SMC

Left side:
1. Committee on Science and Astronautics
2. U. S. Congress - Committee of the House

Right side:
1. Overton Brooks
2. Joseph Edward Karth
3. John W. McCormack

Pocket:
1. Committee on Science and Astronautics, Hearing
2. Committee on Science and Astronautics, Staff Study

TABLE III.—*Personnel manning requirements, Mercury worldwide tracking and communications network*

Site	M and O personnel	Organization responsible
Cape Canaveral	34	DOD-AMR.
Grand Bahama	4	Do.
Grand Turk	3	Do.
Bermuda	49	NASA-Contract.
Atlantic Ship	10	DOD-AMR.
Canary Islands	24	NASA-Contract.
Kano	20	Do.
Zanzibar	20	Do.
Indian Ocean Ship	10	DOD-AMR.
Muchea, Australia	26	WRE.[1]
Woomera, Australia	23	Do.
Canton Island	23	DOD-PMR.
Hawaii	27	Do.
West Mexico	26	NASA-Contract.
California	23	DOD-PMR.
White Sands	7	DOD-WSM.
Texas	23	Do.
Eglin	7	DOD-APGC.

[1] WRE—Weapons Research Establishment, Woomera, Australia.

The project has now crossed the threshold of a major flight test program of short- and long-range ballistic flights, leading first to unmanned, and later on to manned orbital flights late in 1961 if all goes well.

Project Mercury is being pursued with the greatest sense of urgency. This urgency stems from the fact that the project will supply answers to many questions that must be answered before one can proceed with the next step in the manned space flight program. Before future programs can go very far downstream, much must be learned about man's capabilities in space and about the general technology of manned space flight.

As mentioned previously, Mercury carries a national DX priority rating. But a DX priority rating alone does not assure that a project will move forward with great speed. The implementation of a project such as Mercury demands, on a continuing basis, boundless energy, enthusiasm, and determination. Work on Project Mercury, both at the contractor's facilities at St. Louis, Mo., and the Mercury facilities at Cape Canaveral, is proceeding on a three-shift, 7-day-a-week basis. All members of the Mercury team, be they in NASA, DOD, or in private industry, are making every effort to meet the goals established for them.

It must be recognized, however, that Project Mercury is a research and development program, and therefore, does not lend itself to the firm type of scheduling that typifies a production program. Instead, it is only possible to establish target dates with the full recognition that such target dates must be changed as new knowledge is gained or the complexity of the problems confronting the development become more clearly defined and schedules reoriented to overcome them. After all, if there were no problem to overcome, there would be no need for a research and development program.

In Project Mercury, target dates have been established for every facet of the operation. These include target dates for delivery of components, subsystems and complete capsules. Also included are target dates for capsule preparation sequences and launch periods

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INFLATABLE STRUCTURES IN SPACE

FRIDAY, MAY 19, 1961

House of Representatives,
Committee on Science and Astronautics,
Washington, D.C.

The committee met at 10 a.m., Hon. Overton Brooks (chairman) presiding.

The Chairman. The committee will come to order.

Mr. King. Mr. Chairman, could I mention that we have with us the distinguished Congressman from Minnesota, Mr. Albert Quie, who is here by virtue of the fact that Echo I was fabricated in Northfield, Minn., which is in the district of the gentleman from Minnesota.

I think the record should show that he is here as a visitor.

Mr. Hechler. I would like to join in welcoming my colleague, Mr. Quie, to the committee.

The Chairman. We are happy to have you this morning, Mr. Quie.

This morning we open a 1-day hearing on the matter of the potential uses, problems and funding, and research and development on "Inflatable Structures in Space."

We have a good many witnesses this morning. I think it is entirely proper that we follow the hearings that we have had by this one on "Inflatable Structures in Space."

We have, of course, our distinguished colleague. We want to hear from him in just a moment.

We have Mr. L. K. Loftin, Jr., Technical Assistant to the Director of the Langley Research Center of NASA; Mr. William J. O'Sullivan, Space Vehicle Group, Langley Research Center, NASA; Mr. Robert W. Richardson, vice president, Goodyear Aircraft Corp.; Dr. Robert S. Ross, Goodyear Aircraft Corp., and Mr. Robert T. Madden, Goodyear Aircraft Corp., also.

We are glad to have these gentlemen here with us this morning.

Mr. Quie, I know of your interest, because I just talked to you.

It is customary for the committee to hear the Members of Congress first. If you have a statement you would like to give us on this, we would be glad to have it at this time.

Following that, we will be glad to have you come up and sit with the committee and stay with us as long as you like.

Mr. Quie. Thank you, Mr. Brooks.

STATEMENT OF HON. ALBERT H. QUIE, A REPRESENTATIVE IN CONGRESS FROM THE FIRST DISTRICT OF THE STATE OF MINNESOTA

Mr. Quie. My name is Albert H. Quie, Congressman from the First District of Minnesota.

I appreciate the opportunity to appear before the committee.

I will have to decline from accepting your invitation to stay with you this morning, since our Education and Labor Committee is meeting and we have some problems confronting us there, as you so well know.

In Minnesota and in my congressional district we are indeed proud of the work that is being done by one company in Northfield. So often out in the Midwest—and I come from a little farming community next to Northfield, Minn.—we tend to think of space exploration that is being done some distance away, a long ways away, and people have wondered if they would see anything like that accomplished in their little community. We were indeed proud when the Schjeldahl Co. in Northfield, Minn., played such an important part in the construction of Echo I and now Echo II. The community is really enthused about what is being done. They feel the old pioneer spirit and their esprit de corps in these space endeavors would surely ignite one's faith in America; these people, no matter what their job is in the part of fabrication, are so enthusiastic that when called on they have been willing to practically work around the clock.

As we read of this person, Commander Shepard—people had kind of lost faith with the Americans, and he renewed their faith in themselves.

I think if you could come out there and see that company, too, you would have a renewed faith in the American people.

I feel inadequate, speaking here upon such a technical subject, because I have no technical experience, myself. For that reason I was glad I was able to speak first, because I would surely feel inadequate after hearing some of these other men like Mr. O'Sullivan, whom I have heard so much about, not only read about, since Mr. Schjeldahl speaks of him in glowing terms.

