.

So if you want to put the satellite up and we take—shall we say our approach—we have to say that for 13 satellites up we have to launch about 39. Or we say 40. And now when you look at it this way the problem becomes serious. Because if we do launch 40 and if you have 4 weeks between the launches, 4 times 40 is 160 weeks. And that is more than 3 years to put up a whole system.

And as a matter of fact, you will find it comes out to about 4 years when you take into account the fact that satellites die while you are filling up the complete system.

I don't want you to forget, however, that if one is up there the first time, you can start using it.

But I am really talking about an overall problem. And unfortunately, that is the way we have to look at the problem.

By the way, 40 launches, if you keep paying the prices that our contractors charge us, are going to be about \$360 million.

Now, I am trying to give you these numbers—not to say that we intend to do this, but I am trying to give these numbers to give you a feeling as to the type of problems people like us are presented with when we have to come to make decisions on systems. When Gordon Murphy starts talking about 3 satellites up and does not say what he is going to do when he has to put another up—because the end result is not his responsibility—I find I would want to give him a firm fixed price contract to keep up 13 satellites and working for the price he says he is going to charge. But I think it would be unfair.

Now, I don't want to be misunderstood. This is by no means an attack against a synchronous satellite per se. I think synchronous satellites have a tremendous series of advantages. And we will come to it I am sure during this hearing.

But in order to be fair, I want to give you a similar story of the medium-altitude satellites so you do not think that all is rosy on the other side.

Mr. HECHLER. You make it sound so complicated that I wonder why you are even considering the synchronous system as a possible ultimate system.

Dr. FUBINI. Let me try to make a statement, about the troubles of the other types: The medium altitude satellite. And you will find that the degree of unhappiness is about equal. Perhaps this will give you a clearer picture as to why we decided to go both ways at once.

Let us consider the medium altitude satellites at 5,000 miles, with maybe 30 satellites in orbit—25, launched 6 to 7 at a time.

With that, the total number of launches required, including allowance for reliability amount to roughly nine or ten, the total cost of setting it up is not so great.

But the trouble begins after that.

In the medium altitude satellite system we are making the satellite easy, but we make the ground problem difficult.

And why is it difficult?

It is because to talk from station A to station B, you have to know which satellite to take and when.

You must make sure that that satellite is not being used by somebody else.

The total number of stations that we would like to have around the world is around 30.

So all possible communications from one station to another, if everybody wants to talk to everybody else—and they always do—is about 450 links, and each one of these links could use or must use one of the satellites when they come.

So now you see the total number of combinations that you have to deal with in order to do the proper job of dispatching and scheduling gets into the thousands.

There is no problem in the satellites. The problem is on Earth.

And there we have to have a digital computer—let me change that and say a group of digital computers all of which have the ephemerides put in, and updated periodically.

Pointing information must be given to the ground stations so the antennas can be pointed to the satellites when they come in.

Decisions must be made as to when you leave satellite 1 and go to satellite 13, and you must make a computation of all the problems which you are buying on earth in order to simplify the satellite.

I find you are buying yourself quite a bit of complication.

So there we have it. On one side a relatively complicated set of satellites which we can only put up one at a time today, and on the other side, a group of satellites which are very simple and which we can put up on a multiple-launch basis but which will create a very serious series of difficulties on the ground.

When we weigh one system against the other, we decide that it is most likely that a combination of the two will give us the best overall performance.

And it is these considerations which have led the Department of Defense to take the actions that they have taken.

Mr. HECHLER. Mr. Boone?

Mr. BOONE. I was going to suggest that if it is so difficult as this, why did you start at all, Doctor?

Dr. FUBINI. I think the question is a good question.

We are in a position today where communication is one of the most important items with which we have to deal. And this is not only in military life.

But let me talk only for the military.

Today in the United States I believe we spend roughly \$200 million only in lease payments on leased lines.

Now this is only a very small percentage of the total money we spend on communications.

We have problems for communications overseas.

The yearly expenditure on communications for the Department of Defense is more than \$1 billion per year.

And let me say we just do not have enough communication means, and we are going to have even less communications 2 or 3 years from now.

The reason for that is that part of the communications go through the high frequency links and they will roughly be cut by a factor of two and perhaps by a factor of three.

While this does not represent the bulk of our communications today, it is going to make trouble for us because we are presented with a situation where the need for communications is increasing and the available communication means are decreasing. That is No. 1.

No. 2: The increased span of the communications makes worldwide communications more important.

And when we compare the costs of satellites with cables—because now we are comparing quality—we find that cables are very expensive.

And may I say cables also have troubles. And I don't only refer to the fact that trawlers can hook cables and cut them.

The facts of the matter are that the world is based on communications. The world is willing to pay for communications. And the military need communications.

And we at this moment have no better means than communications satellites to supply the long-range high quality communication means that are needed.

It is an expensive and difficult proposition, but so are all other means of achieving the same result.

Mr. BOONE. Well, I believe the committee fully supports your need to develop a communications satellite.

I think though, the previous testimony has brought some confusion about, in that it seems that you are taking the most difficult approach, certainly the most expensive approach, if you truly mean to meet the 1964 deadline.

Now are you trying to meet a 1964-65 deadline?

Dr. FUBINI. We are trying to meet a 1964-65 deadline not for a fully operational capability.

In other words, we will not meet what we call the minimum essential requirements for a survival communications system—MESU, in short.

We will not meet those requirements in the 1964-65 age.

We will meet a subset of those requirements.

Mr. HECHLER. Would it be fair to say that you are trying to utilize a stopgap system through the medium altitude route, hoping that the synchronous system would be developed with a sufficient degree of reliability so that you could pick it up after 1964?

Dr. FUBINI. May I rephrase your words?

Mr. HECHLER. Yes.

Dr. FUBINI. And then I will say "Yes."

Two crucial developments are needed and if we succeed in doing it we will buy the synchronous type only.

The first is that reliability must be improved out of all proportion to what we have today.

And the second is a capability for multiple launch of these capabilities.

Now I am going to make a rash statement. And I will leave it on the record but I want to make sure it is understood that I am expressing only a very personal opinion.

I believe that a global communications system which is not based on multiple launch will always be uneconomical.

Mr. BOONE. Uneconomical?

Dr. FUBINI. Uneconomical.

I don't believe we can get a reliability so high that we can find it economical to have a global—and may I emphasize the word "global"—global communications system on any other means except multiple launch.

Now, I don't want to be misunderstood. I am expressing my own personal opinion, and I am extrapolating.

But also I want to remind you that I say "global." Because I believe that it may make, and perhaps it will make, a great deal of sense to have a combination of the two.

Give up the coverage of the northern regions by means of high altitude satellites, and give up the idea of having the synchronous satellite immediately ready to work if one fails.

Let the medium altitude back it up, and use the synchronous to carry the large number of communications, as many as are there, and have something to fall back on for the minimum requirements when it is not there.

I have not thought the economics of this through. I don't think anybody has.

I believe that until we have a clearer picture of the reliabilities and the costs involved, we cannot determine what the optimum is.

Our business, very much our business, is to look at the future and try to hedge our bets. And that is what we are doing right now.

Mr. HECHLER. First—

Dr. FUBINI. Excuse me. May I have a moment?

(Mr. Hechler nods.)

Dr. FUBINI. I am told that I may have left the impression that if we had a synchronous system we would buy the synchronous system only. I did not mean to say that.

I said in order for a global synchronous system to be economical, we have to meet two points:

The point of reliability and the point of multiple launch.

That does not mean that we are only going to buy a synchronous system only.

It means that we are going—if we had this, we would buy for global usage.

And it does not mean that we will not use, also, a medium altitude for other uses, especially if we have some satellites up.

Let me take an example.

Titan III is going to be available in the reasonably near future.

And at—

Mr. HECHLER. Can you estimate a date on that?

Dr. FUBINI. I don't want to say that, you see, because it is not my business.

I think I have a mental estimate, which I was going to say, and then I decided to change, and I said in the reasonably near future.

At that time, we will have the capabilities to put at least, at least, three Syncom II type satellites up.

Now I don't know what the costs will be. And I don't know if at that time we will want to put just the Syncom II types up.

But that starts buying you something, you see. It buys you a multiple launch by a factor of 3. And it may make quite a difference.

I am not ready at this time, and I don't think anybody is ready at this time, to make a good guess as to the overall cost situation between the two systems in the years to come.

Mr. HECHLER. Well, I am sure you have considered the fact that the synchronous system would require fewer ground stations and could be moved into an area a little bit quicker; isn't that correct?

Dr. FUBINI. I thought I had made the point before that the synchronous system makes the problem of ground stations very much easier. And that is the reason why I tried to put in contrast the medium altitude satellite and its difficulties in connection with ground stations.

And I was trying to give the impression that when we put them on the scales, the difficulty on the ground for a medium altitude system just about matches the difficulties in space for the synchronous systems.

Colonel PEACOCK. Doctor, when General Schriever was up here the other day he pointed out the great importance of an operational communications satellite system from a military standpoint in such situations as to the Lebanon action.

He said it would have been nice to move in quickly and rapidly with ground facilities and have a satellite that could be responsive, to give us positive communications to any point on the globe.

From a military standpoint, is it your opinion that you could be responsive to this type of activity with a medium- or low-orbit communications satellite system? Would it be much easier to do this with a synchronous system?

Dr. FUBINI. But let's state it this way:

No satellite, and I mean no satellite, it does not matter which or what, can give you communication with a single satellite to all the points on the globe. You need at least two.

Just to make sure that this point is clearly explained, you cannot talk to your antipodes by means of a single satellite. You need at least two. You can bounce from satellite to satellite or you come back to earth, but you need to have two.

I am making this point because not only do you need two but two are enough.

So, this applies both to synchronous and nonsynchronous. And this is geometry.

I believe, to answer your question, Colonel Peacock, that we can promptly and quickly move a station with forces such as we had in Lebanon and talk to the United States.

I also would believe that we could do that in every point in the world provided we have made suitable provision for relay points. And this proviso is an important proviso.

Let me make another point.

We are now equipped with movable ground stations which are air transportable, which can be used with Telestar, Syncom I—and I am using both the medium altitude and a synchronous to make the point—and will have capabilities sufficient to meet the most elementary military needs.

Colonel PEACOCK. Well, the reason I asked the question, sir, is: The point had been raised that with a medium altitude or a low altitude satellite, the ground station complex would be so great that it would be very difficult for rapid deployment to remote areas. But with a synchronous satellite it would be much easier to move in with air transportable equipment and set it on the ground rapidly to start operating right away.

We are mainly addressing our remarks to the ground station complex.

Dr. FUBINI. I was asking Mr. Clark how many vans, trailer types, the ground station has.

I really don't know. I am not sure. I believe that it is six to eight. And about half of the vans are the power supply.

Frankly, I don't think that the problem—let me put it this way.

When you start analyzing it, the fact that you do not need to track in a synchronous satellite might conceivably, and I am not sure—save you a van.

Mr. HECHLER. Could I ask Mr. Clark: Do you want to speak to that point?

Mr. CLARK. Well, if you consider communicating just to one point, that is if you want to go into Lebanon and establish a circuit back here, you only need at most two antennas.

Colonel PEACOCK. We were referring to something like the ground facilities for Telstar at Andover, Maine.

If you had to move in with something like that, it would be quite a time-consuming operation where if you moved in a couple of Craig shelters with your equipment you could start communicating at once.

Mr. BOONE. Dr. Fubini, in discussing this, will you discuss this part of it, and I think a more important part, of what the require-

ments are for the computer, the ephemeris information, and all the other factors involved.

Dr. FUBINI. All right; can we break the problem in pieces now? Because again it is pretty complicated.

And may I ask a question of you, Mr. Chairman?

If I am going too much into technicalities, will you please correct me and tell me and I will refrain from doing so.

Mr. HECHLER. I am not worried about technicalities.

I am sure you are aware that this is an open hearing.

Dr. FUBINI. Oh, I am fully aware of that.

Andover, Maine. The Andover, Maine, antenna I think is what you would call a world champion.

I believe the antenna has the lowest noise of any antenna ever designed—and I suspect that it is going to be very difficult to beat it appreciably.

The antenna is designed for one specific purpose, and that is to transmit and receive television, and in some cases more than one television channel.

It was admirably designed for that purpose, and as you know, it does it admirably.

We do not care about television. We don't intend to use television.

With Lebanon, if you could have had one 60-words-per-minute teletype directly to Washington, it might have been useful, although four of those would do very well.

The difference is a difference between roughly 5 million cycles band width and 200. There is quite a difference.

We do not intend to match anything like the Andover, Maine, capabilities.

As a matter of fact, for the purpose we have in mind, a rather conventional 30-foot antenna and a rather conventional 10-kilowatt transmitter will do the job.

And that is the reason we have it in vans.

We are leasing it for a few hundreds of thousands of dollars. And we can buy it for not very, very much more.

Now as to your problem.

The problem of aquisition of satellites from a ground station: My understanding is that with a little bit of training with Echo I, the engineers of the Bell Laboratory had no trouble.

The ephemeris gives the pointing data with an accuracy which depends upon the rate at which the ephemeris is updated.

In the case of Lebanon, I would assume it would be updated within 24 hours, and at 5,000 miles. Which is higher than Telstar, that gives almost perfection.

Which means we will know the position of the satellite from the ground station with an accuracy—I am not sure, but it is about, between 1 and 5 seconds.

So we need—just what we need then is a teletype message which includes from the central computer in the United States the pointing data for the satellites which we will have up and then we can acquire them with no trouble.

The problems which I was referring to, Mr. Boone, in my previous talk, were related not to the single communication from Lebanon to Washington, but to a worldwide network of communications from every point to every point.

Mr. BOONE. This means that you have to go from one satellite to ground to another satellite. And this was the point of my question. That means some interrelated communications.

Dr. FUBINI. We don't need a relay point from Lebanon.

Let me tell you this: Again, I am now quoting from memory. And I purposely did not bring any documents.

I was not sure in what direction the questions would go, so I am sure I could not bring everything and so it did not make any sense to bring anything.

So from Washington to Hawaii, which I remember, and that is substantially more than from Washington to Lebanon, we would have 24 satellites, that gives us 1 percent downtime, with one relay point at Riverside.

Mr. BOONE. With one relay point at Riverside.

Dr. FUBINI. With one relay point at Riverside. If we do not have a relay point at Riverside, the downtime would be more than 10 percent.

I don't remember exactly what it was.

The point I am trying to make is this: We can still live with it if we have to in the case of a single channel Lebanon to Washington. It would be absolutely unforgivable if this were a global military system of satellites all over the world.

Which means that if we want to have it from Washington to CINCPAC, we are going to put a relay point at Riverside.

Mr. BOONE. Is that true if you go to Vietnam?

Dr. FUBINI. We also go to Vietnam with only one relay point.

Mr. BOONE. I would like to ask one other question.

Some of the previous witnesses have indicated the desirability of going to the Syncom type of system, and I think you have not specifically said so but you have pointed out certain advantages that it might have over the medium altitude system.

If this be true and if—in your previous statement you said that the complications are about the same on the medium altitude and the synchronous one, of course, considering where they may be, why don't you just go to the synchronous one?

This is, I think, a perplexing problem for the committee.

Dr. FUBINI. Mr. Boone—

Mr. BOONE. You have only one problem, and that is the launch problem that is peculiar to the synchronous orbit.

Dr. FUBINI. I choose not to list all the other problems because I think they are very much less important than the fundamental problem of the launch.

Would you—suppose that I had recommended and the Secretary of Defense had decided to go only for the synchronous satellite.

If we had made that recommendation and that recommendation had been agreed upon by the Secretary of Defense and I were sitting where I am sitting now with Mr. Clark, and you asked me the question, "You mean to tell me, sir, that you are going to spend roughly \$400 million just to put it up," and "Where is that money in your budget," I would have a real hard time getting out of that line of questioning.

Mr. BOONE. Well, General Schriever told us that he felt that within a year or roughly that time following the operational medium altitude satellite, that we might have a synchronous orbit system.

And I think that is also bothering the committee.

If truly 1 year is the difference that we are talking about and if the problems are almost the same, it seems to me that it is pretty hard to defend.

Dr. FUBINI. Remember I have intentionally said nothing about the difficulties of synchronous satellites. I have not said the orbit is difficult. I have not said, "Look at what happened when we tried to make difficult space shots."

I did not come and tell you this one has so many parts and another one has so many parts and this is simple and this is complicated.

I have stayed very clearly out of all these things, because you have heard them all.

Mr. BOONE. Except to say that they are roughly the same—

Dr. FUBINI. No; wait a second.

Mr. BOONE. In magnitude.

Dr. FUBINI. No.

I have said this: If we knew how to make synchronous satellites which cover the earth and worked for 10 years and we never have to worry about them and we knew now, I guess we would hesitate—we might hesitate to initiate the medium altitude satellites.

But the very facts are, that Telstar is flying. And so did Courier, and so will Relay and so will all the others. And Syncom has not gotten there.

And then if it did, we still would have the problems—if the Syncom I were flying, we would still have the problems which I listed for you a minute ago.

Because I did not want to have arguments on the fact that things may not go.

I don't want to base any argument on the fact: "Let's see what happens if things go."

Now Mr. Clark has a comment to add to this.

Mr. CLARK. Well, I just might say that Mariner has now been flying for about 30 days and that is the longest that we had had a satellite fully stabilized in orbit.

Mr. HECHLER. Highly successful, too.

Mr. CLARK. Yes.

Dr. FUBINI. After the third shot.

Mr. HECHLER. I would like to ask a few questions about money now, Dr. Fubini.

How much money is the Department of Defense spending in fiscal year 1963 for communications satellites, that is the development of them?

Dr. FUBINI. The present budget figure is \$95 million.

Mr. HECHLER. How does that compare with last year, roughly?

Dr. FUBINI. Last year the figure was 92.

Mr. HECHLER. And what is the projected figure for the next few years?

Dr. FUBINI. The projected figures read \$100 million a year for the next—

Mr. CLARK. Three years.

Dr. FUBINI. For the next 3 years. This is research and development money and does not include operational money.

And I think the year afterward it is projected to be cut down to 75.

Mr. HECHLER. And what is the reason for cutting it down to 75?

Does that mean any less interest?

Dr. FUBINI. Because we believe that the research and development should be completed in 1967, and we should be operational at that time.

Mr. HECHLER. And when you are operational, does this mean both a synchronous and a medium altitude system as you discussed it?

Dr. FUBINI. In the present plans; yes.

Mr. HECHLER. If the reliability of the synchronous system is proven by that time, would this enable that \$75 million figure to be cut down because of the smaller number of ground stations needed and other economies which would result from the synchronous system?

Dr. FUBINI. Sir, the reliabilities we are talking about are measured in years.

Mr. HECHLER. Yes.

Dr. FUBINI. The chances of proving 5 years, a reliability of 5 years, as you know, is very small.

Because you know very well that you can have a satellite whose statistical life is 10 years and it will die in 1 year.

So I don't think we will know enough in 1967 about true reliability to be able to make a firm decision at that time.

Now, I am not sure about this data, because there is enough of an effort being made now to get information on the reliability without having to go through the waiting period and the number of reproduced items which the pure mathematics would indicate, that we may be able to make a decision in 1967.

All I can say is this: that I am not by all means sure that we will.

Mr. HECHLER. Now if as you say you are going to proceed in the next year or two with a medium altitude system, the question I would like to ask is this. Will it involve such an investment of money in the development of ground stations that the Department of Defense would feel a reluctance to turn to a demonstrated new capability?

I realize, of course, that at other installations, such as at Sugar Grove, W. Va., for example, that the Department of Defense has shown no reluctance whatsoever to with a stroke of the pen say, "Well, we will just wash that amount of money off."

And it may well be you will face the same type of decision at the medium altitude system.

The Department of Defense does not face perhaps the same problem that other agencies in Government face in this respect.

I wonder if you would comment on whether the investment in medium altitude ground stations would cause any reluctance to move forward on a system that might have proven and demonstrated reliability?

Dr. FUBINI. Mr. Hechler, first of all let me establish a fact.

We took the ground environment from Advent and turned it around to make it work with both Syncom and the future medium altitude satellites.

So at least in that direction we have gone.

Now what you are asking is whether we will go in the other direction; and my answer is "Yes."

And I believe that the investment problem has unduly worried you, because of this.

The main investment problem, as we say, is in the large installation of digital-type devices and peripheral equipment. That I think can easily be used for something else.

The switching part, namely, the communications switching part, is necessary in any case.

The part which might correspond in your mind to an excessive investment is the number of antennas.

But when we look at the costs of the overall ground environment, the antennas appear to represent a relatively small fraction as a whole.

So that I do not believe and I do not see how this particular antenna problem is swinging a problem of the magnitude and of the importance of the overall satellite communications systems.

And now let me say, since you did bring Sugar Grove on the record, I would like to say something about Sugar Grove on the record.

Mr. HECHLER. Wonderful.

Dr. FUBINI. Sir, Sugar Grove—the Sugar Grove decision has been one of the most soul-searching decisions that the members of the Department of Defense have had to make.

They have involved the highest authorities of the Department of Defense for a large number of days.

They have brought about discussions and personalized anguish on very many members, of the people who had to sit down and finally make a decision.

Sir, it was not the stroke of a pen. It was an act arrived at after a great deal of deliberation, and weighing a large number of very difficult factors.

And to the extent to which I have participated in that decision and to the extent I consider myself in agreement with it, I want you to be sure—I want you to be real sure—that when one is in the position in which I am and Dr. Brown is, let me assure you that the responsibility weighs very heavily on one's shoulders, very heavily.

Mr. HECHLER. I realize it was a very, very difficult decision. And of course there are many of us—I don't mean to confine this remark to those who represent simply the State of West Virginia, but there are many of us on the committee and all over the country that are interested in seeing whether some other uses could be made of this installation.

As you perhaps know, last week Colonel Peacock, Mr. Boone, and Dr. Whipple of the Smithsonian Institution and several others of us went out to Sugar Grove to make an onsite inspection of the facility and to make certain inquiries about what possible use could be made. Congressman Harley Staggers, of West Virginia, met us at the site.

And I know—well, you are certainly aware because you are taking the lead in investigating whether other uses possibly could be made either by the Department of Defense or by the National Science Foundation or the Bureau of Standards or the National Aeronautics and Space Administration or other agencies.

I wonder if you are prepared to make any further comment at this time.

Dr. FUBINI. No, sir. I think this matter does not clearly belong in this hearing.

Mr. HECHLER. Yes.

Dr. FUBINI. Frankly, it may be that I should apologize, but I felt I had to say what I have said because the matter had been brought in the record.

Mr. HECHLER. Thank you, Dr. Fubini.

I would like to ask a further question about the way in which the Department of Defense more specifically intends to pursue its inquiry and expend its 1963 funds.

Exactly how do you propose to proceed with your 1963 funds on communications satellite development?

Dr. FUBINI. I think that Mr. Rubel had discussed this problem rather in detail with your committee when he came as a witness on the same general subject.

Mr. HECHLER. This was the other subcommittee.

I am merely trying to preserve some continuity.

Dr. FUBINI. I am sorry.

Mr. HECHLER. I am not trying to create any jurisdiction problems. I just wanted to preserve a little continuity in our hearing.

Dr. FUBINI. Well, let me try to summarize roughly how we see it, that is, how we see the problem of answering the question that the chairman asked.

We believe that first of all we must keep our commitments in Syncom I.

In other words, first expenditure—and that is going—is to establish the ground stations, the mobile ground stations, and the ship which will cooperate with Syncom I to start with.

These mobile ground stations and the ship are by no means limited in usage to Syncom I. Rather, they are going to be an intrinsic part of any communications system that we develop.

Second, we intend to continue and have continued some work on the reliability problem, which I told you was one of our goals.

Also, we intend to go out with a request for quotation for a medium altitude satellite and corresponding modification to the ground environment as may be required to match it in the very near future.

And I believe that the director of the Defense Communications Agency has stated that he hopes to be under contract on this in the very early part of next year, the very early part meaning January or February.

In addition, we intend to spend part of our money in initiating an effort on synchronous satellites of the Syncom II variety or other varieties to be decided.

And final decision on exactly which variety has not been made yet.

Mr. HECHLER. In the hearings before the Karth subcommittee, Mr. Boone asked General Schriever a question on research and development.

Since Mr. Boone is here and was there, perhaps he better read it and follow it up.

This thing hit me in the face when I read it myself.

I will let him take it over.

Mr. BOONE. The purpose of this question was to ask General Schriever do you intend to get involved in a long R. & D. program on the Advent follow on.

And I asked this question—I will repeat it verbatim.

I was going to ask if you don't have to go through the same R. & D. phases on the new program that DOD has now approved?

General Schriever says:

No; we do not think so.

First of all, the booster that we are using is essentially off the shelf.

Dr. FUBINI. Yes.

Mr. BOONE (continuing).

We are not even going for a stabilized system on our low altitude system.

The communications equipment contemplated in the new package is also essentially off the shelf.

Based on what has been done as part of the Advent, as part of Relay and as part of Telstar, and just generally from advance in the state of the art of electronic componentry, that goes into a communications package, we feel that there is little or no development as such involved in the low-altitude system.

The Army suggested this morning that the satellite itself was essentially a new program and that the development of the satellite would have to have to almost commence anew.

And General Schriever said:

The fabrication of it, yes, but I think it depends entirely on whether you are fabricating, with a good deal of know-how and using essentially existing components or whether you are going into something that you are moving into for the first time, which was essentially the position that we were in when we moved into the Advent program some 3 years ago.

Mr. HECHLER. Well, I am not trying to create any artificial differences of opinion here—

Dr. FUBINI. No.

Mr. HECHLER. Among the services.

I am just trying to see whether we can resolve this question.

Dr. FUBINI. Mr. Chairman, I am fully aware that this is a perfectly correct question.

I am not worried about talking about differences.

I think that General Schriever was answering the question now regarding the word "same."

I think Mr. Boone asked him will the same development have to be done on the new system as we had to do in Advent.

And, had I been General Schriever I would have said "No," also.

Because it is really very different. And it is really very much less.

But, the idea that we are not going to have to do R. & D. in the medium-altitude satellite is incorrect.

We are going to have to do some, substantially different and substantially less, than that which would have been required for Advent.

And let's be a little bit more specific about it.

We need a new tube. The tube is within the state of the art and it is one of the very few cases that I remember in my reasonably long experience where our problem is that we have too much power.

Now usually we've got to take a tube which is small and make it big, and now we have a tube which is too big and we have to make it small. But that is development. So that is the way it is.

The second thing is that we have never done multiple launching of this type. We have done multiple launching of a different type. And this is very definitely a R. & D. problem, which has never been solved.

Mr. BOONE. Well, in this regard doesn't the multiple launching buy you much more in the synchronous orbit than it does in the medium-altitude orbit?

Dr. FUBINI. Let me say you just come in with me and give me a multiple launch of a Syncom II with an Atlas-Agena and you are good.

You can't do it.

Mr. BOONE. We can try it.

Dr. FUBINI. You can't, because there is a weight limitation which prevents you from putting more than one into an Atlas-Agena.

Mr. BOONE. It is my understanding that Atlas-Agena has a 500-pound capability, or more than this—

Dr. FUBINI. And Syncom II will work out at just about 500.

Mr. BOONE. Why go to Syncom II?

I think this is one of the problems that is worrying the committee.

Why not go to Syncom I if you truly want—I don't mean to say Syncom, but a Syncom I type of system, if you truly want a minimum capability again.

Dr. FUBINI. Excuse me, let's take the questions one at a time if I may.

I really am trying to the best of my ability to be as clear and frank and not to hide difficulties, as I possibly know how to be.

Let me take, first of all, the testimony of General Schriever, so we will dispose of that one.

Then we will go back to the other problem.

The R. & D. work in the medium altitude satellite is necessary.

It is very different in both type and quantity from the amount of work which would have been required and was required in the case of Advent.

So I believe that that testimony should be interpreted—and may I say if it is not so interpreted I will disagree with it—to mean that we must continue the research and development work in this field.

But it is different from the one of the Advent type.

Now let me have that one—

Mr. BOONE (continuing). But may I comment on that?

The purpose of asking that question was to make some determination as to whether you really could meet a 1964-65 deadline.

And if you have to go through these R. & D. phases, do you fully believe that you can meet that deadline?

Dr. FUBINI. I do.

Mr. BOONE. Doing the R. & D. as well?

Dr. FUBINI. Let me tell you—I told you what I think is the R. & D. necessary.

We have to have a tube. And we are starting. We need a tube, may I say, of low enough, or lower power than what we have. And we think that that tube will be available in time with the reliability necessary to amply meet the 1964-65 deadline.

Mr. BOONE. Historically tubes have been an extremely long lead-time development.

Dr. FUBINI. Mr. Boone, this is the first time in our experience where the tube has to go from 35 watts down to two and a half watts, and not vice versa. I think it is the first time in your experience. Certainly I have never seen it.

Second, insofar as the communications part of the problem and everything which goes with it, we look at Courier, Telstar, and Relay, and say it is done, and because of the multiple launch it is not done.

I have recently been brought up to date as to what this one requires. I think this has not been done. It has to be tried. We will never know until we do it.

And in complication, it is substantially less than Ranger, Advent or any of the complicated satellites which we have seen. I don't say that it is a snap.

Colonel PEACOCK. And you are thoroughly convinced we can do it?

Dr. FUBINI. I am thoroughly convinced we can do it, sir. As a matter of fact, since that is the only thing we have not done—because I don't think the tube is really a very serious matter—It may be useful for you gentleman to get yourselves briefed as to this spin table. Because this is multiple launch, suitably dispersed and spun.

Colonel PEACOCK. And this is the major problem that you have to whip, is that correct?

Dr. FUBINI. I was going to say this is the only problem.

Colonel PEACOCK. The only problem?

Dr. FUBINI. And it is therefore the major.

Now wait a minute. That is for satellites. Let me go back to the ground.

Before we have a complete system, with a capital "S," with the medium-altitude satellite, we have got to go through a substantially long period of training, and learning, on how to deal with these things.

Just think of all the number of years which it took to go from the patched switchboard into a long-distance-dialing exchange.

We are trying to compress the time scale to a very few years. But we are not going to be successful on the ground just the first time, I do not believe.

So in the establishment of an overall system, the difficulties for the interim case as for the final case are going to be mainly on the ground and not in the satellite.

The other way around for the Synchronous version.

Colonel PEACOCK. Doctor, during the Advent hearings indications were that \$76.5 million had been expended in the research and development activity on this particular program which were unrecoverable and therefore must be considered a total loss of the taxpayers' money.

In your opinion, is any of that research work going to be utilized in the new R. & D. program for the carryon of the second generation Advent program?

Dr. FUBINI. The direct usage of the modulae built for Advent by the General Electric Co.—and now I am using this to refer to your \$76 million—and the Bendix Co., are not going to be directly usable in the medium altitude satellite.

As to the follow-on synchronous, it depends a great deal upon a number of things. And that means which synchronous satellite and which manufacturer is going to make it.

Of those \$76 million, I would say that of the really recoverable, and it is an intangible way of recovering, I could trace perhaps 25 Eeros, if it comes through, might use the same equipment, in part. OAO uses the same equipment in part.

Eeros, if it comes through, might use the same equipment, in part.

Several of the components have been used and will be used.

So when I weigh the whole thing, I would say that of that \$76 million, if GE does not get any follow-on contract, we will lose about sixty.

Colonel PEACOCK. Doctor, would we save more by utilizing the same contractors that were originally utilized in the Advent program?

Could we recover more of the money by doing this, other than by enlisting new contractors for that portion of similar work?

Dr. FUBINI. As you know, in the Secretary of Defense's instructions I believe of May 23, I think of May 23, it was stated that we were not going to continue the Advent program into the follow on, but we were going to initiate another follow on.

Which leads me to the belief that the intent is not necessarily to have the same contractor do the work.

Colonel PEACOCK. You don't think that we would realize any saving in case we did do this?

Dr. FUBINI. Let me say this decision was made personally by the Secretary of Defense. And he was presented I believe with all the factors which enter into making this decision.

I believe the decision is a correct decision.

And I like to leave it just that way.

Colonel PEACOCK. What you are inferring is Secretary's decision is overriding this consideration.

Dr. FUBINI. May I assure you, the economy was very much in the mind of the Secretary when he decided that.

Mr. BOONE. Mr. Chairman?

Mr. HECHLER. Mr. Boone.

Mr. BOONE. Dr. Fubini, did you have a chance to complete your expenditure or commitment of 1963 money?

Dr. FUBINI. Certainly not.

Mr. BOONE. Would you like to continue and tell us more about what you are going to do?

Dr. FUBINI. No, I did have a chance to complete.

I said with Syncom, reliability, medium altitude study and initiation of the synchronous, that takes care of the 1963 funds.

Mr. BOONE. You are going to initiate the development?

Dr. FUBINI. Plus some groundwork, you understand. I included that.

You see, the groundwork—while we are using the whole Advent ground environment, we need extra things over and above what we have to meet that requirement.

So when I say—when I talked about satellites, I said don't only think about the space-borne version.

Let me repeat it.

Ground environment for Syncom.

Ground environment for all other satellites.

The initiation of the medium altitude satellite.

Initiation of a procurement in the field of synchronous satellites.

Mr. CLARK. And development.

Dr. FUBINI. And development—excuse me.

The word "procurement" is intended to mean R. & D., I am sorry.

Mr. BOONE. Would you tell us if the first R. & D. medium altitude system that you are going for is truly a minimum requirement, to meet a minimum requirement?

General Schriever says two channels, for example, two voice channels.

Is this really what you are thinking about?

Dr. FUBINI. That is exactly what we are thinking about.

Now if you are asking me is this a minimum requirement, I will say no, we could get along with less.

We need much more but we could get along with what we have, because we always do.

So, let's say this. Two voice channels or the equivalent teletype channels don't even begin to meet the full military needs.

But to the extent they are available, they represent a tremendously important contribution to our overall military worldwide needs.

Mr. BOONE. Did you consider using a passive system for that?

Dr. FUBINI. We certainly did.

And as you know, we have a substantial program of exploiting passive communications satellites, which we have in cooperation with NASA, where they put up the satellites and we use them.

And also we have Moon relay work in which I believe—in the case of Moon relay, I think voice is rather out of the question, right at this very minute, in which 12 to 16 teletype channels are available, or might be available.

The moon, of course, has one fundamental disadvantage. It isn't always there. And it is very expensive to put another moon up right there, I mean. [Laughter.]

Mr. BOONE. Well, there have been some proposals to do that, have there not?

Dr. FUBINI. I have seen proposals to put another sun up there. [Laughter.]

That was even a more interesting one. [Further laughter.]

Mr. BOONE. In view of your emphasis on getting experience and the training of personnel for the groundwork, why didn't you put up the Advent satellite even at a low orbit and get some experience along this line?

It is possible, is it not?

Dr. FUBINI. Frankly, I would like not to have gone back to the details of that story, which may I assure you, is not quite so soul searching as Sugar Grove, but quite difficult anyway. [Laughter.]

Have you—let me put it this way.

The total cost of putting up an Advent-type satellite in a low orbit to acquire the type of experience you are talking about would have been completely out of proportion, and I mean with no uncertainty, with the value obtained.

Mr. BOONE. Would you assure the committee that the Defense Department has participated in Telstar, Relay, Syncom to the point of where you have very good background as to where to go from this point on?

Mr. HECHLER. I want to make sure the channel of communication is very open here.

Dr. FUBINI. The channels of communications in this field are just simply wonderful.

I think we know everything—first of all, we know everything about Telstar that we wanted to know. We got every answer to every question we asked. We even got more than we asked.

We are participating in an enterprise where we are going to use Telstar when the apogee moves south, to do some training and learning of our own using some ground stations.

We are going to put some ground stations which will be leased by the military and operated by the military, and operating Telstar when Telstar—or sharing the time with A.T. & T. for the specific purpose to even learn more about it.

And we want the military to see what it means to acquire satellites and to run and to work, turn them on and off, and so on.

And this is going right now, may I say, as a joint enterprise of the Air Force, the Army, and the Defense Communications Agency, and I believe with Navy observers.

As you know, Syncom I has been a joint enterprise with NASA. And the relationships really are surprisingly good.

Mr. HECHLER. One of the things that interests me, of course, in this whole field is the number of people that are playing in it, in developing it.

What about having sort of a communications czar to pull everything together?

Dr. FUBINI. We do have a communications czar, sir, and I think it is Mr. Stewart. And he sits in the White House, and he is very competent.

Colonel PEACOCK. What are his duties in relationship to the NASA, DOD, and say A.T. & T., with pulling all three programs together, of which I think there are seven projects, if you count them all.

Dr. FUBINI. May I say I don't think he has duties to pull these projects together. He is a very experienced man. And he sees them all and talks to all of us.

Insofar as communications satellites are concerned, as you know the Space Council has acted very much, and I believe very effectively in establishing the cooperation between the agencies involved.

I am not trying to say that without the Space Council such cooperation would not have occurred anyway. I think it would.

We have a Joint Committee with NASA, which is the AACB, which works very effectively.

Colonel PEACOCK. Aeronautics and Astronautics Coordinating Board.

Dr. FUBINI. We don't have an overall communications czar as such, and I am not sure that we should have one. But now I am getting into the business of personal opinions.

Mr. HECHLER. You haven't mentioned the corporation, of course.

Dr. FUBINI. The corporation is somewhat of an unknown in our mind right now. We have gone on record and we mean every word we say, by stating that we will lease a lot of communication from any commercial satellite which may be up there, the same as we lease a large amount of the commercial facilities which are now available.

Colonel PEACOCK. Doctor, if the commercial corporations were willing to build a satellite system to meet all the military requirements and have it available, ready to go on a moment's notice in case of an emergency would you be willing to negotiate a contract on this basis where they would carry out the necessary research and development and provide an operational capability?

Dr. FUBINI. Well, let me—before I answer that, I think you must realize that today there is a situation of this kind. And we are not very happy about having some of our vital links in the hands of foreign countries.

The point I am trying to make is that by the very charter of the corporation, they must cooperate, with the British Post Office and with all the other other post offices or state agencies or nonstate agencies which do the common carrier work in foreign countries.

Now we can live with that for a substantial percentage of our traffic. And we are living with it with a substantial percentage of our traffic.

There is some traffic with which—which right now we live with and we would like not to live with.

And I think it is important you realize that there is even a small percent of the traffic which must be in the hands of the Department of Defense personnel, and no fooling about it, because it is that traffic upon which the future of the Nation may depend in crucial moments.

To answer, then, your question: Yes; we would use these facilities to the maximum possible extent.

But this does not mean, and as a matter of fact it specifically does not mean, that we will use it for 100 percent of our needs.

Colonel PEACOCK. So you still would need your own military system.

Dr. FUBINI. No; we would need a very much reduced capability to keep that very reduced minimum, essential, but I mean now really minimum, essential needs, that we would have anyway.

Colonel PEACOCK. Have you actually tried to negotiate an agreement with the commercial people, for a satellite capability to meet these military requirements?

Dr. FUBINI. To the best of my knowledge, we don't have anybody to negotiate with.