We in Minnesota and that area are indeed proud of the work being done.

At this time, I would like to include in the testimony a statement by Mr. G. T. Schjeldahl—the head of the G. T. Schjeldahl Co.:

Erectable and Inflatable Structures in Space

By G. T. Schjeldahl Co., Northfield, Minn., May 24, 1961

Having already ventured briefly into space, man is developing a host of vehicles and capsules to propel him and protect him as he soars into the interplanetary void. Highly complex rocket systems and compact and efficient space capsules will of course play the major role in helping man leave this Earth for parts unknown.

Yet man, as he plans for his most epic voyage, is turning his attention to the same spectacular device that enabled his predecessors to leave the ground some two centuries ago—the balloon and its modern counterpart, the inflatable satellite, or "satelloon."

THE INFLATABLE STRUCTURE IS ALREADY IN ORBIT

On August 12, 1960, the National Aeronautics and Space Administration shot into the heavens the largest volume satellite ever thrust into orbit—Echo I. This 100-foot diameter plastic sphere, designed and manufactured by the G. T. Schjeldahl Co. of Northfield, Minn., is still in orbit—a visible symbol of American creativity for all the world to see.

The Schjeldahl Co. is already at work on other space inflatables. These include the forthcoming Echo II on which successful inflation tests have been concluded by NASA, Langley Research Center, and Project Rebound in which several inflatable satellites will be launched in orbit from a single rocket carrier.

All these inflatable satelloons have a common ancestor—the balloon. But while the balloon is designed to go up and come down again within a very short period of time, the satelloon is so constructed that it will remain in orbit for extremely long periods—perhaps many years.

The inflatable satellite, such as Echo I and Echo II and other satellites developed by the Schjeldahl Co., must be precisely engineered and sealed by means of a super adhesive that will withstand the hostile environment of space. The Schjeldahl Co. has developed such an adhesive—called "Schjel-Bond 301," which has held Echo I together for nearly a year despite the ravages of extreme temperatures, radiation and low vacuum.

AN EFFICIENT AND ECONOMICAL DEVICE

The inflatable space satellite is an efficient and economical device that can be packed—uninflated—in a small canister, shot by rocket into space and then inflated to become a massive satellite, perhaps 100,000 times its uninflated volume. It can be prefabricated in an unlimited variety of shapes and sizes to perform specific functions, such as reflecting electronic signals, gathering solar energy, providing safe shelter for man in space and for storing gases and fuels in space.

Up to the present time, inflatable space structures have been used mainly to reflect electronic signals. Man's first space balloon, the Robin (*Ro*cket *B*alloon *In*strument), is a one-meter diameter Mylar sphere with a built-in corner reflector for ground radar tracking. Robin was designed, developed and built by the Schjeldahl Co. for meteorological purposes. More than 200 of these unique devices have been shot by the U.S. Air Force to altitudes of about 50 miles, inflated and allowed to drift back to Earth. The radar plots of their corner reflectors yield such meteorological information as wind direction, wind speed, air density and air temperature.

PASSIVE SATELLITES

Robin is an example of a "passive" communication satellite. "Active" communication satellites carry into space a radio receiver and transmitter so that they can receive signals from one point and relay them to another point. The active satellite must carry its own power or possess the means of deriving power from external sources. It has certain inherent disadvantages: (1) it cannot be repaired in space if something goes wrong and (2) its signal can be jammed.

The passive communications satellite is in effect one or a series of electronic "mirrors" in space which reflect signals beamed to it from the ground. Such signals, since they are beamed, cannot be jammed.

This Earth's only orbiting passive communication satellite is Echo I, launched by the National Aeronautics and Space Administration August 12, 1960, from Cape Canaveral and still circling the globe 1,000 miles out in space. Echo I was manufactured by the Schjeldahl Co.

Echo I's chief disadvantage as a passive communication device is the low ratio of power of the reflected signal to that of the projected signal. This low response is due to the fact that it is spherical. Although Echo I is 100 feet in diameter, the effective reflective "disc" is only a foot or so in diameter, because the surface of the satelloon is extremely shiny.

Echo II, 135 feet in diameter, which only recently was subjected to successful ground inflation tests at Weeksville, N.C., has a duller surface than Echo I and will present a much larger reflective surface and hence will provide a greater ratio of response to input signal.

ECHO II 50 TIMES STRONGER THAN ECHO I

This material in Echo II is 50 times more rigid than the material used in Echo I. It is a laminate consisting of two layers of aluminum foil only 18 hundred-thousandths of an inch thick bonded to a center sheet of Mylar 35 hundred-thousandths of an inch thick. The rigidized spheres will weigh about 500 pounds each.

When Echo II is inflated in space, the folds and wrinkles it receives as a result of packing will disappear. When the sphere is punctured by meteorites, releasing its inflation agent, it will not deform, for it will not "remember" the folds and wrinkles it incurred in its "fetal" position within the rocket's canister.

At the present time, the Schjeldahl Co. is working with the Goddard Space Flight Center of NASA in developing a 200-foot diameter inflatable plastic sphere for rebounding signals from one satellite to another. Goal of the project—called Rebound—is to produce a new light weight material that compares in strength to the material of Echo II. This will be accomplished by chemically "milling" out a pattern of circular "windows" from the aluminum, leaving the Mylar membrane intact. The network of aluminum arches remaining will preserve the rigidity with an accompanying—and desirable—reduction of weight amounting to about 30 percent.

SEVERAL SATELLOONS IN ONE ROCKET VEHICLE

Project Rebound will concentrate on placing three inflatable satellites in a circular orbit from one rocket vehicle. These will be spaced at predetermined intervals in order to test their effectiveness in bouncing radio signals from one satellite to another, thereby extending the range of radio wave propagation far beyond that of a single satellite, such as Echo I and Echo II.

Launching of the first three Rebound satellites is scheduled during the first quarter of 1963. A launching of six Rebound satellites from a single rocket to form a "string of beads" around the Earth will occur sometime in 1964.