Colonel PEACOCK. You don't feel that there is any commercial organization capable of carrying out this type of a mandate, now, such as A.T. & T.?

Dr. FUBINI. No, no, no.

There is no corporation to negotiate any agreement with.

As soon as a corporation is available, we will be very happy to state in a concrete form through negotiation what has been a clearly established policy of the Department of Defense, that we will lease a substantial amount of facilities to meet a substantial percentage of our needs.

Colonel PEACOCK. I was referring to A.T. & T. and the Telstar organization at the present time.

Dr. FUBINI. To the best of my knowledge, A.T. & T. does not have yet enough satellites in orbit, nor do they plan to have enough satellites in orbit, nor do they plan to have the necessary ground stations, nor do they plan to have the necessary terminals, to even begin to meet what we need.

Colonel PEACOCK. If the military placed this requirement on A.T. & T. and were willing to pay for it, don't you think that A.T. & T. would be responsive to this type of request?

Dr. FUBINI. In other words, what you are saying is: Would we want to ask A.T. & T. to put up the satellite system for us?

Colonel PEACOCK. That is correct.

Dr. FUBINI. Well, may I say I have the impression that A.T. & T. is going to bid on the military communications satellites, and if they win the competition—

Colonel PEACOCK. I was thinking not only put them up, but to carry out the necessary research and development in addition to operating

them for the DOD, rather than acting as a hardware contractor for a portion of the system which you would manage and operate within DOD.

Dr. FUBINI. This particular problem has not been considered in the terms in which you state it.

Colonel PEACOCK. That is all I have.

Mr. HECHLER. Dr. Fubini, or Mr. Clark, there has been some press comment indicating that both our friends and our enemies have had some reactions to the West Ford System.

And I believe the comments have run something along these lines from Jodrell Bank and also from some of the Soviet representatives, that this has been placing garbage in the sky.

I wonder if you could tell us anything about your reaction to any international opposition to the West Ford System, or if you could tell us anything further about what the future of the system is.

Dr. FUBINI. Well, let me say first of all the Department of Defense has cooperated very actively with the Scientific Adviser to the President, who was given the responsibility to deal with the international aspects of the West Ford problem on behalf of the President.

And he in turn made sure that all interested agencies could bring their inputs into the problem.

Now, as you know, out of a great deal of consideration and discussion, the decision was made to make the test.

And the test was attempted twice, with no real success.

To the best of my knowledge, programs are available to try it again.

And I personally hope that the experiment will be successful.

And I firmly believe that once this is done, nobody, but nobody, will be able to find anything wrong with it.

Colonel PEACOCK. Would this eliminate the requirement for these other satellites communications systems, if it was successful?

Dr. FUBINI. No, it would not.

And in order to explain why it would not, I believe you only need to look at the type of terminals which are required for the West Ford experiment as it is intended at the present time.

As you know, the antenna which the Lincoln Laboratory has under construction by the North American Corp., which is called Haystack, is to the best of my knowledge in the Western World one of the largest, high-quality antennas ever made.

The transmitter to be used for Haystack is the same transmitter which is being used by the Air Force in passive communication experiments with NASA. I believe it to be 100 kilowatts.

The point I am trying to come to is that when we go through the passive route, the size of the antenna and the power to be transmitted are very high indeed.

Now, I don't want to be misunderstood, however.

It is not impossible—as a matter of fact, it is definitely possible to establish communication by passive means between a mobile station and a fixed station properly equipped.

In other words, we don't need the high quality on both ends of the terminal. We need it only on one side.

And it is this reason that has led us to continue to support the research and development effort in connection with both Westford and passive satellites.

Now, as you also know, there are today being considered or being proposed and in some cases being financed a number of other schemes which are neither passive nor active.

Now, I don't know if I should call them semiactive or semipassive.

And these schemes are in their infancy, but represent an interesting approach to the problem.

And goodness knows, maybe 5 years from now, when my successor will be in front of you, sir, as the chairman of this subcommittee, the question will be: "Why do you continue with the synchronous satellite instead of shifting to the semipassive system?" [Laughter.]

Mr. HECHLER. I appreciate your optimism.

But we have to run every 2 years.

Dr. FUBINI. Sir, my information is—(further words requested stricken).

Please put that off the record. [Laughter.]

Mr. HECHLER. Well, I think that is a good note to end this hearing on. [Further laughter.]

We certainly appreciate your being before our subcommittee this morning, Dr. Fubini, and Mr. Clark.

The subcommittee will take a 2-minute recess, after which we will hear from witnesses from the Weather Bureau on Tiros VI.

Dr. FUBINI. Sir, I enjoyed being here. Thank you very much for listening to me.

(Whereupon, at 11:06 a.m., the committee proceeded to further business.)

COMMERCIAL COMMUNICATIONS SATELLITES

THURSDAY, SEPTEMBER 27, 1962

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON APPLICATIONS,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
Washington, D.C.

The subcommittee met at 10 a.m., Hon. Ken Hechler (chairman) presiding.

Mr. HECHLER. The subcommittee will come to order.

This morning we are continuing our hearings on communications satellites, and I am very pleased that we have with us the Assistant Secretary of State for Economic Affairs, an old friend of mine, G. Griffith Johnson, from the Department of State.

We in this subcommittee are interested in the extent of participation by other countries in our communications satellite program, both now and in the future, and its future potential for underdeveloped nations of the world. In addition to that, we are also concerned with the international agreements and organizations that exist to cooperate in a world communication system.

We are also interested in what form of joint participation with the Soviet Union might be contemplated, plus anything that you would care to say also about the nature of the negotiations of bodies in the United Nations concerning communication satellites.

It is a pleasure to have you with us, Secretary Johnson. If you have a prepared statement, you may proceed.

STATEMENT OF G. GRIFFITH JOHNSON, ASSISTANT SECRETARY OF STATE FOR ECONOMIC AFFAIRS, ACCOMPANIED BY ARTHUR LABEL, CHIEF TELECOMMUNICATIONS DIVISION, AND WILLIAM GILBERT CARTER, DEPARTMENT OF STATE

Mr. JOHNSON. Thank you, Mr. Chairman. It is very pleasant to see you again.

I have with me two people from my staff who have been working on this particular problem, Mr. Arthur Label, Chief of the Telecommunications Division of the Department, and Mr. William Gilbert Carter, who is on my immediate staff and who has been working particularly on the international organizations aspects.

I am sure you realize that we appear here—at least I do—without any pretense of understanding all the complex technical aspects of satellite communications, but rather on the questions or the problems raised by this new development in the international area.

I do have a statement here which with your permission I would like to proceed to read.

Mr. HECHLER. Yes. You may proceed, Mr. Secretary.

Mr. JOHNSON. I greatly appreciate this opportunity to make a statement on behalf of the Department of State on the international implications and foreign policy aspects of the communications satellite activities of the United States.

The Department of State is intimately involved with the many foreign policy implications and foreign relations problems to which telecommunications in general and the development of a communications satellite system in particular give rise.

The launching of the experimental satellite Telstar and the recent enactment of the Communications Satellite Act of 1962 have created enormous interest, both here and throughout the world, in this dramatic new communications technique.

An operational system, still some years in the future, offers great promise of substantially increasing the rapidity and ease of long distance communications at significantly lower rates.

While there is no technological reason to prevent the use of communications satellites for domestic communications over large land masses, such as our own country, Brazil, India and the U.S.S.R., the economic data now available indicates that their principal use, for some time to come, will be for communications between nations.

It is therefore apparent that the operative communications system in which we are interested is international in scope.

The development of such a system will require the conclusion of appropriate international agreements. Location of ground stations, frequency allocation, channel assignments, technical standards: all these vital elements require effective international cooperation. The system will depend for its very existence on such cooperation and agreement.

The U.S. Government has shown a thorough awareness of the necessarily international nature of a communications satellite system since the inception of its planning.

As a result of intensive interagency study, under the direction of the Vice President and the National Aeronautics and Space Council, President Kennedy issued a basic statement of national policy on July 24, 1961.

That policy statement reflects deep commitment to the principle of developing a communications satellite system in cooperation with and for the benefit of the nations of the world.

His statement can properly be considered as the first definition of our foreign policy objectives in this field.

The President said:

Science and technology have progressed to such a degree that communication through the use of space satellites has become possible. Through this country's leadership, this competence should be developed for global benefit at the earliest practicable time.

This statement also contained guidelines to the means by which the desired objective of global benefit can become a reality. Specifically, the following requirements were established:

Opportunity is to be provided for foreign participation in the communications satellite system; nondiscriminatory use of and equitable access to the system by all authorized communications carriers is to be granted; technical assistance is to be provided to less developed countries to help obtain a truly global system as soon as practicable.

Following the President's policy declaration, the executive branch and the Congress worked intensively to establish the most advantageous legislative framework to implement national policy, culminating in the enactment by Congress of Public Law 87-624, approved by the President on August 31, 1962.

Passage of this bill was a source of real satisfaction to us in the Department of State. As the Secretary of State testified before the Senate Foreign Relations Committee during the hearings on the bill:

* * * there is every reason to suppose that the impetus from the passage of this legislation and the organization of this company will bring measurably closer the time when an effective global satellite communications system is in operation. That, in itself, will be a great advance for the foreign policy of the United States * * *

We are anxious to get on with the job of implementing our national foreign policy objectives which are set forth with clarity and force in the act itself.

In section 10(a) Congress declares:

That our purpose is to establish a "global communications network;"

That our aim is "global coverage at the earliest possible date;"

That our policy is to do this "in conjunction and cooperation with other countries;"

That in so doing, "care and attention will be directed toward providing such services to economically less developed countries and areas;" and

That the system should be so designed so as to "contribute to world peace and understanding."

The language of the act thus explicitly and emphatically recognizes that international cooperation and agreement is a prerequisite to the establishment of a satisfactory communications satellites system and that "international" includes all nations in what is repeatedly referred to as a global system.

The needs of the less developed countries are expressly taken into account.

And, finally, this exciting scientific development is tied directly to a basic goal of U.S. foreign policy which, as the act itself states, is to "contribute to world peace and understanding."

This constitutes a broad, well-defined charter of our foreign policy objectives as related to communications satellites.

There is need for strong leadership by the United States to develop the most efficient international arrangements. The Department of State, as the President's agent in foreign relations matters, expects to play an important role in exerting this leadership.

To realize our objectives through the joint efforts and close cooperation of Government and industry will contribute significantly to both our national and international welfare.

A number of international organizations are also active in this field. The basic policy of the United Nations is contained in part D of General Assembly Resolution 1721, adopted on December 20, 1962.

This resolution was sponsored by the United States in response to President Kennedy's program for space cooperation submitted to the

United Nations on September 25, 1961, and jointly sponsored by the Soviet Union.

communication by means of satellites should be available to the nations of the world as soon as practicable on a global and nondiscriminatory basis.

It then notes with satisfaction that a special conference to allocate radio frequencies for outer space activities is to be held in 1963, recommends that the 1963 conference also consider other aspects of space communications requiring international cooperation, notes the potential utility to the U.N. itself of this means of communication and invites all appropriate U.N. agencies to assist member countries to develop their domestic communications so that they may make effective use of space communications.

There are striking similarities between these provisions and the policy objectives contained in the Communications Satellite Act of 1962. There is the same concern that this means of communication be made available to the nations of the world as soon as practicable; the same conception of the system as being global and nondiscriminatory; and similar recognition of the special needs of the developing nations of the world. This is not entirely coincidental. The United States played a major part in drafting Resolution 1721.

The resolution refers in several instances to the International Telecommunication Union, the member of the U.N. family of organizations most clearly concerned with space communications. The ITU was created in 1865. Since 1949 it has been a specialized agency of the United Nations.

The United States associated itself with the work of the ITU at the time of the Berlin Radio Conference in 1906 and we have since participated actively in its activities.

The basic objective of the ITU is to maintain and extend international cooperation for the improvement and rational use of telecommunications of all kinds. In implementation of its objective, it develops and promulgates by treaty international regulations to govern those aspects of telecommunications operation and use which require uniform international solutions.

With respect to communication satellites, it will play a vital role in the allocation of radio frequency bands and the adoption of technical standards and operating procedures which must be uniform internationally to achieve technical compatibility and maximum efficiency.

The technical work of the ITU is carried on through various permanent committees, including the Radio Consultative Committee, known as the CCIR, which is actively working on various technical aspects of the international use of communications satellites.

At its 1959 plenary assembly, the ITU made limited assignments of radio frequency bands for research activity in outer space, including experimental communications satellites. At that time it judged that it would be premature to attempt to deal with the needs of future operational activities but proposed that this matter be determined at a special conference to be held in 1963. In June 1962, the ITU Administrative Council scheduled an Extraordinary Administrative Radio Conference to begin on October 7, 1963, in Geneva.

As matters now stand, the Conference will deal only with frequency allocation for space communications plus the amendments to other pro-

visions of the international radio regulations necessarily arising out of the allocations for, and use of, space communications.

However, the Administrative Council has asked members to submit by December 31, 1962, information on three matters: their present plans with respect to the development of space communications; the subjects they regard as appropriate for international negotiation in order to achieve global space communications; and which of these subjects, if any, they believe should be included on the agenda of the 1963 Extraordinary Administrative Radio Conference.

The final agenda for the 1963 Conference is, therefore, not yet known. This will be determined by the Administrative Council at its next meeting in Geneva in March 1963.

The significance of the 1963 Extraordinary Conference should be emphasized. As you know, the electromagnetic frequency spectrum is finite. It is already crowded and problems of interference are always present or threatening. It is vital that adequate frequency allocations be available to communications satellites.

The United States is fully conscious of the importance of these considerations and has been working actively for some years in preparation for the 1963 Conference. The technical parameters of a communications satellite system will be determined in large measure by the frequency space assigned.

In turn, these technical parameters will deeply affect many of the international and foreign policy matters, such as number, location, and cost of ground stations, which must be considered in establishing the basic international agreements prerequisite to the creation of an effective global system.

The Department of State, through its Telecommunications Division and in close cooperation with the Director of Telecommunications Management, the Interdepartment Radio Advisory Committee, and the Federal Communications Commission, is actively engaged in the preparation of our final proposals to be presented to the 1963 Conference.

Our preliminary proposals were circulated in October 1961 to many of our comembers of the ITU for review and comment and final proposals are now being prepared.

We are making every effort to insure that our proposals are approved by the 1963 Conference subject to as little diminution of requested frequency space as possible.

The ITU also plays a role in providing technical assistance to member countries to further development of their communications systems. Assistance in communications planning is given under the guidance of a Plan Committee. In addition, ITU headquarters organizes training programs. The Secretary General also provides a valuable source of information and guidance to member countries concerning the sources of international financial assistance for the development of domestic communications.

I have available the first report by the ITU on telecommunications and the peaceful uses of outer space, if the subcommittee would be interested in incorporating it in the record of these hearings.

The United States has well-defined foreign policy objectives in this field. Through our advances in this exciting new technology we as a nation are now able to bring into existence a global communications

satellite system for the use and benefit of ourselves and the other nations of the world.

This will not be accomplished overnight. Much additional work, both technical and organizational, remains to be done.

The step-by-step working out of a truly global system will require the best efforts and intensive dedication of all of us both in and out of Government.

In moving forward we will be building on the accomplishments to date. This committee has heard testimony from a representative of NASA dealing principally with their technical program in communications satellites.

Because of its success and importance for the future I would like to comment briefly on NASA's international program in this field. A basic policy of NASA has been that its experimental and research efforts should be carried out within a framework of the broadest possible international cooperation and results made available to the world scientific community in the largest possible measure.

In implementing this program, NASA, with the cooperation and assistance as necessary of the Department of State, has made various arrangements through which more than 50 countries are now participating in the U.S. space projects.

The extent of foreign participation varies, of course, as a function of the relative degree of advancement in space sciences of the particular country, ranging from the exchange of personnel and the operation of tracking or data acquisition stations to the design and construction of entire satellites.

NASA has provided launching facilities in the United States for a satellite equipped by Great Britain as well as the Canadian designed satellite Allouette.

In the field of communications satellites NASA's international programs have followed a similar pattern. Commencing with Echo I arrangements have been made for observation, experiment and testing with many countries.

In connection with active repeater communications satellite experiments ground stations have been built by France and Great Britain solely at their own expense.

Ground facilities are presently under construction in Germany, Italy, and Brazil. In addition, expressions of interest have been received from and discussions held with many other countries looking toward participation in this experimental program.

Mr. HECHLER. You are talking now about Telstar, are you not?

Mr. CARTER. And the passive program also.

Mr. HECHLER. You mentioned particularly here the active repeater so I assume that you meant Telstar.

Mr. JOHNSON. This would be Telstar and related programs. One includes also current discussions on the passive satellite program.

These activities are a practical demonstration of the desirability of international cooperation. Planned by scientific and technical personnel, they are confirmed by a government-to-government exchange of notes after agreement is reached on the technical level.

Since the inception of our research and experimentation in the field of communications satellites we have constantly expanded these international cooperative programs. This has been and continues to be a

decisive demonstration of our national policy that the benefits of space technology shall be available to all.

We must now move through the experimental and development stage to an operational system as rapidly as possible.

The Department of State is deeply aware that this is a high-priority goal. The guidelines are clear and the means exist to achieve our objectives through the mutual efforts and close cooperation of all concerned.

Mr. Chairman, that concludes this statement, giving a general background picture of this area, and we would be very happy to answer any questions you might have with respect to particular activities that come within our purview.

Mr. HECHLER. Do you feel that the development of a communications satellite system, Secretary Johnson, is an important weapon of our foreign policy?

Mr. JOHNSON. Well, I would put it this way; it is a most important and promising weapon for welding together the free countries of the world by bringing them closer in many respects. From this standpoint, it is therefore an important part of our foreign policy.

Mr. HECHLER. Can it also be a diplomatic weapon with respect to uncommitted nations?

Mr. JOHNSON. I would certainly say that it would be, yes.

Diplomatic in the sense that a good part of diplomacy is communication, and this will greatly expedite our ability to present our viewpoints and our ideas to these underdeveloped countries.

Mr. HECHLER. Would you go beyond this and say that there is any advantage in developing communications satellite systems from the standpoint of the prestige of the United States with relation to uncommitted nations?

Mr. JOHNSON. I think there is no doubt that the establishment of a global system by the United States or under the initiative and the technical know-how of the United States, would be a tremendous feather in the cap of the United States and add greatly to its prestige.

In fact, I would say that the experiment with Telstar has already had broad effects of this character.

Mr. HECHLER. We are going to have witnesses from the USIA later, who will perhaps comment a little bit more on this.

Mr. JOHNSON. Yes. I am sure they will be able to give you reactions from different parts of the world to the Telstar experiment which will indicate the usefulness of it.

Mr. HECHLER. One question we asked the State Department witnesses in connection with meteorological satellites was whether the man in the street understands the implications of the weather satellites.

I would think more with Telstar that the average man in the street in the nations around the world would understand and be inspired by this demonstration; is that true?

Mr. JOHNSON. I am sure that is correct.

Actually the most impressive demonstration comes from the television broadcasts although I understand that from a commercial standpoint, for the foreseeable future, it will be the ordinary communications aspects of the system which will be by far the most important.

But from the standpoint of the man on the street I am sure that the possibilities offered for the international broadcast of television programs will loom the most important.

Mr. HECHLER. What is the timing on this?

Mr. JOHNSON. On the establishment of the system?

Mr. HECHLER. No. From the standpoint of its impact on nations other than Great Britain or France?

Mr. JOHNSON. I would like Mr. Lebel to comment on that, if he would. I do not know that there is a sufficiently definite timetable yet to be able to lay it out.

But we can give the committee some idea, I think, of the time factor involved.

Mr. LEBEL. So far as the functions of the ITU are concerned, the scheduling of the international activities is fairly definite now except, as Mr. Johnson pointed out, the specific agenda for the 1963 EARC conference has not yet been determined. This is, of course, not only of concern to the United States, France, and Great Britain but to the entire world.

Mr. HECHLER. I was not looking for when this particular conference would be held. I was just trying to project into the future when some of these developments would have their impact on nations other than Great Britain and France.

Mr. CARTER. Perhaps the way to direct the answer is to focus first on when we can begin to construct the operational system. Reflecting the best technical judgments we have obtained it is anticipated it would be a period of 2 to 3 years before the choice of the basic technical characteristics of the first operational system can be made with sufficient knowledge.

That is the first stage.

I would anticipate from that point forward there would be an evolutionary development of the system.

It is probably unrealistic to think that overnight a global system will come into existence.

Mr. HECHLER. I asked the general question at the start, Secretary Johnson, about the use or value of the communication satellite system as a weapon of foreign policy.

What about reducing tensions in the cold war, or what about our relations with the Soviet Union, how would this affect relations with the Soviet Union?

Mr. JOHNSON. This, as I understand it from a technical standpoint, is an area where it is most important that we arrive at an agreement with the U.S.S.R. in order to make a global system feasible and operational.

So that in a sense you can say whether we like it or not, or whether they like it or not, the technical aspects of this particular subject force one to attempt to reach a satisfactory arrangement.

I would think that any area in which the U.S.S.R. is brought into effective cooperation with the Western World would tend to reduce the tensions of the cold war.

Mr. HECHLER. How do we stand now?

Has the Soviet Union given any indication of their desire to participate jointly in communications satellite development or operation?

Mr. JOHNSON. Well, yes, they have. In the United Nations, as I

mentioned, they jointly sponsored the resolution with the United States, and there have been conferences with the Russians looking toward consultations on these technical matters, consultations in the very near future.

Mr. CARTER. That is correct. You have heard testimony, I believe, about the conferences between Dr. Dryden of NASA and Mr. Blagavrov of the Soviet Academy of Sciences.

Mr. HECHLER. Yes. I am interested in an assessment of current progress.

Mr. CARTER. We still have not received the official go-ahead on the government-to-government level to implement the technical agreements arrived at by Dr. Dryden and Mr. Blagavrov. We hopefully will receive it soon.

Mr. HECHLER. You are, I am sure, aware of the meteorological workshop that was held in this country that brought in representatives of many nations. The Soviet Union did not send a representative, even though, I believe, they promised to send one.

I am wondering whether any thought had been given to holding a similar workshop for communications satellites techniques for the purpose of enhancing the knowledge and cooperative spirit of the participating countries.

Mr. JOHNSON. I would say the first bridge we have to cross, the first major bridge, is perhaps the frequency matter.

It is very important from our standpoint that we get an appropriate allocation of frequencies for this area.

Obviously, the vast majority of the members of ITU are not very advanced in technical aspects of this and, therefore, we are undertaking a rather elaborate program of contacting these countries, or the majority of them, with an idea of educating them, indicating to them the issues involved and the necessity of proceeding along the lines which we will be suggesting.

It is our feeling that more can be accomplished by this kind of direct approach to these countries, with the cooperation of some of our Western European allies who fully understand the situation, than could be accomplished by calling a conference as such.

This program is now getting underway and will be carried forward very actively in the next 4 or 5 months.

Mr. HECHLER. While you are thinking about planning for international allocation of frequencies, I hope you also won't overlook our radio astronomers who are very concerned about interference. Even though this is not the main reason why we asked you to come up, we have been holding hearings on radio astronomy and have had expressions of concern on the part of astronomers and scientists that there might not be sufficient protection of their radio frequencies.

Mr. JOHNSON. Yes. The U.S. proposal in this regard is, I must say, of a technical nature beyond my ken, but I understand and we are assured that it is being worked out with appropriate attention being paid to all of the various interests involved, and I am sure that the interests of the astronomers will be looked out for.

Mr. Lebel may want to comment.

Mr. LEBEL. Yes. The radio astronomers had requested that radio astronomy be placed on the agenda for the 1963 EARC, so that conference should allocate frequencies not only for space operations *per se*, but also for radio astronomy operation.

Unfortunately when the Council took that up the members of the Council of the ITU had not been informed of this fact and were not in position to make a decision.

Mr. HECHLER. We certainly hope that we can impress on all concerned the importance of this.

Mr. LEBEL. Personally, I am convinced that next spring's meeting of the Administrative Council will put radio astronomy on the agenda of the conference.

I have had conversations with representatives of the foreign governments, particularly in Europe, and they feel the same way, that there will be a lot of pressure exerted so that the radio astronomers will be cared for at that conference.

Mr. HECHLER. If you need help to bring this forcibly to their attention, call on us, because we are deeply interested in furthering radio astronomy and preventing undue interference.

Mr. LEBEL. Thank you. We shall do that.

Mr. JOHNSON. I might just comment, Mr. Chairman, with respect to your suggestion that we think of the possibility of a communications workshop, that we view not only our bilateral conversations but the various meetings of the CCIR that are scheduled as having somewhat this aspect, in other words, this will be an opportunity for doing what you suggested in the communications field.

Mr. HECHLER. I wonder if you could expand a little more on how technical assistance may be extended to underdeveloped nations and also expand a little more on how communications satellites can be used as a weapon of freedom with reference to underdeveloped nations.

Mr. JOHNSON. Well, I will make a few preliminary remarks on this and then ask Mr. Carter to comment.

The nature of the technical assistance will depend a great deal on the type of system eventually selected.

If we move along in a system such as the Telstar type of system, then you will have one set of requirements, as far as ground receiving stations are concerned, which will be very expensive, very elaborate. It is perfectly clear if you are going to have this global system reach into the continent of Africa to make it effective, there is going to have to be an elaborate program of technical assistance with respect to the installation of receiving stations and the necessary ground connections that are required to retransmit the programs.

If a different system should be selected there will be different kinds of requirements on the ground.

I would say that aside from the educational aspects, the particular form, extent, and timing of the technical assistance activities will depend on decisions yet to be made.

Mr. HECHLER. Don't you think this is a pretty important aspect of the work in communications satellites?

Mr. JOHNSON. Yes, I do indeed think so.

Mr. HECHLER. Mr. Carter?

Mr. CARTER. There is, in countries such as Nigeria and Ghana in particular, very strong and sharp development of domestic television facilities.

In places like Upper Volta, I think this is yet to happen. One effect of the interest in communication satellites will be felt in the Agency for International Development and other sources of financial and technical assistance.

It can be predicted that there will be an increased focus on requests for technical and financial assistance for the development of domestic communication circuits and systems as the necessary precursor to a full participation in and use of the future communications satellite system.

I would not say this is limited to that aspect because I can conceive of a country like Upper Volta, to take a place which has limited communications with the rest of the world, being able to benefit substantially from—its government being able to benefit substantially—from having access to a communication satellite system simply for governmental needs in addition to or aside from local distribution of messages. There is that possibility.

One thing in the technical assistance field I think we could probably also anticipate is an increased drive toward regional approaches in developing communications systems.

This has I think justification and reasons in three different fields, economic, political, and technical. Depending on the nature of the communication satellite system we may have real limitations on the number of ground stations, that can technically be included in the system. That would certainly indicate the desirability of a drive toward a regional grouping of, say, the west African nations.

This, of course, creates real problems, as you appreciate. Economically and technically, it might be a good idea to have one ground station cover Israel and the United Arab Republic, but I think we can agree that would not happen, and it is a real problem to give real shape and consistence to this future system.

Mr. HECHLER. I am sure you are not looking at problems. You are looking at the way to further this activity.

Mr. CARTER. That is right.

We conceive that one of the prime prerequisites is to make as close an analysis as we can of the problem.

Mr. HECHLER. Can you look forward beyond the 1963 meeting and tell us what you expect following the 1963 meetings?

Mr. CARTER. It is very difficult to say with any precision, in that our preliminary planning is still going on. Coordination with the agencies of the Government concerned is progressing actively.

The best prognostication I could make would be that it would be an evolutionary process.

Mr. HECHLER. In the last two pages of Secretary Johnson's statement, he mentions the work NASA is doing with the cooperation and assistance of the Department of State.

Who does what in this area?

Where is the dividing line?

Mr. CARTER. The point is made in the statement that the initial agreement is arrived at on the technical level.

That is done under the guidance, and the excellent guidance, of the Office of International Programs of NASA, keeping us fully informed.

They work through our embassy facilities abroad; they work with the various divisions in the Department.

They shepherd us through this stage of technical agreement.

Mr. HECHLER. Where do you pick up?

Do you encourage the negotiation of these technical agreements?

Mr. CARTER. Yes, indeed. We make every assistance and facility we have available.

Mr. HECHLER. Do you push them?

Mr. JOHNSON. I think they have been very active themselves. I don't think NASA has really needed any pushing from the Department. It is mainly a matter of supporting their activities.

Mr. CARTER. I would say that we probably should not be going too far into NASA's affairs here, but, if you have not seen this document [indicating], it is an illustration of their programs. It displays very graphically the tremendous range of participation and interest.

Mr. HECHLER. I was just trying to define what your relation to those programs was.

Mr. CARTER. I would say a mutual assistance relationship, both having the same objectives in view.

Mr. HECHLER. Mr. Fulton?

Mr. FULTON. The comment has been made in the statement that at the present time and in the immediate foreseeable future that for internal communications these space communication systems are probably not economical or comparable to the ground systems.

Could you explain that a little bit?

What are its limitations?

Mr. CARTER. It is not totally clear.

It is possible that in a country such as Brazil—which has relatively little developed internal communications—there is one study I have seen indicating that a microwave terrestrial system, accomplishing the same linkage within Brazil, would be substantially cheaper than a communication satellite system within the present forecast of the technology.

Mr. FULTON. Part of my point is that if we have a satellite in orbit with proper equipment, then what is the economic situation?

I can realize it might be too much for anyone of these smaller and less well progressed countries to put their own satellite system up, but suppose we do in the United States have such a satellite system in operation, then what? How do the economics of the system work out in use?

Mr. CARTER. This would be a possibility depending I would say on the cost of the ground facilities necessary.

If low cost, relatively low capacity ground stations were to become available—and there are prototypes in existence already as you probably know—and for instance during off-peak hours the channel capacity on a given satellite passing over Brazil was not carrying peak traffic, it is certainly conceivable that there would be something of real interest to Brazil in its domestic communications under those set of conditions.

Mr. FULTON. We are not in the United States going to be in position of having this very fancy, very far-advanced technical satellite communications system in operation in space and then have most of the people of the world unable to use it because they cannot afford even a ground station?

Mr. CARTER. No, sir. I would not say so.

I think this reinforces the evolutionary aspect of the global system. Most of the economic forecasts and studies the carriers, the FCC, and others have made to date indicate in the initial years that the chief

traffic flow on the satellite system will be very similar geographically to the major traffic patterns of the conventional communications existing today, which is not to say that the ultimate objective of the global system has been lost sight of.

Mr. FULTON. There seems to be some inference in what you said that the State Department might be having in mind a general idea of under U.S. AID programs supplying these countries with the necessary ground equipment, training the personnel, and supplying that link-up on a worldwide basis.

Do you have anything in mind on that?

Or do you think this type of expansion of the U.S. communications program in space, should that be kept much more on a business level?

Mr. CARTER. I would not like my comments to be interpreted as indicating that the State Department or AID has developed such a policy. That is not the case.

Mr. FULTON. No, but there was an inference of future development.

Mr. CARTER. That there would be increased requests for assistance in this field?

Mr. FULTON. Yes. Then that, of course, brings up the next question: Are you considering such a future development in the State Department?

Mr. CARTER. We are actively considering the implications of the act which itself anticipates the granting of technical assistance.

Mr. FULTON. Under the AID Act?

Mr. CARTER. No, I mean the Communications Satellite Act of 1962, which itself does speak of giving technical assistance to the lesser developed countries to permit them to participate in the system.

The implications of that I think are not fully known, either to Government or to industry, as they will be involved in the Communications Satellite Act.

Mr. FULTON. This is what I am trying to find out.

Where will it be under the Communications Satellite Act or under the Mutual Assistance AID programs?

Or are you going to be in such future foreign assistance, technical assistance at all?

Mr. HECHLER. In any case this would be a great weapon of foreign policy?

Mr. JOHNSON. Yes.

Mr. FULTON. Having come from the Foreign Affairs Committee let us say "instrument" instead of "weapon." [Laughter.]

I like the chairman saying we should get the cooperation of the Russians on joining the space communication system just after he said it was such a good U.S. weapon of foreign policy.

Mr. HECHLER. I defer to the gentleman if he wishes to ask other questions.

Mr. JOHNSON. May I comment on Mr. Fulton's question there?

I think at the present time the implications of a communications satellite system is not a factor in the AID program. This is something that we see some time in the future.

Mr. FULTON. I would agree it is some time in the future you are talking about. I was taking the inference of what the testimony was. Obviously from what the State Department is saying today it looks to me as if the State Department does not have any particular plans,

but they certainly are already orbiting in the realm of policy formation in the communications field with some aspects of a communications technical development program at the U.S. taxpayer's expense.

Mr. CARTER. If I may comment on my original statement. What I was attempting to say was that I believe the large worldwide public interest in the experiments would inevitably create increased focus by some of the lesser developed countries of the world, a glamor backwash, if you will, which would lead to increased requests for assistance in this field.

Mr. HECHLER. Fine.

Mr. FULTON. Is that the AID field or communications field?

Mr. JOHNSON. The communications field. It might be they would come to the new corporation that is being set up under the Satellite Act and it might be that the Congress, if it wanted activity in the field of this kind of communications development, would want to conduct it under the auspices of this corporation. I don't know. These are all problems and decisions for the future.

Mr. FULTON. The business corporation certainly should not be making grants or loans for technical assistance to backward countries to establish ground stations or ground communications equipment to connect with this space satellite communications system.

Mr. CARTER. I think that is correct.

Specifically I think the loans and grant point of your comment is absolutely correct. I think it is not impossible at all that they might embark on technical training programs for oversea training of personnel, as A. T. & T. does today.

Mr. HECHLER. This could well be a very good investment for our foreign policy.

Mr. JOHNSON. True.

Mr. HECHLER. When you measure this against what we are already doing in AID and think of the tremendous future value in terms of building better relationships, it might be considered.

Mr. FULTON. Mr. Chairman, when this Pandora's box is opened, U.S. facilities might be made available to unfriendly nations we would not want particularly to have access, for the first time, to the countries of South America, or the backward countries of Africa.

For example, I could see very well that with an international system such as this that our own good U.S. information service would feel it could not spend the money for it, as has been suggested by the Director of the Agency, and that Castro, because he has not any cares about money of that type, could very well broadcast a 4-hour speech to Africa over our system.

Mr. HECHLER. Perhaps if we moved toward a synchronous system at an earlier date rather than a medium altitude system, the investment in ground stations would be far less.

Mr. FULTON. Yes, but it brings up the point of where business ends and where foreign policy begins.

For example, if we are having this system available to everybody, Communist China could very well get on the system, and say we have a ground station we are preparing in Peking, "We are ready to connect in, what frequency?"

Then what does the United States do?

Mr. JOHNSON. Well, as I understand it, from a technical standpoint it is not possible to prevent any country that wants to disrupt the operation of such a system from disrupting it.

Mr. FULTON. Anybody can contact and receive from the satellite because it is there.

Mr. JOHNSON. Anybody can receive it if they have the proper equipment.

Mr. HECHLER. Don't we have a lot to gain from having our programs received in all nations on both sides of the Iron Curtain?

Mr. JOHNSON. That is right. I think that we have much more to gain than they have. This would provide a method of penetrating parts of the world with our programs in a way which we do not have the opportunity today.

Mr. HECHLER. Mr. Carter.

Mr. CARTER. It perhaps would be useful to state that there seems to be general agreement that for a period of some years in the future the chief use of this system will be not for broadcasting television per se, but for data transmission, telephony, and telegraphy.

In other words, this will be another means to convey the kinds of messages they are conveying today.

Insofar as our programs, to adopt the phrase used here, are concerned I believe that the witnesses you will hear later will confirm that for considerable time in the future, the economics and the technology will be such that we will continue to fly most of our television programs abroad—television tapes and films—by jet aircraft and they will not be used, put on, or broadcast through the satellite system.

I think I am correct in saying there is general agreement that for some time in the future the chief use of the system for live television will be for instantaneous broadcasting of major news events as opposed to feature programs, which would include many of the USIA kind of programs.

I believe I am also correct in stating that the communicators feel that this is an alternate method of carrying messages, and they do not feel that the the satellite corporation itself will have anything to say whatsoever about the message which is transmitted through its facilities.

This is the job of the people who originate and receive the message rather than the corporation itself.

I think it is useful to try to put this in perspective.

Mr. FULTON. So the President's appointees on the board of the satellite corporation are limited to business decisions, and cannot put anything of an administration, political, or foreign policy nature in the decisions.

Mr. CARTER. I am not sure that follows from what I said. May I restate what I am trying to say?

Mr. FULTON. I thought you were trying to say that.

I would be shocked and surprised if we were to have a private corporation through which the United States operates our foreign policy.

Mr. CARTER. I am simply suggesting that the nature of the content carried in the system, as I understand it, as the communicators conceive it, is not going to be a concern of the satellite corporation itself, just as A.T. & T. does not concern itself with what is said over one of its telephone lines.

Mr. FULTON. Then the President's appointees are specifically limited in what they can do within the corporation upon that board?

Mr. CARTER. Insofar as program content or content of what is carried over the system I think that follows, yes. It would be the same for all of the directions.

Mr. FULTON. We had better have the President say whether he is going to limit them.

If we are going to have this system, so that it is partly in the Satellite Communications Corp., partly in the State Department, partly in the ICC or FCC and partly under AID, and partly under the U.S. Information Service, we really have scrambled eggs already coming up, don't we?

Mr. JOHNSON. I think the act lays out pretty clearly the division of responsibility among the various part of the Government, the corporation, the FCC, NASA, and certain broad areas of responsibility are reserved to the President where dealings and relationships with other countries are involved. It is in this area where as a foreign relations adviser to the President, the Secretary of State becomes involved.

Mr. HECHLER. One of the interesting things that I have discovered about coming to Congress is that you occasionally have a chance to put into the record brilliant little statements that you wished you had said and they appear at the proper point. So following Mr. Fulton's statement about the 4-hour Castro speech, I would like to ask unanimous consent to observe that that would probably do us more good than harm.

Mr. FULTON. The question is who it does good to. The question there is whether the good or the bad is to the United States or to the poor countries of Africa and the unenlightened natives who might hear it.

Mr. HECHLER. There have been a number of very spectacular successes with Telstar and it has moved forward I believe a lot faster than originally anticipated.

I wonder if this means that the Department of State is moving a little bit faster so far as informing and encouraging other nations of its potentialities and how they can participate a little more quickly, perhaps, than you had anticipated.

Mr. JOHNSON. Let me say that we are undertaking, beginning in October, this rather elaborate schedule of consultations with other countries, starting out particularly with the technically more advanced countries, and we would anticipate, as I said, that by the meeting of the council of the ITU in March, we will have had consultations with a very substantial number and possibly a majority of the members of ITU, including all of the countries which are sufficiently technically advanced to anticipate an early participation in the systems.

Now, the immediate objective, as I said, is to make sure that the frequency allocation is an adequate one, but of course there are other objectives, too, and broader objectives in terms of the development of the system as a whole.

Mr. HECHLER. Mr. Fulton, any further questions?