In a move to increase the signal response and directionalize it, the Schjeldahl Co. is proposing through the Wright Air Development Division to create a new and different series of inflatable passive satellites. This new inflatable will be comparable to a chandelier in space, containing a multitude of small reflective units which will vastly increase the strength of the reflected signal. Moreover, by maintaining a specific attitude with respect to the Earth's surface as it orbits, the satellite will project a "cone" with signal strength maximum at the perimeter. Thus, a passive satellite in synchronous orbit—with its orbital speed the same as the Earth's daily rotation—would project its strongest signal to the horizon. Since synchronous orbits require high altitudes—approximately 22,500 miles—the "horizon" would be perhaps 6,000 miles away. Such a device would become a tactical nonjammable communications device.

INFLATABLES TO AID ACTIVE SATELLITES

The role of inflatables is by no means confined to passive satellites. They promise to be important to active satellites as well. Huge inflatable antennae, precisely constructed on the ground, will burgeon out in space to enable maximum propagation of the active satellite's signal.

The inflatable concept also will be applied in building all types of space structures. Present thinking at Langley Research Laboratories favors a "marriage" of inflatables and erectables so that combinations of rigid members can be folded into compact forms and "married" to an inflatable object in space. Such a method shows great promise in the problem of creating space stations in which men can survive the space environment. Similarly, inflatable components of various structural devices will be rocketed into space and inflated and rigidized. The economy and efficiency of such a method of erecting devices in space are obvious.

NEW MATERIALS BEING DEVELOPED

At the present time, the Schjeldahl Co. is conducting research in developing new materials to withstand the space environment for prolonged periods. These include combinations with mineral fibers that promise to be as strong as the strongest steels. Other investigations planned are for the development of plastic materials that will not burn—even in the searing blast of a plasma torch.

We believe that inflatables will assume a constantly increasing role in the unfolding drama of the space age. Their economy and their ratio of collapsed size to inflated size command their continued application.

LIMITLESS NUMBER OF MISSIONS

Leonard Jaffe, chief of NASA's communications satellite program, emphasizes that inflatables can be designed and constructed to perform an almost limitless number of missions.

"The feasibility of using a passive satellite as a communications reflector has been established," he says. "The fact that Echo I did not completely collapse upon loss of its internal pressurization material has indicated that the thin wall structure is almost structurally sound enough to withstand the space environment, and that only a nominal increase in rigidity will provide long-life structures."

APPENDIX A

The attached photographs pictorially illustrate a NASA/Langley Research Center conceptual design of an erectable space station. [The pictures in question were not of reproducible quality and have been placed on file.] Note the incorporation of an optimum combination of pneumatically and mechanically erectable segments. This combination incorporates the best advantages of each type component. The rigid sections contain all on-board apparatus. The pneumatically erectable sections made possible the deployment and interconnection of the rigid sections in a ready-to-use condition in a matter of minutes with no requirement to bolt together the parts.

As with project Echo, the G. T. Schjeldahl Co. is following carefully the evolvement of the research done in the Langley Laboratory. Development of materials with which to accompiish this task is an area where GTSCo will make a contribution. Fabrication techniques to translate the concept into an actual test vehicle are under study by the company.

This is an excellent example of the close teamwork between industry and the government-sponsored laboratories, which should lead us forward in man's conquest of space.

The CHAIRMAN. That was a great achievement. I think the people of Northfield should feel justified pride in their contribution to this major accomplishment in space.

We are happy to have you here this morning, and we will give your statement our careful consideration.

Mr. QUIE. Thank you.

The CHAIRMAN. The next witness we have this morning is Mr. L. K. Loftin, Jr., Technical Assistant to the Director of Langley Research Center, NASA.

Mr. Loftin, do you have a prepared statement?

Mr. LOFTIN. No, sir.

The CHAIRMAN. You came up to testify on this subject. So I am sure you are familiar with it. We will be glad to have whatever statement you care to give the committee on this subject.

Mr. LOFTIN. I only learned yesterday morning that I would be expected to discuss inflatable structures today, so I have no prepared statement, and I must apologize for not having any large charts which you can see. I do have some proofs which I might pass around. [NOTE.—The committee placed its request with NASA six days before the scheduled day of the hearing.]

STATEMENT OF L. K. LOFTIN, JR., TECHNICAL ASSISTANT TO THE DIRECTOR OF LANGLEY RESEARCH CENTER, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. LOFTIN. In speaking of inflatable structures, I think it might be appropriate first to point out why it is we should be interested in these things, anyway.

Basically, there are two reasons:

First of all, it takes many, many pounds of propellant to put one pound of payload in orbit. We all know this. So that anything we can do to make the payload light is all to the good. This is one reason that we are interested in inflatables.

Another reason, which is perhaps not quite so well understood, is this: There are many applications in space for which we would like to have a craft in orbit which is large in volume, such as a space station, or large in area, such as a passive communications satellite. However, when one looks at the launch problem, it becomes obvious that a very real difficulty exists in trying to mount a very large payload on the end of a rocket. This difficulty is associated with the fact that the rocket must go through the atmosphere before it reaches orbit, and with this very large area on the front, we encounter an aerodynamic instability which is quite large, depending on the size of the thing we put on. You can, of course, lick this by putting on fins or something of this sort, but this is heavy. Even more importantly, even if you put the fins on, you are encountering very large bending moments in the missile, itself, so it has to be redesigned.

So that, in a nut shell, what we want to do for these large payloads is to squeeze them down into a small package on top of the boost vehicle, get it into orbit, and then in some fashion allow it to blossom into its desired shape.

There have been many applications proposed for inflatable vehicles. Perhaps I should really say erectable for one can have such vehicles either by inflation or by some means of mechanical erection or some combination thereof. This is really what we are talking about.

Things such as communication satellites, solar collectors, corner reflectors of one sort or another, reentry vehicles, space stations, have been proposed to employ inflatable-type structures or erectable structures. Rather than go through the many applications that one might conceive of, in which an erectable structure would be applicable, I thought you might find it of some interest if we would discuss with you some of the specific work which the NASA has done on inflatable, erectable structures.

First, I would like to describe to you briefly some of the exploratory research which we have done at Langley Research Center, aimed at an attempt to find and clarify some of the problems which one would have to overcome in applying the erectable concept to a manned vehicle. We have not been developing a manned vehicle. As I say, we have been studying what we would consider to be salient or pertinent problems which would have to be solved.