If not, we certainly thank you for coming up this morning, Secretary Johnson and Mr. Carter.

Many years ago, when I was a \$2,000-a-year clerk in the Bureau of the Budget, I used to look up to you with great admiration, and I still do.

Mr. JOHNSON. Thank you, Mr. Chairman.

Mr. HECHLER. It is a pleasure to have you here this morning.

Mr. JOHNSON. Thank you.

Mr. HECHLER. The committee will take a 2-minute recess prior to hearing from the U.S. Information Agency.

(Short recess.)

Mr. HECHLER. The committee will come to order.

We are continuing our hearings on communications satellites by having the Special Assistant to the Director of the U.S. Information Agency, Mr. Robert Mayer Evans, with us.

Mr. Evans, you may proceed.

STATEMENT OF ROBERT MAYER EVANS, SPECIAL ASSISTANT TO THE DIRECTOR, U.S. INFORMATION AGENCY; ACCOMPANIED BY STANLEY PLESENT, GENERAL COUNSEL AND CONGRESSIONAL LIAISON, USIA

Mr. EVANS. Mr. Chairman and members of the committee, the Director of this Agency, Edward R. Murrow, landed in Paris at 8 a.m. this morning. He is beginning a month-long working tour of USIA posts in the Middle East. He asked that I convey his apologies to the committee for being unable to attend this morning. In his absence, he suggested that I come and speak to members of this committee regarding Telstar as it is related to the U.S. Information Agency.

This Agency was involved with space communications in two regards. One was the drafting of legislation to establish a space communications corporation. The general counsel of the Agency, Mr. Stanley Plesent, beside me here, represented us on the administration committee preparing that legislation.

Second, the U.S. Information Agency was charged with overseeing four general areas of these efforts in space: initiating preparation of the first transatlantic television demonstration, a task generously undertaken by the three major American television networks; establishing liaison with European television networks for the receipt of the American program and formation of the European program, a task greatly facilitated by contact with the European Broadcast Union; responsibility for contacts with other Government agencies interested in these matters; and responsibility for worldwide exploitation and explanation by all the many media of USIA.

The success of the Telstar effort is, in general, known to you. I think we might usefully concern ourselves with two areas perhaps less widely known. First is a mention of the extraordinary success of these efforts, and second is a brief report on the USIA operations that contributed to that success.

To recount it as a success is to understate the magnitude of the accomplishment. Praise of Telstar was as overwhelming as it was universal. May I suggest two main reasons contributing to this:

First, communications and television are something which, unlike shooting for the moon, can touch each person's life personally. Television comes into the home. Linking a satellite to television literally brings the space age to the hearthside of the world. The senor and monsieur of Europe observe the race for the moon, but they each participate in the communications satellite.

Second, nations both within and without the Western Alliance for the first time were called to contribute to a space experiment. Without their contribution, it could not have been the success it was. Giving them a means of contributing was giving them an outlet for all the emotional curiosity and excitement that has built up over man's thrust into the unknown. Bystanders have become participants, and all exult in the mutual success.

This agency has just completed a study in Great Britain of reactions to Telstar, and some very revealing results were noted.

That Telstar captured the imagination of peoples abroad is supported by the extraordinary level of awareness achieved by the communication satellite in the first weeks of its existence. Measured in the week following the transatlantic television ceremonies of July 23, the order of almost 9 in 10 of the adult population of Great Britain indicated awareness of the new scientific achievement.

A remarkable 82 percent were able to identify the satellite by name—"Telstar." This level of identification in Great Britain erases the mark set in 1957 by "sputnik," which 78 percent of the British public were able to identify by name.

These were the questions put in the survey:

Have you heard, read, or seen anything lately about an earth satellite having to do with television and international communication?

	<i>Great Britain</i> <i>July 26-31, 1962</i>
Number of cases.....	1074
	<hr/> <hr/>
	<i>Percent</i>
Yes, aware.....	88
Unaware.....	12
	<hr/>
Total.....	100

All aware (88 percent) were then asked the following:

Do you happen to know the name the satellite has been given?

	<i>Percent</i>
Yes, Telstar.....	82
Other.....	1
Don't know.....	5
	<hr/>
Total.....	88

Do you happen to know what country developed this satellite?

	<i>Percent</i>
Yes, United States.....	79
Yes, Great Britain.....	9
Yes, France.....	1
Yes, U.S.S.R.....	1
Other.....	1
Don't know.....	3
	<hr/>
Total.....	94

A majority of the British adult population (59 percent) proved not only aware of the new communication achievement but report having seen the U.S. television program transmitted via the new space station.

Pressed for the details upon what they had seen, the largest single proportion (28 percent) cited President Kennedy, with baseball in a strong second place.

These questions were:

Finally, do you happen to have seen any television program that was transmitted via this satellite?

[In percent]

	Saw program transmitted from—	
	United States	Great Britain
Yes, have seen.....	59	60
No, don't know.....	29	28
Total.....	88	88

What did you see (in the program transmitted from the United States)?

*Great Britain
July 26-31, 1962*

	Number of cases	Percent
	1,074	
President Kennedy.....		28
Baseball.....		23
Places, scenery in United States and Canada.....		12
Carvings of past Presidents; Statues; Statue of Liberty.....		6
Man/men unspecified.....		5
News.....		4
Theater/Shakespeare. Choir/singing.....		3
Other things.....		6
Can't remember.....		6
Total.....		93

Success in capturing attention is, of course, only the first requisite of impact. What next were the reactions to this new scientific feat? Judging by peoples' own estimates of the effect of this achievement upon their attitudes and the sentiments of those about them, Telstar emerges as a dramatic impact of the first magnitude.

In brief, the order of half or more of the total British public rated the new satellite a "very great" scientific achievement; felt that friends and acquaintances were "greatly" impressed; and indicated that their opinion of scientific development in the United States has gone up as a result of Telstar.

Asked of those aware of satellite:

How would you be inclined to rate the new communications satellite as a scientific achievement—a very great achievement, a great achievement, average, minor, or very minor?

	Great Britain, July 26-31, 1962	
	Percent of total public	Percent of those aware of satellite
Very great achievement.....	55	62
Great achievement.....	22	24
Average.....	5	5
Minor.....	1	1
Very minor.....	1	1
No opinion.....	4	7
Unaware of satellite.....	12	
Total.....	100	100

How about other people you know—would you say that Telstar has impressed them greatly, a little, or not at all with the state of scientific development in the United States?

	Great Britain, July 26-31, 1962	
	Percent of total public	Percent of those aware of satellite
Impressed greatly.....	55	62
A little.....	17	20
Not at all.....	4	4
Don't know.....	12	14
Unaware of satellite.....	12	
Total.....	100	100

Has your opinion of scientific development in the United States gone up as a result of Telstar, or has it remained about the same?

	Great Britain, July 26-31, 1962	
	Percent of total public	Percent of those aware of satellite
Gone up.....	46	52
Remained about the same.....	35	39
Don't know.....	7	9
Unaware of satellite.....	12	
Total.....	100	100

Much of this reflects the widespread acclaim accorded the television experiments. Less well known in this country were the Telstar telephone experiments, linking 23 cities in the United States with 23 cities in Europe.

The European countries responded with extraordinary enthusiasm to these events, as for most of them it was their first individual participation upon Telstar in their own name.

USIA posts in Europe helped arrange these calls and then marshaled the media to cover the events. Cables extolling the success of the venture poured back to Washington.

These are samples, for example, from an array of countries in Western Europe:

Italy: Italian communications media barraged its public with streamer headlines, photos and diagrams, explanatory articles, radio and TV documentaries, and direct coverage of Telstar events. There was no letup from several days before launching until after the telephone experiments 2 weeks later.

A preliminary survey indicated that press interest and use of USIS text and picture material was considerably higher than even at the time of the successful launching of the first U.S. satellite in 1958 or the orbital flight into space by the first U.S. astronaut.

Spain: Newspapers, news services, radio and TV sent representatives to Toledo (site of the Telstar telephone call). The news coverage was enormous and extended to Saturday and Sunday papers with pictures and long news stories. Speeches of all parties were quoted.

in full. The telephone exchange even made the humor section with cartoon references.

Austria: The city of Graz, receiving a call, covered the city with flags from America and set up loudspeakers for overflow crowds to listen to the call. After the event was over, Austrian telephone subscribers were able to dial a special number and hear the entire Telstar conversation repeated over their home phones.

Denmark: TV coverage was telecast throughout the country. Danish press coverage was excellent and both the Cabinet Minister and lord mayor of Copenhagen were "very happy with everything. Post thanks Agency for arranging this most successful event"—a rather unusual conclusion for a diplomatic cable.

I have chosen only some of the cables. Others told us of towns arranging a festival day when the call was due, renaming streets after Telstar and the American city they called, running culinary contests in restaurants and bakeries to evolve new Telstar dishes, and most touching of all, a town that took the telephone used by its mayor on Telstar and enshrined it under glass for the permanent collection of its town museum.

That recounts in part the success of Telstar.

Let me close by mentioning some of USIA's media role in the experiment. As you of course know, USIA's function is to make the policy and practices of this Government and this people everywhere intelligible and wherever possible palatable.

With the committee's permission, I should now like to submit for your inspection exhibits of the product turned out by USIA media, and end by showing you the television films produced for worldwide distribution.

If the committee would be interested in seeing them, we have some exhibits of various types of publications and magazines that we had distributed abroad.

Mr. HECHLER. I think the result of this survey is heartening.

Mr. EVANS. Yes. We certainly share that opinion. We are most gratified at the results. We have not run similar surveys in other countries. It has only been in Britain.

Mr. HECHLER. Do you plan any further surveys?

Mr. EVANS. Not of this detailed nature. They are expensive, and we feel we now have enough indication for our purposes from on-the-ground observation by local posts in the countries concerned.

The kind of returns we have had in cable traffic from continents other than Europe, as well as Europe itself, have been most heartening and seem, in general, to support the detailed conclusions of the English survey.

Mr. FULTON. Mr. Chairman?

Mr. HECHLER. Mr. Fulton.

Mr. FULTON. Could I inquire, how did you make the survey?

Mr. EVANS. There is in England a professional polling institute which, I am told, is quite similar to the Gallup Institute in this country.

They have worked with us in the past on a contract basis and we have found their methodology and their conclusions most sound and gratifying.

Mr. FULTON. How much in depth did you do the survey?

Mr. EVANS. In depth?

You mean range of sample?

Mr. FULTON. Yes.

Did you go to towns, cities, country areas, and get a fair geographical distribution. Then did you distribute it by types of people, age groups, artisans and professions?

Mr. EVANS. I have not gone into the details of the way the study was composed in England.

I am told, however, that it was done from a sample field of over 2,000 cases, this was done by personal visit, and it encompassed a broad cross-section of the British public in various towns and localities.

Mr. FULTON. It was surprising to me to find, if you put it in the obverse, that 46 percent expressed the thought that the state of scientific development had gone up in the United States, so that was a majority that do not know or felt it had not?

Mr. EVANS. I am not sure just how that would reflect upon the survey.

Mr. FULTON. That does not reflect on the survey.

I am saying that the majority then, when you say 46 percent felt that the U.S. scientific knowledge had gone up in value, 46 from 100 leaves 54 percent thought the scientific knowledge had not gone up in value or did not know.

Mr. HECHLER. Will the gentleman yield?

Mr. FULTON. Yes.

Mr. HECHLER. The figures speak for themselves. It has remained about the same.

Mr. EVANS. If you deduct the 12 percent listed as "no opinion" you do not get quite 64 percent. It is 52 percent. But I think the point in general is quite valid.

I think any time one can by a single episode in a scientific program change the attitudes of perhaps half a nation, one must regard that as a rather overwhelming success.

One might have regrets about not having reached the other half, but I don't think that can gainsay having reached the half we did reach.

It might also be worth mentioning that 35 percent, those listed in the poll whose scientific regard for the United States remained about the same, may well have already had a considerable regard for U.S. scientific achievements.

Mr. BOONE. Mr. Chairman?

Mr. HECHLER. Mr. Boone.

Mr. BOONE. Is this the organization that does this polling work for the BBC or is this a private organization?

Mr. EVANS. I do not know if they do it for the BBC; I am told they are a private organization. I do not know what other clients in the British Isles they have.

Mr. BOONE. They have a rather extensive survey that they conduct on their own programs?

Mr. EVANS. Yes; they do. That is true.

But I do not know if it is the same firm.

Mr. FULTON. I think we should have the background of the organization and the methodology of the survey put in the record at this point.

Mr. EVANS. Surely; if we may do that, Mr. Chairman.

Mr. HECHLER. Yes.

The document is as follows:

A NOTE ON METHOD IN USIA'S TELSTAR STUDY

The Agency's study of the impact of Telstar upon the British public was conducted under contract by the British Gallup Institute (Social Surveys Limited). It comprised a set of questions on awareness and impressions of Telstar, prepared by USIA, which were included in one of the regular weekly national surveys of the Gallup organization.

The fieldwork was timed to follow the ceremonial transatlantic telecasts of July 23, 1962, and was performed by the trained interviewing staff of the British Gallup Institute between July 26 and 31.

The sampling involved a total of 1,074 cases selected on what is technically termed a stratified quota-control basis to be carefully representative of the adult population of Great Britain (over 16 years).

As in all USIA surveys the study was conducted under the auspices of the contracting organization with no indication to respondents of any American connection with the inquiry.

Mr. HECHLER. You may proceed, Mr. Evans.

Mr. EVANS. Let me make brief mention of some of the publications that this Agency has distributed regarding Telstar.

You have had furnished to you some of them.

I might say in advance that before Telstar the Agency supplied all of its posts around the world with preliminary press kits, picture layouts, and various types of feature materials that had quite wide display in many countries.

I am told that in the days since Telstar's success we have shipped to posts around the world some 800 prints per post in black and white and some 79 color transparencies and the posts have been engaged in inserting these in the local press around the world.

I also have a two-page list of individual articles that have gone out on the daily wireless file in the 2 months or so that have elapsed since Telstar, keeping the story in the eyes of the foreign press.

I should be glad to submit this for the record if desired.

These stories have had quite extensive circulation in newspapers worldwide.

The magazines that you have in front of you—magazines and pamphlets—are further examples of the type of publications the Agency has put out.

The magazine that has on the cover the railroad engineer is a copy of Amerika magazine that we distribute in the Soviet Union in a run of 62,000 by treaty arrangement.

Copy No. 72 went on sale the 25th of September and at this moment is being seen and sold in the Soviet Union.

There is in this magazine an article on Telstar, and we have included with it an English translation.

You will notice this article, some five pages in length, does not have a great deal about the launching of Telstar.

The reason, of course, is because of the printing leadtime on magazines such as this.

This went to press far in advance of the successful Telstar date.

The next copy of Amerika magazine, the one with Telstar appearing on the cover, is edition No. 73, and is the copy of the Russian magazine that will go on sale in the month of October.

You will find that that does have, on the page marked with the translations inserted, a result of the successful Telstar orbit.

Incidentally, there are two magazines with Telstar on the cover.

One is the Russian version; the other is the Polish language edition.

There is only one Polish language magazine because our leadtime was such as to allow us to get the entire story in one issue.

The Polish edition goes on sale about October 1 in Warsaw, I am told.

Mr. HECHLER. Mr. Boone?

Mr. BOONE. You really do not have a feel for what this does for us outside of the area in which there was communications—South America, for example?

Mr. EVANS. You mean an indication of the results of Telstar in those areas?

Mr. BOONE. Of its impact in those areas, right.

Mr. EVANS. I think we do.

We had any number of interesting cables quoting extracts of newspapers. On July 19 and July 26 we prepared a list of press surveys which had a number of comments from countries outside of Europe. Some of the pamphlets I was about to proceed to, have been ordered by posts in areas other than Europe.

We have regional service centers in Mexico City, in Beirut and in Manila and from each of those regional service centers have come rather extensive orders for these Telstar pamphlets.

I think this is an indication of interest in areas out of the sophisticated West in Telstar.

Mr. FULTON. It would be interesting to know whether the opinion had changed on who is ahead overall in the space competition, whether Russia is ahead or the United States.

Did it have any effect on that?

Mr. EVANS. We have not inquired into those matters, Mr. Fulton.

As I understand it the director of the Agency has agreed that we should not engage in polling popularity between Russia and this country.

Mr. FULTON. I would not call that a popularity poll. I would say that was the sizeup of the space programs, as to which one is scientifically ahead overall in the space program. That does not mean that they like Russian programs better than ours.

Was there any information found on how it affected the opinion of people on the relative position of our U.S. space program overall?

Mr. EVANS. If I were to hazard a guess I would suppose this kind of estimate varies with the passage of events. I am sure that people polled a week after Telstar would have had fine things to say about this country and space, just as people polled the week after the two cosmonauts were in orbit would have perhaps expressed an opinion in the opposite direction.

Perhaps opinions are really too transient to be quite substantive in trying to evaluate them for program use in these subject areas.

Mr. FULTON. Do you think then that your survey showed up an opinion that was a lasting opinion, or just transient.

Mr. EVANS. I think it showed up as any opinion survey would show up in this type of poll.

These opinions are never solid and longlasting in terms of being able to guarantee a future reaction.

All they can do is indicate at one point in time—the time the sample was taken—what their opinions are.

Mr. FULTON. I would have thought that the opinions once formed would have been more lasting than you seem to indicate.

Mr. EVANS. Perhaps so, sir.

Mr. HECHLER. We will just have to hope to follow up with more spectacular successes.

Mr. EVANS. One can only bat .1000 in this league.

Mr. FULTON. I hope you really give some coverage to the Mariner II Venus shot, because that makes the moon a suburban excursion.

Mr. EVANS. We have been giving that quite extensive play in Voice of America news and commentaries and in various types of news stories that have gone on our wireless files to our posts worldwide.

Mr. HECHLER. While you are at it, don't forget the model of the Green Banks, W. Va., telescope on the table there. [Indicating.]

It is the world's largest movable radio telescope.

Mr. FULTON. No comment from Pennsylvania. [Laughter.]

Mr. EVANS. Just to continue briefly with these pamphlets, if I may, Mr. Chairman.

You have a copy of a blue pamphlet, called the "Great Venture," which is one of the more recent publications, we have gotten out.

Inside the front cover note the insert.

That is a sample of an acquisition that the Agency has made from the National Geographic Society. This type of cooperation is often carried on with American publications.

The early returns on orders for these have run in the magnitude of over 100,000. We do anticipate more orders for these in the weeks ahead.

The next publication is "Space and Stars." This also is a new publication, which has just gone out to the field. The initial run of this publication is only 30,000 in number, in English.

I may say the reason for that number is our custom of only furnishing English copies of these pamphlets to posts.

Once they have indicated their interest and needs in language translations, subsequent orders are placed on the Agency in Washington.

There is another pamphlet, called "Space, the New Frontier."

This is a sample of a different type of pamphlet. It is done in cooperation with the National Aeronautics and Space Administration.

Mr. HECHLER. Do you distribute this?

Mr. EVANS. Yes, we do. We run quite often joint enterprises together where we avail ourselves of one another's talents and facilities, and this has gone out in worldwide distribution in a number of languages.

The last return I had on the circulation of this—this has gone out fairly recently—was over 60,000.

Mr. BOONE. Mr. Chairman.

Mr. HECHLER. Mr. Boone.

Mr. BOONE. These are available in your posts overseas for people to come in and look at; is that correct?

Mr. EVANS. That is true; but that is not the prime use. The prime use is in, I think, two manners: First, presentations to foreign Cabinet ministers, newspaper writers, and other types of hand distribution; for instance, an officer calling and discussing space and leaving a pamphlet.

The second use would be in terms of more general distribution by use of mails to schools, select mailing lists, institutions, et cetera.

The last pamphlet is the one entitled "Telstar." This was an Agency publication that we got out in conjunction with the actual launch of the vehicle itself.

Our orders for this have run at present over one-quarter of a million from posts around the world and in a number of languages, numbering at present over one dozen. The pamphlet has been most successful. Our returns from it indicate many people are, let us say, absorbed and stimulated with what it had to say about the U.S. space experiment.

I have one other brief comment before we do the television films.

We did have a series of exhibits prepared by our exhibit section that went out in over 2,000 copies in some 4 languages.

This is a large 2-foot by 4-foot exhibit with pictures in color called "U.S. Space Progress Report." It was in all posts just after launching.

I think we might cut this presentation short by going immediately now to the television films.

Mr. HECHLER. Proceed.

Mr. EVANS. The Agency prepared two television films, one that went out to Europe before the Telstar telecast and was available for local television stations or networks as a prelude to the actual TV experiment, and the second was a program we produced after Telstar had been a complete success.

This was furnished to Europe and also got worldwide distribution.

Both of these films run approximately 13 minutes in length. We would like to show you, with your permission, the second film first, which was a total recap of Telstar.

If the committee wants to avail itself of time to see the first program, we can then show you that.

There is included in that first program a bit of cartoon, an animation sequence, to show people exactly how the system works.

Mr. HECHLER. We better move fast. The House is in session at 12.

Mr. EVANS. Let us then look at the second one first, and at your option regarding the other film.

(Film is shown.)

Mr. FULTON. What is the name of the film?

Mr. EVANS. "Europe to America to Europe" was the name of this film.

This went out in English, Spanish, Portuguese, Thai, Japanese, and Arabic.

Mr. FULTON. Is that available for showing in this country or only for abroad?

Mr. PLESENT. It is available only for abroad, sir, except in special circumstances.

I think perhaps you know, Mr. Fulton, we have this longstanding problem about the availability of USIA material for domestic distribution.

Mr. FULTON. I had a resolution, cosponsored with Senator Gore, to let you show excellent films of broad U.S. interest in this country.

Mr. PLESENT. That resolution has passed the Senate of the United States unanimously. It has not been reported out by the House For-

eign Affairs Committee. It relates solely to the two films of Mrs. Kennedy's trip to Pakistan and India.

We are, as you know, given funds to disseminate information abroad, and the Congress has been very clean in their comments through the years that this money is not to be spent "to propagandize the American people."

So we have had to be awfully careful in this area.

There is a way for this film and others in our program to be seen domestically. It is somewhat limited.

We have the OK of all parties to putting this type of film into a pool of Government-wide films that can be used for educational purposes only.

There is a system whereby GSA on behalf of the Office of Education of HEW, contracts with a distributor for the use of Government films for educational purposes and many of our films are in that pool.

We do not control that. It goes into the pool and schools and other educational institutions can request it.

There is a fee that is charged for the film. But they can get it through that medium.

Unrestricted domestic usage is not within the purview of our authority.

Mr. HECHLER. I think the committee might have to subpoena the film for showing in Pennsylvania, Mr. Fulton.

Mr. FULTON. My point is really in connection with the educational TV station in Pittsburgh, would film of this type be available.

Mr. PLESENT. Well, some of our material is shown on educational TV here. We justify it on the ground that there is an ultimate gain in oversea value. Since our assigned mission is to inform peoples abroad, to the extent we make cooperative arrangements with educational TV stations whereby we trade domestic use of our material for oversea use of their material we are ahead in terms of our oversea program.

There is an additional problem, Mr. Fulton, when we contract for these things, keeping in mind our oversea mission in terms of talent, in terms of unions, and so forth, our rights are more often than not limited to oversea use.

So that any ultimate domestic use would require renegotiation.

The problem you state in your question is one of long standing.

Certain of these films, frankly, I don't think, really fall in the "propagandizing the American people" category, but that is the concern, and the worry is, if we start with one, where do we stop. It is true that much of our material is directed at specific oversea audiences with very specialized messages.

Mr. HECHLER. We appreciate your clarifying statement, Mr. Plesent. I think if we are to see the other film, we should begin.

Mr. EVANS. It is about as long as the previous one.

(Showing film.)

Mr. HECHLER. Mr. Evans, did you want to add anything?

Mr. EVANS. No. I think that concludes our presentation.

(The document entitled "International Telecommunication Union, Administrative Council, 17th Session, Geneva, May-June, 1962," is as follows:)

Document No. 2835/CA17-E
(II/4-13)

May 24, 1962
Plenary meeting

FIRST REPORT BY THE INTERNATIONAL TELECOMMUNICATION UNION ON TELECOMMUNICATION AND THE PEACEFUL USES OF OUTER SPACE

I. INTRODUCTION

The International Telecommunication Union (ITU) appreciates the active interest shown by the United Nations General Assembly in the potential importance and application of space telecommunications, and, in response to paragraph 5, part D, of the General Assembly Resolution No. 1721 (XVI), it has pleasure in submitting this first report to the General Assembly, at its 17th session, and to the Economic and Social Council at its 34th session.

Telecommunication is involved and is essential in practically all uses of outer space. It is of great importance in the operation of all types of space vehicles and in the exploration and study of celestial bodies. At the same time, space vehicles and systems will provide new telecommunication facilities for purely terrestrial requirements, new meteorological data to be used in improved weather forecasting and new navigational aid facilities for use by ships and aircraft.

Over the years the ITU has found solutions to the new problems raised by the development of telecommunications such as the revolutionary use of radio-communication at the turn of the century and it is confident that it will continue to deal effectively with any similar development. At the present time, many problems related to the use of telecommunication in space have yet to be solved. Consequently, this report is of an interim nature only and it will be followed by subsequent reports as developments justify.

As soon as the terms of Resolution No. 1721 (XVI) of the General Assembly became known, the ITU sought the advice of all its members on the nature of the report that would be given to the United Nations. During its 17th session, held in May 1962, the Administrative Council of the ITU considered the matter in the light of the replies received from the members with close attention and keen interest.

The Council is very mindful of the tasks which these new techniques impose upon the ITU and desires to assure the General Assembly and ECOSOC that the ITU will use all the resources available to it under the International Telecommunication Convention and the agreement between the U.N. and the ITU to achieve the widest use of telecommunication in space for peaceful purposes in the interest of all countries.

II. STRUCTURE AND ROLE OF THE INTERNATIONAL TELECOMMUNICATION UNION

The questions raised by the U.N. Resolution No. 1721 involve the ITU in all its normal tasks. These include the orderly utilization of the radio frequency spectrum and the development of internationally accepted technical and operating standards associated with all means of telecommunication, both in relation to telecommunication system performance and national and international network performance. They include also assistance to new or developing countries in adapting their national telecommunication systems to those standards, and integrating them into the worldwide telecommunication network.

Consistent with its convention, the ITU maintains and extends international cooperation for the improvement and rational use of telecommunication of all kinds. It also has a responsibility to promote the development of technical facilities with a view to increasing their usefulness and availability to the public and the harmonize the actions of nations to this end.

The Plenipotentiary Conference is the supreme organ of the ITU. It meets at intervals of about 5 years and its main task is to revise the International Telecommunication Convention if it considers this is necessary and to fix the ITU budget for the interval between Plenipotentiary Conferences. The next meeting of the Plenipotentiary Conference is scheduled to take place in 1965—the year of the centenary of the ITU—and this could be well timed to afford the Conference an opportunity to review the policy of the ITU in relation to the use of telecommunication in space.

In the intervals between meetings of the Plenipotentiary Conferences, the governing body of the ITU is the Administrative Council comprising 25 members of the ITU. The Council meets annually and in addition to insuring efficient coordination of the work of the ITU, it is empowered to make policy decisions within the framework of the Convention and in conformity with the directives of the preceding Plenipotentiary Conference.

Members of the ITU also meet at Administrative Radio Conferences which revise the radio regulations, taking into account the recommendations of the International Radio Consultative Committee (CCIR), and the recommendations of the International Registration Board (IFRB), and also at Administrative Telegraph and Telephone Conferences which revise the ITU telegraph regulations and the telephone regulations, taking into account the recommendations of the International Telegraph and Telephone Consultative Committee (CCITT). As mentioned in the United Nations resolution, the ITU proposes to convene an Extraordinary Administrative Radio Conference for late 1963 to deal specifically with the allocation of frequencies for space telecommunications services.

The permanent organs of the ITU consist of the General Secretariat, the International Frequency Registration Board (IFRB), the International Radio Consultative Committee (CCIR), and the International Telegraph and Telephone Consultative Committee (CCITT).

Apart from its responsibilities in the administrative area, under the direction of the Administrative Council, the General Secretariat administers the ITU technical cooperation programs designed to help in the development of the telecommunication systems of ITU members.

The IFRB consists of 11 independent radio experts, all nationals of different countries, elected by the preceding Administrative Radio Conference and working at the ITU's headquarters. The Board is assisted by a specialized secretariat. It is responsible, among other matters, for the registration of frequencies, the study of the usage of the radiospectrum with the view of making recommendations for its more effective use and the technical planning of radio conferences.

The two CCI's are separate bodies. All members of the ITU can participate in their work and also certain private agencies operating telecommunication services. Each CCI holds a Plenary Assembly, at approximately 3-yearly intervals, which constitutes a number of study groups. The study groups meet and draw up recommendations which are submitted to the next Plenary Assembly. Recommendations adopted by the CCI Plenary Assembly have an important influence with telecommunication scientists and technicians, administrations and operating agencies, manufacturers and designers of equipment throughout the world.

All the study groups of the two CCI's consist of experts from members of the ITU so that their work and achievements are the results of the most advanced technical knowledge and experience of all the members of the ITU in all fields of telecommunication.

The CCIR deals with technical and operational questions relating to radio communications, and of its 14 study groups 1 is concerned with technical questions specifically relating to space telecommunications.

The CCITT deals with technical and operational questions relating to telegraphy and telephony and to telecommunication network operations generally. One of its 19 study groups is dealing with data transmission, which is one of the techniques of primary importance in space telecommunication. Other groups are concerned with the development of national and international telecommunication network principles.

A joint committee and regional subcommittees of the CCITT and the CCIR have responsibilities for establishing a general plan for development of the international network to help administrations and recognized private operating agencies when they conclude mutual agreements to organize and improve the international services between their respective countries. So the joint committee, known as the Plan Committee, is the appropriate body to study the integration of space telecommunication systems with the world telecommunication network.

III. MEASURES TAKEN BY THE ITU IN THE SPACE TELECOMMUNICATION FIELD BEFORE PASSING OF U.N. RESOLUTION NO. 1721

As will be seen from the information supplied in annex I to this report, the formal activities of the ITU in the area of space telecommunication began shortly

after the launchings of the first artificial satellites. In 1958, study groups of the CCIR formulated questions involving the protection of frequencies for the operation of artificial satellites. The Plenary Assembly of the CCIR meeting at Los Angeles in April 1959, established the special study group for space telecommunication problems with and between space vehicles. Significantly also, the special study group was established in 1958 by the CCITT to deal with data transmission. The CCITT also has a study group dealing with time delay and echo effects associated with very long transmission circuits.

The 1959 Plenipotentiary Conference was mindful of possible developments in the field of space telecommunications, and in Resolution 34 entitled "Telecommunications and peaceful uses of outer space vehicles" considered "the importance of the role that telecommunications and, in consequence, the ITU, will necessarily play in this sphere." The text of Resolution 34 is included in annex 1.

At the 1959 Administrative Radio Conference, frequency allocations for "space" and "earth-space" radiocommunication services, conditions for the use of these frequencies, and provisions for a radio astronomy service were included in a revision of the ITU radio regulations. At that time this Conference also took cognizance of likely problems and regulatory requirements envisaged in regard to the peaceful use of outer space. (Resolution No. 7 and recommendation No. 36 of the Conference are also included in annex 1).

The IFRB, in October 1961, invited Administrations' attention to recommendation No. 36 of the Administrative Radio Conference, Geneva, 1959, and to the program of activity in connection with the formulation of technical principles on which the allocation and use of frequencies for space radiocommunications might be based and requested them to send information concerning existing and projected use of the parts of the frequency spectrum which may also be used by space services. The results of this preparatory work for the Extraordinary Administrative Radio Conference is set forth in paragraph 5 of annex 1.

Reference has already been made in section II of this report to the work of CCITT and CCIR study groups and to the work of the joint CCITT and CCIR plan committee, all of which are preparing the ground for the time when the integration of space telecommunication systems with world network may be necessary and relevant technical cooperation projects will need to be firmly developed.

IV. MEASURES TAKEN OR CONTEMPLATED SUBSEQUENT TO THE U.N. RESOLUTION

Study group IV of the CCIR mentioned above met in Washington in March 1962, and a number of important recommendations were drafted by the meeting on technical questions concerning space telecommunication.

The principal subjects examined by the study group were the following:

(a) Telecommunication systems between fixed (and mobile) earth stations using earth satellites as relays. Direct broadcasting from earth satellites.

(b) Technical characteristics of earth-space and space-space telecommunication systems.

(c) Satellite systems for navigation and meteorology.

(d) Radio-astronomy.

(e) Propagation and noise.

The list of draft recommendations, draft reports, draft new questions and draft study programs adopted at the Washington meeting appears in section 3 of annex 1.

As mentioned earlier, the Secretary-General of the ITU reminded Administrations of the recommendations contained in Resolution No. 1721, and the Administrative Council has made a careful study of the U.N. resolution, and, taking into account the views of the Administrations, recommended to members of the ITU, that the proposed Extraordinary Radio Administrative Conference (EARC), be convened in October 1963, and suggested a provisional agenda, which is attached as annex 2. The agenda may be revised by the Council at its next session, which is likely to be held earlier than usual, so that a final agenda can be proposed to Administrations at least 6 months in advance of the EARC, as required by the convention.

In the light of part D of Resolution No. 1721 and paragraph 5 of the provisional agenda referred to above, some members and associate members of the ITU may make specific proposals for the addition of items to the provisional

agenda, for consideration by the Administrative Council at its 1963 session. It is possible that some of the items proposed will be considered by the Council as not appropriate for inclusion in the agenda of the 1963 Conference; the Council in those cases may be able to suggest the proper forum for their consideration, such as, for example, the Plenipotentiary Conference.

Meantime the Secretary-General has been instructed by the Administrative Council, in extension of Recommendation No. 36 of the Administrative Radio Conference, Geneva, 1959, to invite all member countries and associate members of the ITU to inform the Secretary-General, for the information of the Administrative Council and of the permanent organs of the ITU of the frequencies used and of the technical progress they may have achieved in the use of telecommunication in connection with outer space.

The Secretary-General has been instructed to submit a report to the Administrative Council at its 1963 session.

A further meeting of Study Group IV of the CCIR, followed by the Plenary Assembly of this organ, is to be held in January 1963, to consider technical progress and formulate recommendations that will be useful for the work of the EARC.

Subject to the receipt of the approval of the members of the ITU to the holding of the Extraordinary Administrative Radio Conference in 1963, notifications will be sent to all interested international organizations; these are shown in annex 3. Provisions of the Convention, Regulations and Administrative Council resolutions provide for full cooperation with other international organizations interested in telecommunication matters. No difficulties are envisaged in connection with organizing satisfactory coordination in the field of space. As usual, such coordination will be achieved primarily through the participation of the interested organizations in the work of the administrative conferences and consultative committees (CCITT and CCIR)).

It is noted that, in paragraph 4 of part D of Resolution No. 1721 (XVI), the special fund and the expanded program of technical assistance in consultation with the ITU, have been invited to give sympathetic consideration to requests from members for technical and other assistance for the survey of their telecommunication needs and for the development of their domestic telecommunication facilities so that they may make effective use of space telecommunication.

Until such time as space telecommunication systems are established as a reliable and practical telecommunication media with known operating properties and cost structures, it is too early to plan for their general integration into worldwide networks. Such developments will need to be based on firm information and are only likely to proceed after careful consideration of alternative means of telecommunication in relation to operating and economic factors. In the long run, a new means of telecommunication establishes its place in worldwide networks on the basis of its relative performance and cost level.

The immediate task in the technical cooperation field would seem to be the survey of needs and the development of the domestic facilities of member countries. This is a longstanding requirement and its importance would have increased even if space telecommunications were not anticipated. As indicated earlier in this report, the ITU is already active in this field of technical cooperation both in relation to the activities of study groups of the consultative committees, the plan committee, and in relation to the United Nations program (EPTA and Special Fund).

V. CONCLUSION

The Administrative Council of the ITU at its next session in 1963 will examine the current position in all its aspects and will take any further action which appears necessary. In the meantime, studies concerning space transmission will be carried on in the Administrations by their own specialists and at the same time in the IFRB, as well as in the international consultative committees (CCIR and CCITT) in whose work these same specialists take part.

The Economic and Social Council may wish to take special action to support the extension of technical cooperation in the field of telecommunications under the expanded program of technical assistance and the Special Fund.

The International Telecommunication Union wishes to assure the United Nations General Assembly and the Economic and Social Council that it will do all in its power to insure that the development and use of space telecommunication will proceed in an orderly and regulated fashion.

ANNEX 1

MEASURES TAKEN BY THE ITU IN THE FIELD OF SPACE TELECOMMUNICATIONS

1. Decision taken by the Plenipotentiary Conference of the ITU, Geneva, October-December 1959

The Plenipotentiary Conference was interested in the very general aspects of outer space telecommunication. After having been informed of the action taken by the appropriate organs of the ITU, it adopted the following resolution:

"RESOLUTION No. 34

"TELECOMMUNICATION AND THE PEACEFUL USES OF OUTER SPACE VEHICLES

"The Plenipotentiary Conference of the International Telecommunication Union, Geneva, 1959,

mindful of

the problems which arise in the international field from the use of outer space for peaceful purposes;

considering

the importance of the role that telecommunication, and in consequence the Union, will necessarily play in this sphere,

instructs the Secretary General

1. to inform the United Nations and the other international organizations concerned of the decisions of the Administrative Radio Conference, Geneva, 1959, and of the technical studies being undertaken by the International Consultative Committees;

2. to keep the same organizations informed of progress in this field, as far as the Union is concerned."

2. Decisions taken by the Administrative Radio Conference of the ITU, Geneva, August-December 1959

The Administrative Radio Conference of the ITU considered in detail the requirements for outer space telecommunication from the radio point of view. Among other documents on this subject, the report of the United Nations Special Committee on Peaceful Use of Outer Space was submitted to the Conference as Document No. 58.

The decisions finally reached by the Conference are given hereafter.

2.1 Definition of new radio services and stations

The following definitions were adopted:

Space service: A radiocommunication service between space stations.

Earth space service: A radiocommunication service between earth stations and space stations.

Space station: A station in the earth space service or the space service located on an object which is beyond, or intended to go beyond, the major portion of the earth's atmosphere and which is not intended for flight between points on the earth's surface.

Earth station: A station in the earth space service located either on the earth's surface or on an object which is limited to flight between points on the earth's surface.

2.2 Allocation of specific frequency bands

The following frequency bands have been allocated on a worldwide basis for research purposes in connection with space and earth-space services:

136	-----	137 mc/s
400	-----	401 mc/s
1427	-----	1429 mc/s
15.15	-----	15.25 go/s
31.5	-----	38.8 go/s

In addition, the following frequency bands have been allocated for the same purposes on a secondary basis:

10003	-----	10005	kc/s
19990	-----	20010	kc/s
39985	-----	40002	kc/s
1700	-----	1710	mc/s
2290	-----	2300	mc/s
5250	-----	5255	mc/s
8400	-----	8500	mc/s

Furthermore, the frequency $183.6 \text{ mc/s} \pm 0.5 \text{ mc/s}$ is also allocated for the same purpose subject to causing no harmful interference.