Secondly, Mr. O'Sullivan, who is sitting on my right here, will discuss with you some of the work which we have done and some of the experience which we have had in actually applying the erectable technique to unmanned space vehicles such as Echo.

To talk now about the manned space station, we at Langley started thinking about the use of inflatables for such a vehicle about 2 years ago. In order to try to fix what the problem areas were that we should be looking at, it was necessary to arrive at some sort of a concept of what the vehicle might look like.

I have some photographs here of an early version. These pictures were—this model was designed and constructed not as a proposal for a space vehicle, as I say, but rather to permit us to fix on what kind of problems you would run into with something like this and what studies we should make.

If I could pass these around. They are in sequence. They start by showing what the vehicle would look like on top of the rocket. Then as you pass down the group of pictures you will see this craft slowly blossoming out. The toroidal shape, which is in the form of sausage links in this case, would be the living quarters of the crew.

The apparatus which looks like an umbrella is a solar collector, which would supply power to the power plant.

The various other pieces of apparatus on there are sun seekers, star seekers, various guidance and stabilization systems.

In looking at this there were several problems that were apparent to us that we should study. One of the most obvious ones was that of the material, itself, that we can construct this toroid out of. It has to withstand the space environment. This means that it will be subjected to various type of radiation. It will be subjected to high vacuum. It will be subjected to temperature cycling, and we don't know the effects of these phenomena on the material as to its brittleness; does it become brittle with time? Does it tend to evaporate or boil away? We don't know what the micrometeorite problem is here. We don't want to puncture this thing. Finally, we did not want a material which would outgas in such a way as to provide poisonous or noxious odors inside.

We undertook a study of material properities. The Goodyear Aircraft Co. undertook a set cf studies. They provided us with some samples, and we more or less worked in cooperation on this. At the present time we have subjected many samples of materials to a vacuum environment which is about 10^{-6} of mercury. We have subjected it to radiation, and to temperatures up to about 300 degrees, Fahrenheit.

The things we have found out are these: We have found materials that do deteriorate, which one would not use for such application. On the other hand there are other materials one can use. What it boils down to is the material problem is not a critical one in the sense that it does not require any fundamental technological breakthrough. I think we can find the material. We may have to search some. But it looks like something we can do.

With regard to the micrometeorite problem, we haven't done too much on this. We are making some experiments now. In that connection I would like to show you another group of pictures here of a somewhat different concept of an orbital space station which involves some inflatable elements and some mechanically erectable elements.

As you look at this sequence, I think you will see that what this really is is a series of cams that are actually rigid. These unfold and are connected by inflatable components. This system has a number of advantages. One of these is that large portions of this erectable structure are in fact rigid and can be protected from micrometeorites. It is not an unusual problem. So you could put air-lock-type doors at the ends of these compartments and close them up. And then when you wanted to go around this toroid you could open them and go through the inflated portions. This is another concept of the way one might do it.

I have a couple of samples of the kinds of materials that we have studied. They actually look pretty much like pieces of rubber. These I believe were provided by Goodyear. They are three-ply with nylon cords, and they have a butyl elastomer—this is the rubber-like mateial that sticks it together. It weighs about six-tenths of a pound per square foot.

Talking about these materials, another area which we have looked into and are looking into is that of how best should you make the inflatable portion of the vehicle. One way of doing it is to make plies of material very much like this, three-ply material. Another way of doing it is to make a sort of network-like cage and inflate the rubber portion within it.. But there are other ways, too. We at present have some studies underway under a contract of a technique or a concept which is referred to by the name of Isotensoid. I don't know who really cooked this name up. It is a different way of putting the cords in and reputedly this system would allow you to develop a strength, the required strength for a much lower weight. Whether it will in fact turn out this way we don't really know. We have a model which has been built and which we are going to do studies on to determine whether there is really anything in this method of construction.

Another area we have looked at is that of dynamics. If one rotates one of these space stations to provide artificial gravity, which may or may not be required, then there is an interesting dynamics problem. We have done analytical studies using analog computers and things of this nature, in which we put in effect masses representing men in different parts of the vehicle, and although they have no weight in orbit, they do have mass. When a man walks from one part of the vehicle to another, he changes the mass distribution. The analog computer study shows that one can then experience some wobbling motion, various types of perturbations of the vehicle. We have done some work on what is called a wobble damper, a possible scheme for getting around this problem. Perhaps more importantly, we are looking to see whether there is really a problem. We have built a 10-foot diameter elastically scaled model of this craft. For such a model the mass distribution is correct. It has the correct stress characteristics, and you would put the correct pressure in it. We intend to rotate it on a free mount with diffeent distributions of mass within the vehicle to determine what the motions are and to determine the coupling between the overall body motions of the vehicle and any vibration modes which may develop in the inflatable structure, itself. This model has just been completed. We should get underway with this fairly soon.

Another model which is under design deals with the thermal balance of the vehicle. You have the vehicle in orbit with the Sun on one side, the reflection from the Earth on the other side; you have power plants and things of that nature in it. There is a question of what is the temperature distribution in this vehicle and how do we have to paint it. Do we make it black so it absorbs radiation or do we make it silver to reflect and in what proportions and this sort of thing, to obtain an environment within the vehicle which is suitable not only for the occupants but also for the equipment which we are required to operate.

This is a model which is under design. It is not a terribly easy model to design because of the scaling laws, but we are working on this.

One further type of model, and this is a fairly large one—it is 24 feet in diameter—is being constructed for us by Goodyear. This is a mutual arrangement. I believe we are funding about half of it and Goodyear about half of it. This again is a research model. What we hope to do there is to learn something about how you package one of these things. You talk about squeezing it into a small bundle, but you don't just pick up and squeeze it. It has to be done in a fairly exact way.

for all flight tests. As is always the case in a complex research and development program, some of these target dates have been met ahead of schedule, others on schedule and some behind schedule. Setbacks in the flight test qualification program have become apparent and should come as no surprise since this is the most critical point in any development program. All of the major missile and aircraft programs have experienced them. This is a natural result of the bringing together into an integrated system all of the many new developments which go into the makeup of the project. The proof of the design is in the flight test program, and target dates are not predicated upon failure, but upon success.