2.3 Recommendation for the convening of an Extraordinary Administrative Radio Conference in 1963

"RECOMMENDATION No. 36

"CONVENING OF AN EXTRAORDINARY ADMINISTRATIVE RADIO CONFERENCE TO ALLOCATE FREQUENCY BANDS FOR SPACE RADIOCOMMUNICATION PURPOSES

"The Administrative Radio Conference, Geneva, 1959,

considering

(a) that several delegations participating in the Administrative Radio Conference have proposed to allocate frequencies for space research purposes only on the basis of the research requirements for the next few years;

(b) that the CCIR has already under study technical questions relating to radiocommunication with and between space vehicles;

(c) that the Administrative Radio Conference has recommended to the CCIR that the identification and control of space vehicle emissions be questions for study by the CCIR;

(d) that until the results of some space research programs are available, the extent to which space radio communication services and other radio communication services may share frequencies, without harmful interference, cannot accurately be assessed;

(e) that additional research experience and the results of studies by the CCIR, and other interested organizations, relating to space radio communications are essential before it will be feasible for the Union to take decisions on firm frequency allocations for space radio communication purposes;

and bearing in mind

(f) that the Union is the specialized agency in the field of telecommunications and that it is necessary for the Union to provide adequate frequency allocations for all categories of space radio communications as soon as the results of research and studies by the CCIR and other interested organizations make this possible;

recommends

1. that an Extraordinary Administrative Radio Conference be convened, in principle during the latter part of 1963 with a duration of approximately 1 month and with an agenda which should include the following basic items:

1.1 to examine the technical progress in the use of radio communication for space research and the results of technical studies by the CCIR and other interested organizations;

1.2 to decide, in the light of this examination, on the allocation of frequency bands essential for the various categories of space radiocommunication;

1.3 to consider whether there is a continuing need for the allocation of certain frequencies for space research purposes and, if so, to take appropriate action in this regard;

1.4 to adopt, if such action is considered desirable, new provisions revising the radio regulations to provide for the identification and control of radio emissions from space vehicles, taking into account possible recommendations of the CCIR;

2. that the Administrative Council review the situation during its 1962 and 1963 ordinary sessions on the basis of information received from members and associate members of the Union, the CCIR and other interested organizations. Should the Administrative Council decide that there is sufficient justification for

the convening of the Extraordinary Administrative Radio Conference in 1963, it shall recommend to members and associate members of the Union the date and place for the Conference and its agenda ;

and invites

those members and associate members of the Union which launch satellites during the period of space research before the convening of the Extraordinary Administrative Radio Conference referred to above, to keep the Administrative Council, and the relevant technical organs of the Union, informed of the frequencies used and the technical progress achieved in the use of radio communication for space research purposes."

2.4 Resolution entrusting the CCIR with special studies

"RESOLUTION No. 7

"RADIO EMISSIONS FROM ARTIFICIAL SATELLITES AND OTHER SPACE VEHICLES

"The Administrative Radio Conference, Geneva, 1959,

considering

- (a) that it is desirable to study the question of identification for radio emissions from satellites and other space vehicles ;
- (b) that it is desirable to study the question of providing for the cessation, at appropriate times, of radio emissions from satellites and other space vehicles ;

invites

1. the CCIR to study the above-mentioned questions ;
2. members and associate members of the Union launching satellites and other space vehicles to give consideration to the above-mentioned problems and to present the results of their study to the CCIR"

3. Measures taken by the International Radio Consultative Committee (CCIR)

The International Radio Consultative Committee (CCIR) held meetings of some of its study groups during the month of August 1958, and, following discussions at that time, added three new questions for study to its program.

Two of these questions were Nos. 168(V) and 169(VI), both bearing the title "Protection of Frequencies Used by Artificial Earth Satellites, or Other Space Vehicles for Observation and Positional Observation." The third one—No. 188(VIII)—deals with "Monitoring at Fixed Monitoring Stations of Radio Transmissions From Space Vehicles."

As a result of its studies, the CCIR, during its ninth plenary assembly in Los Angeles, in April 1959, formulated a recommendation on "Selection of Frequencies Used in Telecommunication With and Between Artificial Earth Satellites and Other Space Vehicles," and also issued a report on "Factors Affecting the Selection of Frequencies for Telecommunication With and Between Space Vehicles," both giving general consideration on the frequency bands necessary for the purpose.

The findings given in these two documents have been presented to the Administrative Radio Conference, 1959, mentioned above and they were considered in connection with the allocation of frequency bands to the new space service.

Further, the ninth plenary assembly of the CCIR has formed a new study group: "Space Systems," with the terms of reference: "To study technical questions regarding systems of telecommunication with and between locations in space." This study group met in March 1962 to prepare draft recommendations which will be submitted to the 10th plenary assembly of the CCIR scheduled to meet early in 1963. This will be well in time to submit such views which will be of interest to the Extraordinary Radio Conference which, toward the end of 1963, will consider the allocation of new frequency bands for use in space telecommunications.

The list of draft recommendations, draft new questions and draft study programs adopted by the above study group of the CCIR (study group IV) at its meeting in March 1962 is as follows (the documents mentioned in brackets are available at CCIR Secretariat, ITU, Geneva) :

A. Draft recommendations

Cessation of radio emissions from satellites and other space vehicles (doc. IV/12).

Identification of radio emissions from satellites and other space vehicles (doc. IV/13).

Active earth-satellite communication systems. For frequency-division multiplex telephony and monochrome television (use of pre-emphasis by frequency modulation systems) (doc. IV/60).

Active earth-satellite communications systems for frequency-division multiplex telephony (reference circuit) (doc. IV/67).

Active earth-satellite communications systems for frequency-division multiplex telephony (allowable noise power in the reference circuit) (doc. IV/68).

Active earth-satellite communication systems for monochrome television (reference circuit for intercontinental systems) (doc. IV/69).

Active earth-satellite communication systems for monochrome television (video bandwidth and permissible noise in the reference circuit) (doc. IV/70 (revised)).

In connection with this draft, the IBTO should be asked whether the bandwidth of 5 mc/s would be acceptable for the transmission of television signals of the IBTO television standard over satellite links.

Preferred frequency bands for use in telemetry, tracking, remote control, voice, and video in experimental and operational earth satellites and probes (doc. IV/80 (2d revision)).

Radio-frequency channeling arrangements for telemetry and remote control in operational satellite-relay communication systems (doc. IV/81 (revised)).

Frequency requirements of radionavigation systems utilizing earth-orbiting satellites (doc. IV/82 (revised)).

B. Draft reports

One-way time delay (appears in Doc. IV/65).

Sharing of the radio-frequency spectrum by space-space and earth-space links (Doc. IV/66).

Active earth-satellite communication systems for monochrome television (Form of the reference circuits: the video bandwidth and permissible noise level) (Doc. IV/71 (Rev. and Corr.)).

Active earth-satellite communication systems for frequency division multiplex telephony: (Reference circuit and allowable noise standards) (Doc. IV/72 (Rev.)).

Active earth-satellite communication systems for frequency-division multiplex telephony and monochrome television (Use of preemphasis by frequency modulation systems) (Doc. IV/77).

Frequency sharing between communication satellite systems and terrestrial radio service (Doc. IV/79) (Rev.)).

Technical characteristics of earth-space radio navigation systems and meteorological space satellite systems (Doc. IV/83).

Factors affecting the selection of frequencies for telecommunications with space vehicles reentering the earth's atmosphere (Doc. IV/88) (and Corr.)).

Radio-astronomy (Doc. IV/89) (Rev.)).

Some technical factors affecting direct broadcasting from earth satellites (Doc. IV/91) (Proposed for inclusion in the Chairman's report).

Considerations relating to radio-frequency channeling arrangements for active earth-satellite communication systems sharing the same frequency bands with line-of-sight radio-relay systems (Doc. IV/92) (Rev.)).

Draft revision of Report 115:

Factors affecting the selection of frequencies for telecommunications with and between space vehicles (Doc. IV/93 and Corr.)).

C. New draft questions

Characteristics of active earth-satellite communication systems for frequency-division multiplex telephony (Doc. IV/65).

Time-delay, echoes and switching discontinuities in satellite communication systems (Doc. IV/74).

Active earth-satellite communication systems for frequency-division multiplex telephony (Transmission characteristics of audio channels) (Doc. IV/75 (Rev.)).

Draft question for submission to Study Group VI:

Natural noise in space and noise due to plasma in communications with space vehicles (Doc. IV/84) (Rev.)).

Effects of plasma on communications with space vehicles (Doc. IV/85) (Rev.)).

D. Draft study programs

- Draft programs for Study Group VI:
 - Ionospheric characteristics affecting space telecommunications systems (Doc. IV/95).
 - Draft programs for Study Group V:
 - Tropospheric absorption and refraction in relation to space telecommunication systems (Doc. IV/96).
 - Draft program for Study Group V:
 - Tropospheric propagation factors affecting the sharing of the radio frequency spectrum by space and terrestrial telecommunication systems (Doc. IV/99).

4. Measures taken by the International Telegraph & Telephone Consultative Committee (CCITT)

The CCITT is especially interested in the working and the development of the international telecommunication network. This network may ultimately be called upon to handle a considerable amount of traffic in connection with the operation of space vehicles. The CCITT has already decided to set up a special study group to deal with data transmission, a matter of general interest for purely terrestrial communications, but which is particularly important for space telecommunications. This study group held its second meeting in 1961.

5. Measures taken by the International Frequency Registration Board (IFRB)

The IFRB has special responsibilities in the technical preparation of the Extraordinary Administrative Radio Conference contemplated for 1963. It has requested the Administrations of the ITU to furnish information on the frequencies used, and the technical progress achieved, in the use of telecommunication for space research purposes. Also, since the technical problem of frequency-sharing between new space telecommunication and the very great number of existing earth services is one which the Extraordinary Conference will have most carefully to consider, the Board has requested full particulars of the use which each Administrator is making, or expects to make, of frequencies for all services in the band between 1 Gc/s and 10 Gc/s.

Under the decisions of the Administrative Radio Conference (Geneva, 1959), the IFRB has the duty, according to a procedure specified in the Radio Regulations, of recording, in the Master International Frequency Register—which is charged to compile and maintain—particulars of all radio stations which are capable of causing harmful interference to the radio services of other countries. The particulars to be furnished by the Administrations of the members and associate members of the ITU in respect of such stations operating in the frequency bands allocated to space telecommunications, are also specified in the ITU Radio Regulations. The prompt notification of the particulars of such stations is an essential prerequisite to the securing of radiocommunications free of harmful interference, on which the effectiveness of these communications depends.

ANNEX 2

PROVISIONAL AGENDA FOR THE EXTRAORDINARY ADMINISTRATIVE RADIO CONFERENCE OF 1963

1. To examine the technical progress in the use of radiocommunication for space research and the results of technical studies by the CCIR and other interested organizations concerning earth satellite systems for operational purposes (communication, radio navigation, and meteorology).
2. In the light of this examination—
 - (a) To consider the allocation of radio frequency bands for operational earth satellite systems, together with bands for the telemetry, command, and control facilities necessary for such systems;
 - (b) To consider whether there is a continuing need for the allocation of certain frequencies for space research purposes, including the associated telemetry, command and control.
3. In accordance with Nos. 61 and 249 of the International Telecommunication Convention, Geneva, 1959, to revise only such provisions of the radio regulations, Geneva, 1959, as may be essential for the effective implementation of the decisions of the conference relating to the allocation, recording and use of fre-

quencies for operational earth satellite systems, and space research, for example, articles, 1, 5, 9, 14, 19, 20, and appendixes 2, 3, 4, 9, and 10.

4. In accordance with Nos. 61 and 249 of the International Telecommunication Convention, Geneva, 1959, to adopt such additional provisions to the Radio Regulations, Geneva, 1959, in particular to article 7 as may be essential for the effective implementation of the decisions of the conference concerning the technical characteristics and operation of earth satellite systems and the space research service.

This agenda may be amplified on proposal by the Administrative Council at its 18th session in 1963, taking into account as appropriate additional items in connection with United Nations Resolution 1721 (XVI) and points of view of administrations; some of the latter have already expressed the wish that frequency requirements for radio astronomy should be considered by the conference.

ANNEX 3

INTERNATIONAL ORGANIZATIONS WHICH MAY POSSIBLY COOPERATE WITH THE ITU
IN THE FIELD OF SPACE TELECOMMUNICATIONS

In addition to the Specialized Agencies and the International Atomic Energy Agency, the ITU has, so far, consulted the following organizations:

- International Broadcasting Association.
- International Association of Radio Maritime Interests.
- International Air Transport Association.
- International Chamber of Shipping.
- International Radio Maritime Committee.
- Special International Committee on Radio Disturbances.
- Inter-Union Committee for Frequency Allocation for Radioastronomy and Space Science.
- International Electrotechnical Commission.
- Committee on Space Research.
- International Astronautical Federation.
- International Broadcasting and Television Organization.
- International Astronomical Union.
- European Broadcasting Union.
- International Amateur Radio Union.
- International Radio Scientific Union.
- International Council of Scientific Unions.

The above organizations will be notified of the 1963 Extraordinary Administrative Radio Conference so that they can attend.

Mr. HECHLER. Because of the fact that the House is in session, the committee stands in adjournment.

Thank you, gentlemen.

(Whereupon, at 12:10 p.m., the subcommittee was adjourned.)

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COMMERCIAL COMMUNICATIONS SATELLITES

THURSDAY, OCTOBER 4, 1962

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON APPLICATIONS,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
Washington, D.C.

The subcommittee met at 9:38 a.m., Hon. Ken Hechler (chairman) presiding.

Mr. HECHLER. The subcommittee will come to order.

Yesterday there were millions of people in Europe who shared in the thrill of the successful flight of Walter M. Schirra, Jr., by means of viewing television relayed by Telstar satellite.

Less than 3 months have elapsed since the historic launch and first test of Telstar, on July 10, 1962. And during that period the success of Telstar has been nothing short of phenomenal.

We are pleased to have with us today a scientist who was and is instrumental in the Telstar development and the tests which have been conducted since it was placed in orbit on July 10.

I would like to welcome to the committee Mr. Alton C. Dickieson, executive director of Transmission Division, Bell Telephone Laboratories, New York, N.Y.

Mr. Dickieson, do you have a prepared statement that you would like to open with?

STATEMENT OF ALTON C. DICKIESON, EXECUTIVE DIRECTOR, TRANSMISSION DIVISION, BELL TELEPHONE LABORATORIES

Mr. DICKIESON. Yes, Mr. Chairman.

I have a prepared statement. As you know, it was planned that it would include as part of the presentation a 27-minute movie. I gather because of the change in the agenda, that we cannot have the movie.

Mr. HECHLER. I want to point out the House will be in session at 10 a.m., which is the reason that perhaps we cannot see the film.

But the committee would like to see and is interested in the film, and would like to see it at some future time.

Mr. DICKIESON. Yes, sir. And I am sure we can work that out at your convenience.

Mr. HECHLER. You may proceed with your statement.

Mr. DICKIESON. I am at your disposal. I will read the statement if you like, or I will answer questions, if that is what you prefer to have.

Mr. HECHLER. I think it would be better to proceed with the statement.

Mr. DICKIESON. All right.

Mr. Chairman and members of the subcommittee, my name is Alton C. Dickieson. I am executive director, Transmission Division of Bell Telephone Laboratories. I have overall supervision of the Telstar project and of other systems which transmit communication from one place to another, such as microwave relay, submarine cables, and so forth.

Since the eventful date of July 10, Telstar has gone around the earth some 788 times. And we have had it in view during part of about 350 of these orbits. We have made tests and demonstrations, either locally at Andover or with our partners in England and France, on about 300 of these orbits. We have received extensive telemetry data from Telstar at Andover, and from NASA minitrack stations around the world.

We have conducted many tests and entirely satisfactory demonstrations of the transatlantic transmission of two-way telephony, television—both black-and-white and color—telephoto, facsimile, high- and low-speed data.

Only 2 days ago, October 2, Telstar relayed business-machine-type data across the Atlantic at the rate of nearly 1,500,000 words per minute.

And, as you mentioned, Mr. Chairman, the launching yesterday of Astronaut Schirra into space was carried on the European TV networks, including Russia, by Telstar.

Mr. HECHLER. How do you know, if I may interrupt here, what reception was had in Russia?

Mr. DICKIESON. I have only the report that I saw in the newspaper this morning, which came by way of England.

And I gathered that the reception in Russia was good, but not too wonderful, if I may put it so.

Mr. HECHLER. You may proceed.

Mr. DICKIESON. Telephone calls also have been made from Hawaii to London, and from an airplane 30,000 feet above Pennsylvania to London. The master clocks of the United States and Great Britain have been synchronized by signals transmitted over Telstar, to a precision something like 100 times better than we have been able to do before.

Now as to the result of the engineering tests: We have gone through an elaborate series of experiments, both up and down, at Andover and across the Atlantic. Prior to these tests we predicted the results, either from fundamental scientific principles, or from previous measurements of the equipment on the ground. We then compared the actual measurement with these predictions.

The purpose, of course, is to see whether we are on a sound engineering basis—that is, whether by careful analysis and experiment on earth we can tell in advance what is going to happen when the satellite is in space.

Our general conclusion is that we have done very well on Telstar in this respect. The measured results are very close to the predicted values.

We have considerable confidence that we could take the next step in the development of Telstar satellites as an engineering job, with no more uncertainty than is normal to any development in a new field.

Mr. HECHLER. Mr. Dickieson, what do you mean by the next step?

Mr. DICKIESON. I mean that the next step in the development of a communications satellite system is to move from the experimental Telstar I into a satellite such as you would need to use in a system.

Mr. HECHLER. Fully operational?

Mr. DICKIESON. Yes, sir.

Mr. HECHLER. Thank you.

Mr. DICKIESON. Let me take the various aspects of the satellite in turn and give you some feel for the results and conclusions:

First, radio transmission. There is a loss in strength as the signal goes through the atmosphere and space from the ground to the satellite and back. This is completely predictable. The microwave signal is very steady, with much less fading than we encounter in our terrestrial microwave relay systems. The reason is that fading generally is caused by the atmosphere. In the case of Telstar, the signal goes through a few miles of atmosphere, and then is in the quietness of outer space.

Second, heavy rain in the vicinity of ground stations increases the noise picked up by the ground antennas. Our experiments, however, have shown that the effect is not so great as to present a serious problem.

Third, the radio equipment inside Telstar is, as far as we can tell, working in space exactly as it did in the laboratory. There was no apparent effect from the shock and vibration of the launching.

Fourth, the temperature to be attained by the satellite is a matter of considerable concern to the designer. As you know, the satellite absorbs heat from the sun, and has to get rid of a good part of it by radiating to cold outer space. It calls for a careful balancing of absorption from the sun, and emission to space to achieve a desired temperature. If mishandled, the temperatures can run up to hundreds of degrees, or down toward absolute zero.

Our objective was to attain satellite temperatures pretty much as we have them here on earth. The reason is that a lot of work has been done on electronic components, materials, fastenings, etc., to optimize their performance, life and reliability under our normal earth conditions, and we wish to take advantage of this work.

Quite a few of our telemetry channels are devoted to having the satellite tell us what the temperatures are in its various parts. To summarize, the inner canister, which holds the electronic equipment, is running between 60-75° F. When the satellite goes into full eclipse, this will drop somewhat lower, but still remain within a normally comfortable range. The outer shell is running between 0 and 50° F., which is within 10° of our expectations.

Fifth, the Telstar satellite is stabilized—that is, prevented from tumbling over and over—by being spun around its polar axis. This spin slows down with time. This is due to various effects caused by interactions with the earth's magnetic field.

For example, Telstar was launched spinning at 177.7 revolutions per minute. It is now at 142 r.p.m., and in 2 years is expected to be at 26 r.p.m.—again quite close to our expectations and entirely adequate to maintain stability.

Sixth, radiation damage to solar cells. It was expected that the solar cells, which take energy from the sun and turn it into electricity, would be aged gradually by the electrons and protons in the Van Allen

Belt. Two of the major objectives of Telstar were to acquire more quantitative knowledge of the intensity and nature of this radiation, and to measure the effects on solar cells which have been especially designed and armored to withstand radiation.

The solar cells are indeed aging. The battery charging current is down to about 85 percent of its initial value; from the shape of the curve to date, and our knowledge of why the aging occurs, we predict that the charging current at the end of 2 years will be 67 percent of initial. Telstar will still function satisfactorily with only 50 percent of the initial charge rate, so we think that we will meet our design objectives satisfactorily.

Mr. HECHLER. Excuse me, Mr. Dickieson.

Mr. DICKIESON. Yes, sir.

Mr. HECHLER. Do these percentages of the effectiveness of the solar cells meet with what you had anticipated, or how do they compare with what you had anticipated.

Mr. DICKIESON. I would say that we are encountering damage to about the degree we had designed for. In other words, it is about what we had expected, or allowed for, at least.

Mr. HECHLER. Now you may cover this later in your statement, but I wonder if you would care to comment on the effect of radiation on other parts of Telstar in addition to the solar cells.

Mr. DICKIESON. There is indeed an effect of radiation on transistors and diodes that are used in the Telstar satellite, and in other satellites, too.

This was discovered by measurements made at Bell Telephone Laboratories, by subjecting transistors to radiation in the cyclotron and other sources of radiation.

We then chose transistors to use which are especially resistant to this and shielded them by putting them inside the canister, and so forth.

So that so far as we can tell we are not encountering any damage to our transistors that is measurable from radiation.

Mr. HECHLER. Would you care to comment on why Telstar has been able to withstand radiation perhaps better than other comparable satellites that are in orbit?

Mr. DICKIESON. On Telstar, when we went into the Telstar project, Mr. Chairman, we gathered together as much data as we could from all sources—from NASA and the scientific community generally—as to the conditions existing in the Van Allen belt, that is, the amount and intensity of radiation, of electrons and protons.

We then studied the performance of solar cells by subjecting them to radiation on the ground, simulating outer space conditions as best we could.

And we discovered that we could design cells particularly to withstand these conditions better than some cells that had previously been available.

We also examined into the question of how to additionally protect them against the effect of radiation. And as you know, we decided to cover the cells with artificial sapphire covers of a certain thickness which tend to absorb many of the electrons and partially shield it from some of the protons.

We also designed the satellite system very conservatively, so as you see, we could still work with only 50 percent of the initial current available.

So, I guess the broad answer to your question is that we had allowed perhaps conservatively for the deterioration to be expected.

Mr. BOONE. Mr. Chairman, may I ask a question?

Mr. HECHLER. Mr. Boone.

Mr. BOONE. Mr. Dickieson, does this mean that you made a calculation of what the nuclear blast would leave in space and were able to design such that you did get what you expected.

Mr. DICKIESON. No, sir, no, I did not mean to imply that.

As you know, the measurements from Telstar are in a range of interest to physicists all over the world. We are probing areas of space that no other satellites are in right now with measuring equipment.

As to the effect of the high altitude nuclear blast, this is one that is being discussed and argued about by physicists and I am not really competent to enter into their discussion.

But so far as the results on Telstar are concerned, that is, whatever the reason for the existence of the electrons and protons that we find there, we are living through these effects satisfactorily.

Mr. HECHLER. You may proceed.

Mr. DICKIESON. The results of the radiation measurements made by Telstar are of intense interest to physicists everywhere. As you know, a discussion is taking place regarding the possible effects of the high altitude nuclear blast of July 9. We understand that NASA is planning to launch a special satellite to study the matter.

But from the standpoint of Telstar, the radiation damage we are encountering is about what we had designed for. Now, as you know, the orbit we have in Telstar goes through the most intense part of the radiation belt. If a Telstar satellite were placed in a higher, circular polar orbit, say 6,000 to 8,000 miles up where the radiation intensity is less, we believe we can design for a 10-year life of solar cells.

Mr. HECHLER. Is that what you are recommending?

Mr. DICKIESON. Yes, sir, for a medium altitude system.

Seventh, in the ground system, the question that concerned us most was our ability to point the very sharp needle beam of the ground antennas accurately enough at the rapidly moving satellite. This has turned out to be no problem; we have pointed accurately and successfully in hundreds of passes, so that it is now a routine matter. Our second approach to the design of a ground station will result in considerable simplification.

Let me close with these general conclusions:

1. We believe that we can approach the design of a second-generation, more complete and more sophisticated Telstar satellite with considerable confidence as a straight engineering project.

2. We are in a position to design satellite communications ground stations, making the usual design trade-offs and optimizations with real understanding of the difficulties and the possibilities involved.

I will be glad to answer any questions that you may have, Mr. Chairman.

Mr. HECHLER. Thank you, Mr. Dickieson.

When you refer to a second-generation or complete and more sophisticated Telstar satellite, what does that mean in terms of timing?

Mr. DICKIESON. Well, we have been considering what we would do if we were taking on the task of designing a Telstar-type satellite that might be used in an initial operating system.

And this would be somewhat larger and heavier, would have two amplifiers within it instead of just one, would be designed for operation at a higher altitude, and have some more effective antenna gain than we have in Telstar I.

The Telstar I, as you know, was tailored to fit the capability of the Thor-Delta rocket and was very acceptable as an experiment. But it is not the orbit or the kind of satellite that we would in fact use in an operational system.

Mr. HECHLER. I wasn't looking so much for your differences in the second generation as when you hope to achieve these perfections.

Mr. DICKIESON. Well, I would like to answer the technical side of that question, Mr. Chairman.

Mr. HECHLER. Yes.

Mr. DICKIESON. I believe that if we started designing such a satellite we could bring it to the hardware stage where we could start launching in approximately 2 or 3 years.

Mr. HECHLER. I think everyone has been heartened by the dramatic successes that Telstar has achieved since its first launching less than 3 months ago.

Have these successes exceeded your expectations and caused people to come in and expect things that you can't deliver?

Mr. DICKIESON. Well, as I pointed out in my statement, Mr. Chairman, the measurements of the satellite in space are very close to the measurements on the ground, or from what we had predicted on the ground.

So in that sense we are simply confirming our expectations.

Mr. HECHLER. Proceeding according to plan?

Mr. DICKIESON. Yes. On the other hand, one of the major objectives of any experiment is to find out whether something unexpected happens to you.

In that sense, I can say that nothing so far unexpected has happened to us. But I am not sure that I planned for that.

Mr. HECHLER. There has been a lot of discussion of both the cost and the complexity of the medium altitude ground stations that would have to be constructed.

I wonder if you would direct your remarks to this question: Do you think that they are unusually expensive or complex? Do you think you can handle them in an operational system with a reasonable amount of economy?

Mr. DICKIESON. As I pointed out in my statement, I think that we could now, with the knowledge we now have available to us as a result of experience we can simplify the kind of station that we have built at Andover, Maine, in an operating station.

It is a large and complex station. But so far as we can tell, it is an economical station for the very large traffic capacity that we would derive from it.

Now, of course, if you did not have the need for hundreds of telephone channels but perhaps for only a dozen, then, of course, you wouldn't need anything like as big a station.

You could use much smaller antennas. They would be easier to point. The whole station would be much simpler.

In fact, if your needs dropped down to where you were satisfied with only one telephone channel, as perhaps some military operations might be, then you could manage—and in fact we demonstrated in a somewhat crude experimental way recently to the military, that you could use quite small antennas, such that you could make them rapidly transportable by airplane or what not, and perhaps put them in some remote theater of operations, quickly.

I think I answered your question in a rather roundabout way by saying that if your needs are large then your station is going to be large and complex in keeping with it.

But if your needs are smaller, then you can make the station smaller and tailor it to your needs.

Mr. HECHLER. I am not going to ask you to comment on or try to contrast the high altitude versus the medium so far as its economy or complexity is concerned.

But as you know, one of the great arguments against the medium attitude is this sheer expense and complexity of the ground stations.

And you mentioned its feasibility for military use in remote regions. My question was more directed toward its possible commercial use.

Mr. DICKIESON. Well, Mr. Chairman, I guess I would like to answer your question in a roundabout way, if I may.

A lot of the discussion so far of this kind of thing has carried within it the implication that this world will have only one satellite communications system ever.

I think all the history of communications indicates that this is not sound. And in fact, as you know, the British Commonwealth nations are considering the possibility that they will have a system. Some of the other countries are talking about a joint effort to do the same.

I suppose, though I don't know, that Russia and its satellites may be considering the same kind of thing.

As I see it, the various systems will find their place depending on the strengths and weaknesses that they exhibit as they become closer to reality.

And it may well be, it wouldn't surprise me in the least, if in the long run we have half a dozen satellite systems, including both high altitude and low altitude systems, as part of our toolkit for supplying the communications of the world.

Mr. HECHLER. Well, are you against a high altitude, that is, the adoption of a high altitude system?

Mr. DICKIESON. No, sir. I guess I take the engineer's approach, sir. I am not for or against any kind of a piece of hardware.

I guess what I am saying, sir, is that I believe the high altitude system and the low altitude system are different. They have different strengths and different weaknesses and they will find different uses.

And I don't believe that this is a matter of one or the other, or black or white. I believe that they will find their place.

Now I believe that the low altitude system is nearer to fruition, that is, we are nearer ready to actually use it.

The high altitude system has problems still ahead of it, of actually launching the satellite and getting it into position and maintaining its position, and finding out what kind of a satellite is required to do that.

Now what its life and reliability and performance and cost will be, so far as I can see, is still not known and will not be known until it

really is attacked as an engineering job, of actually producing it. And until that time comes, I don't feel that I or anyone else is in a position to form a judgment one way or the other on these matters.

Mr. HECHLER. In the transmission yesterday of the Shirra flight by Telstar, you mentioned that there have been some fluttering or fading of the television pictures.

Is there any way that this could be improved, or what do you think caused this?

Mr. DICKIESON. I am informed by our people in the long lines department of the American Telephone & Telegraph Co. that this television tape—as you know the actual pictures were taken at one time at Cape Canaveral and then put on tape for later transmission.

Mr. HECHLER. Yes.

Mr. DICKIESON. I am informed that the tearing and breaking of the picture was a characteristic of the tape, and not of the transmission through Telstar.

In other words, the signal as it left the United States had these characteristics in it.

Mr. HECHLER. Well, that is another spectacular first, of course. And I wonder if you have any plans for other coverage in the future that you could tell us about.

Mr. DICKIESON. I am afraid I can't.

This is being handled by the long lines department of our company; that is, the operating part of my company.

My people now are concentrating simply on getting the satellite circuit going and what use is made of it we leave to our operating people.

There are a large number of test demonstrations and actual television uses planned ahead, but I am not really in position to answer that question.

Mr. HECHLER. Mr. Dickieson, I understand before you came to the committee this morning you talked to the lord mayor of London via Telstar. Can you tell us a little bit about that?

Mr. DICKIESON. Yes, I did.

I might first explain the occasion—there is going to be a conference in Boston, the Northeast Electronic Research and Engineering meeting. It is sponsored by the Institute of Radio Engineers and some of the other scientific groups. And they have some participation by their counterparts in England.

So, this was a three-way conversation in which there were several people in Boston, including the mayor, Mr. Collins of Boston, myself in Washington, and two or three people associated with this conference in Boston, and then on the other side of the ocean the lord mayor of London and Dr. Williams, who is head of the British counterpart of the Institute of Radio Engineers.

Everyone said a few appropriate words what could be used later in the actual ceremonies of the opening of this conference.

Mr. HECHLER. How did it go?

Mr. DICKIESON. It went very well.

The transmission was good. It was, shall we say, an unstructured three-way conversation, which was a little difficult to manage.

Mr. HECHLER. You don't have any problems as a high altitude system has with echo or feedback, do you?

Mr. DICKIESON. Well, the delay in a transmission path is of course dependent on the actual distance that the radio waves must traverse at the speed of light.

Since in this lower altitude system the distances are never more than perhaps—well, in Telstar I never more than about 5,000 miles to the satellite, we have less problem than you would in a higher altitude system where the distances are greater.

Mr. HECHLER. Mr. Dickieson, do you have anything further to add?

The committee will have to adjourn in a few minutes.

I wondered if there is anything further you would like to tell us about future plans or dreams with respect to Telstar?

Mr. DICKIESON. I don't know that I can add very much to my statement, Mr. Chairman.

Of course, I, like all other engineers in this field, hope that the satellite communications system will come to fruition, and quickly, because I think it is something that this country needs to improve its communications with the rest of the world.

I think that we are in a position to move ahead with it in fairly rapid order.

Mr. HECHLER. From your contact with developments to date, other than technical developments, do you have any recommendation as to how to speed this thing forward, or any way that the committee can be helpful to you in moving it forward?

Mr. DICKIESON. Well, I am not sure I do have any suggestions, Mr. Chairman.

I gather the immediate problem is to get this corporation in being, and I guess that is a matter for businessmen and lawyers to deal with. I don't think I can help that situation very much.

Mr. HECHLER. Mr. Boone.

Mr. BOONE. I would like to ask one question, if I may.

Mr. HECHLER. Yes.

Mr. BOONE. Mr. Dickieson, in your actual transmissions of the television program, did you find that the practice in accordance with the low incidence angle, was confirmed, or do you have to stay above say 5° or something like this?

Mr. DICKIESON. Yes.

Mr. BOONE. Were there any theoretical things that were either proved or disproved along this propagation line?

Mr. DICKIESON. Well, I think there was, Mr. Boone, in this sense.

As you point one of these very large antennas, of which you had a model here a little while ago—if you point it directly up, you see the very cold outer space and you pick up very little noise.

As you point it nearer and nearer to the earth you begin to pick up noise from the earth which is relatively warm.

So we had sort of expected we might have to limit ourselves to perhaps within $7\frac{1}{2}^\circ$ of the horizon.

I think now we feel we can go down to about 5° . And this gives us a little more usefulness of the satellite.

Mr. HECHLER. If there are no further questions, without objection, the biographical statement of Mr. Dickieson's background will be placed in the record.

(The biographical sketch is as follows:)

ALTON CONANT DICKIESON

Executive Director, Transmission Division, Bell Telephone Laboratories.

Mr. Dickieson has been associated with design and development of communications systems for nearly 40 years.

He began his business career in 1923 in the engineering department of Western Electric Co., which 2 years later, became the Bell Telephone Laboratories. In succeeding years Mr. Dickieson moved through various assignments in systems development work and in engineering of transmission systems.

During World War II he was in charge of development of communications systems for the Signal Corps. He also worked on acoustic torpedoes for the Navy and received the Naval Ordnance Development Award for this work.

Mr. Dickieson is a fellow of the Institute of Radio Engineers, and of the American Institute of Electrical Engineers. He is a member of the American Association for the Advancement of Science. He is chairman of the editorial board of the Bell System Technical Journal.

In September of this year he shared with Dr. John R. Pierce the H. H. Arnold Trophy of the Air Force Association as "Aerospace Men of the Year 1962." Their work on Telstar brought the award.

Mr. Dickieson is a native of New York City. Born August 16, 1905, he attended New York public schools and studied at Brooklyn Polytechnic Institute.

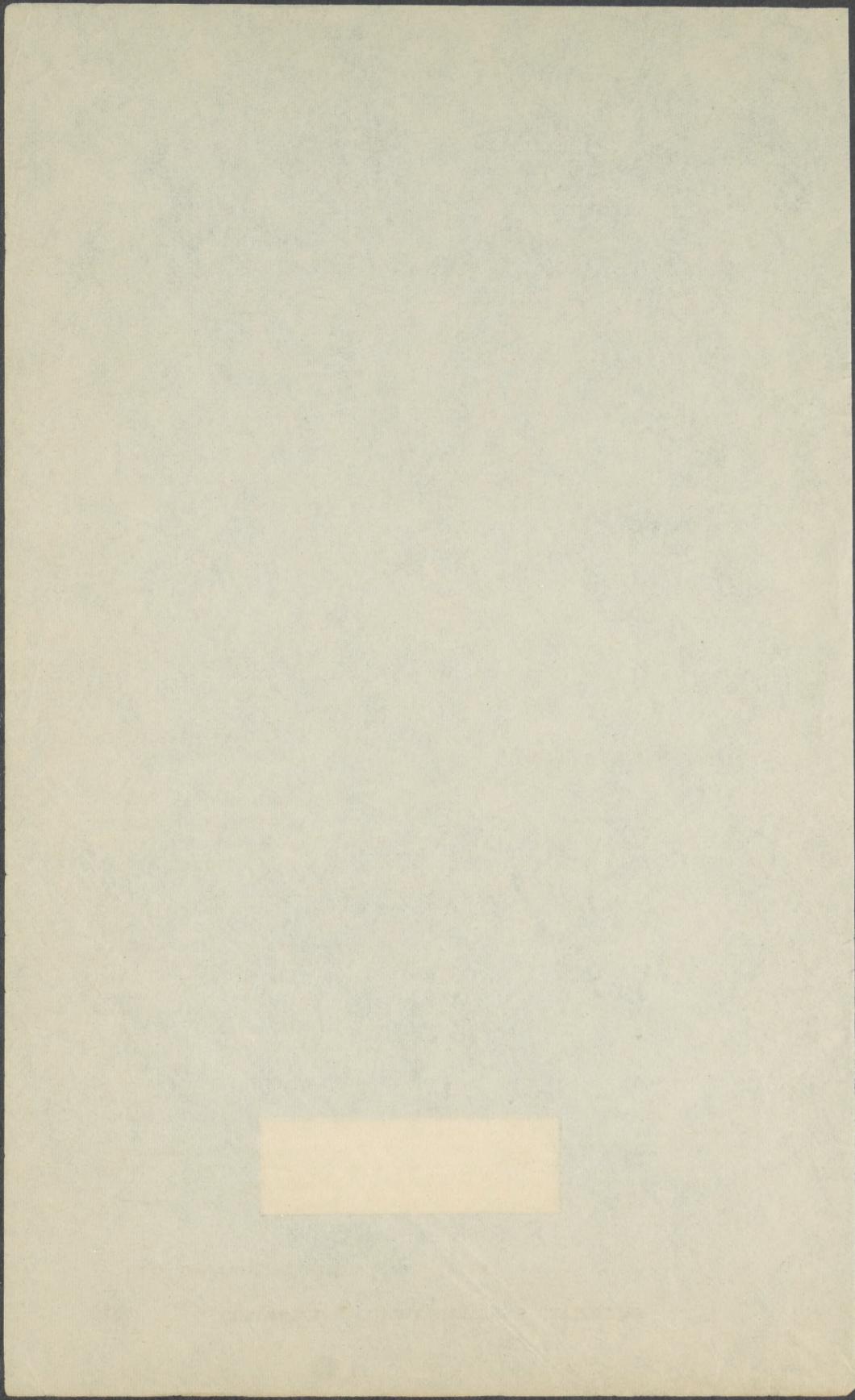
Mr. HECHLER. We want to thank you for coming up this morning and congratulate your company for the spectacular successes which your Telstar has achieved.

The committee stands adjourned.

Mr. DICKIESON. Thank you, sir.

(Whereupon, at 10:15 a.m., the committee adjourned to meet at the call of the Chair.)







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