Perhaps the most important target date in the overall Mercury schedule is that for achievement of manned orbital flight. Dr. Dryden, Deputy Administrator of NASA, in congressional testimony in 1958, implied that this mission could be accomplished sometime in 1961. If no setbacks are encountered during the flight qualification program, it is possible that this target date may be met. However, as stated earlier in this report, the critical period in the flight test program is just now upon us, and Dr. Dryden's statement must be considered as a project target goal to be strived for and not a hard statement of fact.

Department of Defense support of Project Mercury

The Department of Defense provides a very broad range of support to Project Mercury. The Air Force Ballistic Missiles Division supplies and launches Atlas vehicles. The Air Force also provides air rescue service aircraft for capsule search and recovery operations, mapmaking services of the Aeronautical Chart Information Center, the loan of aircraft for network station checkout, and astronaut normal flight and zero-g training, Atlantic Missile Range launch facilities, control center facilities, medical support at Cape Canaveral and remote stations, and the use of existing network facilities and manpower at several Mercury network stations. The Aerospace Medical Center of the Air Force has also given assistance in astronaut training and has supplied animal test packages for use during the Mercury flight test program.

The Army has loaned tracking equipment to NASA, has made White Sands Missile Range ground facilities available for network use, and will provide a substantial share of DOD medical support to Project Mercury; has supplied communications equipment and amphibious vehicles for use in possible launch site recovery operations. The Army Redstone launch vehicle will be used for unmanned and manned ballistic flights.

The Navy has been given and accepted the responsibility for the Mercury spacecraft recovery operations. The Navy recovery commander will have elements of the Atlantic Fleet and Air Rescue Service at his command for effecting rapid recovery of the capsule. Destroyers, landing ships, dock, miscellaneous service vessels, Marine helicopters, patrol aircraft, and early warning aircraft will all be utilized for search and recovery operations.

The Navy is also providing assistance in the construction of the Canton Island network station, has loaned commander transmitter equipment to NASA, and has given a number of tracking radars to NASA.

To give you an idea of what I am talking about, I again have some photographs.

This is a small model that we made, which shows it fully inflated, and then the various sequences that you must put the thing through in finally folding it up into a small package.

When we get this rather large model, this is the kind of work which we will be doing with it.

There are also some other questions of internal arrangement, and so on.

To summarize our feeling on this, I think we can say something like this:

So far as we know, so far as we have gone at the present time, we don't see that there is required any fundamental scientific breakthroughs that are required in order to design one of these things. However, we have not undertaken at the Langley Research Center a detailed engineering research design study. If such a study were undertaken, you might run into some problems that we haven't been smart enough to think about that are fundamental. I don't know if you would, but you could.

In such a careful engineering design, this is a long-term proposition. We are not really sure when you got all done whether you would have something you really want or not. This is something that can only be found by a careful developmental design.

I think this is about the status of our feeling on it at this time.

This concludes what I have to say about space stations.

Mr. O'Sullivan can talk to you some about the actual experience we have had in developing actual inflatable satellites, two of which are now in orbit.

The CHAIRMAN. To save time, we will hear from you at this time, Mr. O'Sullivan.

After that we would like to ask both of you questions.

STATEMENT OF WILLIAM J. O'SULLIVAN, SPACE VEHICLE GROUP, LANGLEY RESEARCH CENTER, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. O'SULLIVAN. I, too, must apologize for not having time to what I consider adequately prepare for this hearing, because yesterday I was at Weeksville, N.C., participating in a structural test upon what we hope will in time become the Echo II satellite, which would be a prototype of an operational version, rigidized operational version of a long-range communications satellite of the passive type.

I came by the laboratory and I picked up some samples yesterday of the materials that we are employing in connection with this rigidized version of the communications satellite, because they illustrate some of the problems that we are faced with in trying to build erectable structures that can survive the environment of space. These samples I believe will illustrate ways in which we have found solutions to these problems.

I have here some photographs, which unfortunately are not large because they were taken yesterday with a Polaroid camera, and I brought them with me in my pocket, showing the test of the Echo II satellite.

I will pass these around.

This satellite is 135 feet in diameter. The test that we were performing was for the purpose of proving that structurally it is strong enough to withstand being pneumatically erected after being transported into space, and we were quite fortunate in proving that.

We have designed it such that it will encounter, due to the internal pressure used to inflate it, a stress within its skin of approximately 4,000 pounds per square inch. We inflated the satellite to a pressure such as to produce this stress within the skin, and we held it there yesterday for $4\frac{1}{2}$ hours without even the faintest sign of failure.

To determine the factor of safety that we have in the design, we then increased the pressure inside of the satellite until we reached the point of rupture of the satellite. We found that it ruptured yesterday at a skin stress of 18,000 pounds per square inch. This means that we have a factor of safety of four and one-half. The satellite is capable of withstanding a pressure four and one-half times that which will be the maximum required for inflating it in orbit.

I have here some material of which this satellite is constructed. It has been made of a laminate that consists of a plastic film whose thickness is .35 mil, that is, .35 thousandths of an inch thick.

Into each side of this has been bonded an aluminum foil of two-tenths of a mil thick. This gives a three-ply laminate.

This concept of a material which could be compactly folded for transport into orbit and there pneumatically erected to shape is one of our ideas that we developed in the NASA of how we can build this erectable structure.

I would like to pass some samples of this material around.

This illustrates one of the ways of solving the space environment problems.

Let's consider first the problem of compactly folding and transporting into orbit.

We can fold this satellite, which is 135 feet in diameter, into an approximately spherical container which is only about 40 inches in diameter, transport it up through the Earth's atmosphere and there erect it after it has gotten into space. This avoids the first problem that Mr. Loftin mentioned, namely, the problem of the stability of our launching vehicles. If we have a great big object, we can not place it on the front end of the launching vehicle because it causes aerodynamic instability. The concept of having an erectable structure overcomes this difficulty.

The next problem that we have to face in space, after it has been pneumatically erected, is the problem of rigidization, in the case of the communications satellite.

Here in the case of a space station we are faced with some such problem as that, too. The problem comes about because of the cosmic dust which will undoubtedly cause puncturing of our space station or our satellite.

In the case of this Echo II satellite, the skin has been made sufficiently stiff and rigid so that once it has been drawn out and set into spherical shape, we no longer require the internal pressure to hold it spherical. It can be punctured by micrometeorites and it will not change its shape; it will not collapse. We know this is so from our tests.

In the case of the Echo I satellite, which is now in orbit around the Earth, we designed it not as a rigid structure but merely as one which was to last a short time, retaining its spherical shape by means of an internal pressure. We believe that it lost its internal pressure approximately two to three weeks after it was placed in orbit. Yet it has not greatly changed its shape. It is still essentially spherical. This is because the forces that tend to deform it are quite small and because even the skin of the Echo I satellite is almost sufficiently stiff to retain its spherical shape.

With the skin that we are employing on this larger Echo II satellite we are quite confident it will retain the desired shape so it is a good high quality communications satellite.

We think the same concept of a material that can be folded for transporting into orbit and then stretched out pneumatically, set into shape, can be employed with regard to space stations. The problem of protecting the material against a harsh environment of space is also accomplishable in this manner with such material as this.

We know, as Mr. Loftin has mentioned, many materials in the very hard vacuum of space will evaporate. In the case of the samples that we have passed out we have aluminum foil on each side of the plastic film. This forms an excellent vapor barrier so that the plastic can not evaporate.

We can also by choice of the plastic material select those which have large molecules and by the treatment of polymerization, make the large sections of the vehicle into what the polymer chemists would call one very large molecule. The importance of that is this:

The material evaporates in space only by virtue of its vapor pressure, that is, the pressure of the gas that it generates as it evaporates. The larger the molecule we employ, the lower the vapor pressure at any given temperature. By this process of polymerization we can produce molecules not of the ordinary size that we encounter in chemistry but of sizes tens and hundreds of thousands of times bigger. Their vapor pressure becomes so fantasticly low that we do not have instruments capable of measuring it.

This prevents also evaporation in space.

To protect against ultraviolet radiation we have run tests which tell us that by employing a very thin metal covering over our materials, we can shut out the ultraviolet radiation. We have subjected polymers to a radiation under ultraviolet lamps for long periods of time. We find that without such protection as this they do degenerate in time and become somewhat embrittled. By the simple process of using a thin metal foil we can prevent this.

With regard to the problem of thermal balance, we have in our research discovered that we can put layers, coatings, on this material which are so thin that they have the thickness of only a few molecules. Yet we can by this process adjust the ratio of the absorbtivity of the surface such that we can bring the temperature balance of our satellites or space stations to that which will not be too hot nor too cold, and the materials will survive in space, virtually indefinitely.

There are a number of other problems that we have found solutions to in this manner. I would like to point out the facilities of the NASA are as yet too few and meager in number to be able to carry out all the basic ideas of how to build space stations or satellites that we have been able to discover. We have been compelled to call on industry to follow out the exploration of these ideas, and recently we placed a contract with the Hughes Aircraft Co. to investigate approximately a dozen concepts of producing rigidized materials in space that could be compactly folded, transported into orbit and there caused, after erection, to shape, to become rigid.

This exploratory work has resulted in some very promising, although not yet ready for use materials, and this gives us great hope in this field.

In this field further work is required.

I think that Mr. Loftin is quite correct in stating that we have not as yet encountered any fundamental barrier to the ability to produce long lifetime satellites or space stations; that, however, there is a considerable amount of engineering work required in order to translate this exploratory research that has been done in the laboratories into actual usable hardware or materials, fabrication of materials that would be suitable for employment in space stations.

I thank you gentlemen.

If I could answer any questions that may have come to your mind, I would be delighted to do so.

The CHAIRMAN. Thank you very much.

I think we all have a good many questions. I would like to ask you this, for instance:

A man in one of those stations goes up in the capsule, doesn't he? How do you get him from the capsule to that circular station?

Mr. LOFTIN. There has to be a passageway, a really inflatable passageway that would lead from the capsule into the toroidal portion of the space station.

I didn't make this clear. The toroidal space station does not reenter the atmosphere. When the crew gets ready to come home, they go back through the passageway into the capsule, close up to the capsule, disengage from the toroid and leave that in orbit and reenter the capsule. The toroid itself is not suitable for a reentry-type vehicle.

The CHAIRMAN. You are just going to allow that to float around in space?

Mr. LOFTIN. This is one possibility.

Another thing you might do, depending on what size of operation you are talking about, is to develop the capability of rendezvousing what you might call a space ferry, a reentry-type vehicle, with the space vehicles, so that as one capsule left to take one crew home, another one could come up, perform a rendevous maneuver and transfer a new crew in. This is a much more sophisticated-type operation. Ultimately something like this could perhaps be worked out.

The CHAIRMAN. You state the body up there in space will not have weight; that they will have mass. What effect will the mass have on the materials which you use for the station?

Mr. LOFTIN. I think the thing we have to worry about with regard to mass, as I pointed out, is the dynamics of the situation, that is, when this thing rotates and you move mass from this part to this part, you are changing the center of gravity—this is a bad word to use because we don't talk about gravity up there—you are changing the center of mass of the station so it will tend perhaps to rotate around a new center or oscillate in some way. I think this is the context in which we need to talk about mass.

It doesn't really affect the materials except perhaps in this way: If the man in some way propels himself from one side of the station to the other, propels himself hard enough, we want this material to be strong enough so he doesn't break through and go out on the other side.

The CHAIRMAN. He still has momentum?

Mr. LOFTIN. Yes, sir.

The CHAIRMAN. To offset the momentum, you have to have a material sturdy enough to resist it?

Mr. LOFTIN. That is correct.

The CHAIRMAN. You will substitute for the gravity the use of centrifugal force?

Mr. LOFTIN. This is a possibility. We don't really know whether this is necessary. If in future manned space operations it is found desirable to have some simulation of gravity, although perhaps not the full one g, perhaps a quarter of a g, it would be possible to rotate this thing such that the centrifugal force would simulate, as far as the man knows, the effect of gravity. You would have to be a little careful about this. There are some effects—as I understand it, and I am not too familiar with this subject—on the inner ear that come into play if the radius of the space station is too small and it rotates at too high an rpm, there are some secondary effects that are supposed to occur which can result in nausea or something of this nature.

The CHAIRMAN. Like seasickness?

Mr. LOFTIN. Yes.

I am certainly not a medical expert, so I don't think I can speak with much authority on this.

The CHAIRMAN. Any questions?

Mr. KARTH. What would the primary function of this so-called space station be?

Mr. LOFTIN. It could have many functions. We are not really proposing a space station. What we are doing here is saying if you want one, we would like to look into the problems of how you might make it. If you ask the question, though, what could you do with it, there are a few ideas that come to mind.

For example, if ultimately we want to send a man on a long space journey that takes weeks at a time, such as journeys of such a nature that once he is committed to this, once the rocket is finally burned out, he is going to make that journey and he can't come back until he has gone around to where he is going to go and then he is going to come back, before we do this, one might say it would be desirable to have a space station in orbit where we could put men, materials, different kinds of mechanisms, we could put them up there for weeks at a time and see if there are any undesirable effects that we have not foreseen. If these effects crop up, then you bring the man back. You could get him back from there. This is one possibility, one way in which you could use this.

Mr. KARTH. You are talking about long distance space flights then, much longer than from here to the Moon?

Mr. LOFTIN. Yes. You might even call it a space laboratory.

Suppose you wanted to know the effect of long-term space exposure on certain kinds of materials. We can simulate it only to a certain

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extent on Earth. It would be nice to go up in the environment you are going to have to be in to do your experiments.

Mr. KARTH. Are we proceeding with the actual construction of a vehicle of this type?

Mr. LOFTIN. No, sir.

Mr. KARTH. Do you have any plans?

Mr. LOFTIN. We at Langley have been studying this particular concept as a research problem to try to see what the problems are. If a space station is a thing that is desired, then I think this concept as well as other concepts should be subjected to the most careful engineering evaluation to determine which way in fact do you really want to do this job. This is one way of doing it.

Mr. KARTH. Could it have any communications capability?

Mr. LOFTIN. Yes, I suppose scientific observations of some sort. Perhaps a telescope or something of this nature. There are various missions that one can think of that would make desirable a station in orbit around the Earth. The question of how you build this station, whether you use an inflatable or erectable technique or use some other technique, depends on what you want the station to do, how big it is going to be, and a detailed engineering study of the thing. You can't just, on the basis of some research explorations of particular problems, say this is really the thing you want. It has to be subjected to a very detailed engineering evaluation of various concepts.

Mr. KARTH. We are talking about something that is in its very infancy of research?

Mr. LOFTIN. It has only been in the past two years that we have worked on this concept. I believe the kind of thing that Mr. O'Sullivan talks about, the communications satellite, and so on, I believe that goes back maybe five years, something like this, is that right?

Mr. O'SULLIVAN. Yes.

Mr. KARTH. Let's talk about this big inflatable balloon that you passed the picture around on.

This would be a passive communications satellite, is that correct?

Mr. O'SULLIVAN. That is correct. It would be a prototype of an operational version, in that it is designed to be capable of withstanding the space environment for a period of 5 to 10 years.

I might suggest, since you asked the question, could a manned space station be of value with respect to, say, communications, I think it definitely could.

One of the studies that we have made at our research center has been a comparison between passive and active communications satellites. It is quite readily shown if you can postulate that the tubes and all the components of a receiver and of a re-transmitter could continue to operate for a period of 5 or 10 years without attendance, then it would be very desirable to have an active type of communications satellite.

I would like to recall that I believe 15 to 20 years of research was required before it was possible to have amplifiers of sufficient reliability that it was practical to put them in trans-Atlantic cables where they couldn't be readily hauled up and serviced. This is somewhat the situation that we are in at the present moment with respect to communications satellites. I think that you can show that definitely there would be great advantages to an active type of satellite, that is, the kind that receives the signal and re-transmits it.

Mr. KARTH. How much work has——

Mr. O'SULLIVAN. The problem is that we do not yet know how to build sufficiently reliable components, and we cannot be certain that the environment to which we subject them here on the ground is the same that they will encounter in space.

A space station might be employed in part as a research tool for the development of active communications satellites.

Mr. KARTH. From what you say, I assume NASA has made, shall we say, baby steps in the direction of active comunications satellites systems?

Mr. O'SULLIVAN. Yes. We are pursuing that.

Mr. KARTH. You are very much in the state of infancy? The reason I ask is because some of the groups of the comunications industry who have been before the committee have indicated that they have the capability to go ahead and construct an active communications satellite and have it in orbit on an experimental basis within a year.

Would you care to comment on that?

Mr. O'SULLIVAN. I think we can put up an active communications satellite in a period of a year or two that would be quite serviceable with respect to research on how to build one that would have the capability of lasting for a period of 5 to 10 years. I think if we go into the economics of the matter, it is necessary to have satellites that do not have to be serviced over a period of, say, 5 years.

Mr. KARTH. When you say "we" could do this in a year or two, do you mean NASA or industry or a combination?

Mr. O'SULLIVAN. A good combination of NASA and the industry.

I think we have many good ideas that could be contributed to the matter that would be of great assistance, and I think industry does, too.

Mr. KARTH. If NASA worked on an active communications satellite system with the idea that they were going to themselves do the job, how long would it take NASA to, shall we say, develop an active communications satellite system?

Mr. O'SULLIVAN. I think that is a very difficult question to answer, because we do not know what are the problems that we are going to face in trying to make one that is sufficiently reliable that it is worth being placed in orbit on a commercial basis.

That is the reason why we have pursued first the passive satellite, because we could see our way clear to making something that had the capability of lasting 5 to 10 years in orbit without service.

You know, it is a bit difficult to get up there and put in a new tube when one burns out. But in time this will be accomplished.

One of the reasons that it is quite important to do so is because, for example, if we wish to have television communications, then we must have a quite wide band width, as we call it technically, in order to be able to transmit our pictures. This means——

Mr. KARTH. This can not be done by a passive satellite system, can it?

Mr. O'SULLIVAN. It could be done with a passive satellite system where it is large enough in diameter and where the transmitter on the ground is sufficiently powerful and the receiver at the other end of the link is sufficiently sensitive.

Mr. KARTH. Is this a capability that you see in Echo II, for example?

Mr. O'SULLIVAN. I think in Echo II, on the basis of our tests of Echo I, we will be able to perform what I would class as initial steps in television communications by means of the Echo II satellite because of its larger size and the lower altitude at which we will fire it.

Mr. KARTH. What would that altitude be?

Mr. O'SULLIVAN. We have tentatively in mind an altitude of approximately 700 miles.

Mr. KARTH. We have capable boosters, we have boosters capable of achieving this right now?

Mr. O'SULLIVAN. Yes.

Mr. KARTH. What booster would be used?

Mr. O'SULLIVAN. We tentatively have scheduled for the orbital launching the Thor-Agena B vehicle.

Mr. KARTH. Thank you.

The CHAIRMAN. Further questions?

Mr. VAN PELT. With reference to Echo I and what you have said about the debris that is in outer space that might puncture a vehicle, how long will Echo I withstand that? Is there a possibility of complete disintegration?

Mr. O'SULLIVAN. No. Echo I will not disintegrate in orbit. It was designed for research on communications to confirm or disprove that we could do what we thought was theoretically possible, namely, send a signal from the surface of the Earth up through the Earth's ionosphere to a satellite in space, reflect it off this satellite, back through the Earth's ionosphere and receive it and have a signal which did not fade out, did not undergo polarization or have other things happen to it which would destroy its usefulness. This was proven with Echo I. Since that was its purpose, it was designed only to last in orbit a sufficient length of time to accomplish this research objective. As such, it was not designed as a permanent satellite but one that was held spherical and a good reflector of radio signals merely by retention of its internal pressure. We calculate it was punctured at the rate of about 1.4 square inches of hole area in it each day due to the micrometeorites that impinge upon it. This caused the loss of its internal gas that inflated it and held it drawn out into a nice, smooth sphere. Our measurements of the radar cross-section of it indicate it retained its spherical shape nicely for a period of about 2 weeks.

Our second step now with Echo II is the building and verifying that we can build a satellite which is not dependent on the retention of its internal pressure for maintaining itself as a good reflector of radio signals. We think that Echo II, on the basis of our present knowledge, should have the capability of lasting in space for a period of between 5 and 10 years. However, the orbit that we plan to put it in will not cause it to remain in orbit that long because of the minute amount of aerodynamic resistance that it encounters. This will bring it down much sooner than any 5 to 10 years.

The reason for not using a higher orbit is because we would have to employ a much larger satellite than 135 feet in diameter if we were to conduct television—exploratory television communication tests over a distance, say, as great as across the Atlantic Ocean. If we were to put the Echo II into an orbit, say, as high as 2 to

3,000 miles, then it would definitely last, I am quite sure, 5 to 10 years as a good reflector of radio signals.

Mrs. WEIS. Didn't Echo I stay up longer than you anticipated it would, Mr. O'Sullivan?

Mr. O'SULLIVAN. It will stay in orbit, I think, approximately another year, but it is not the high-quality reflector of radio signals that it was when we first put it up.

Mrs. WEIS. Is it useful at all?

Mr. O'SULLIVAN. Yes, it is still quite useful. We are very happy about that. It has proven much better than we really anticipated. We thought by now it would have degenerated quite badly, but it seems to be withstanding the space environment much better than we had anticipated.

Mrs. WEIS. That was my impression, that it had functioned better.

Is there any instrumentation on this or is it simply the globe? Is this purely a reflecting operation?

Mr. O'SULLIVAN. It is purely a reflecting operation, just like a mirror. One of the great advantages of that over, say, an active communications satellite is that the mirror does not care how many signals bounce off it, what their frequencies are, what language is employed, or what the band width is. It reflects them all just as well. There is no maintenance.

Mrs. WEIS. It has no instrumentation or other things?

Mr. O'SULLIVAN. That is right. The only instrumentation that is aboard the Echo I satellite were two radio tracking beacons. These had nothing to do with the communications. They did not receive any signals and retransmit them. They were merely markers, beacons, so that we could track the satellite by means of the Minitrack system, so we would know where it is.

Mrs. WEIS. Are those outside?

Mr. O'SULLIVAN. They are mounted on the skin of the satellite.

Mrs. WEIS. I was interested in this model on display.

The CHAIRMAN. That is the Goodyear. That is what I am going to get to.

Mrs. WEIS. I think the question would go for any of it. If you have your instrumentation in any of these things, the man and instruments has to stay in the nose cone, there is nothing but pressure in what is being inflated?

Mr. LOFTIN. The men stay in the reentry capsule or the command module, whatever you want to call it, until it is inflated, and then they enter. It is possible that certain instrumentation could be carried in the inflated portion as it is folded up. It is a detail of engineering.

Mrs. WEIS. You could put some——

Mr. LOFTIN. You could. This is a matter of detailed design of how in fact you put it together.

The CHAIRMAN. Before I recognize the next member for questioning, I would like to ask the Goodyear people about how long would your presentation require? We have three witnesses from Goodyear.

Mr. RICHARDSON. I think our presentation we would like to give you would take somewhere around 50 minutes.

The CHAIRMAN. I will recognize Mr. King, and then if there is no objection——

Mr. KING. I yield to Mr. Hechler on the ground of seniority.

Mr. HECHLER. A number of advantages have been cited for inflatable vehicles. It rather makes me shudder to think of the total amount we have to spend on the entire space program. I think it is our obligation, of course, to make sure we expand the economy that can support the expenditures that we feel are necessary.

I think one advantage of inflatable structures is their smaller cost. I wondered if you could present any comparable figures that will serve to drive that point home.

Mr. O'SULLIVAN. I am sorry that I am ill-prepared to quote any comparable cost figures. I know it has been our experience in constructing the Echo I and the Echo II satellites and also the Explorer IX satellite, which we now have in orbit, all three of which are erectable structures, that the cost has been surprisingly low. I think this has been in large measure due to the working out and the solution of many of the problems in the laboratory so that we had a clear idea of how to proceed. This is one way that costs can be cut down.

Mr. HECHLER. If I may interrupt a second, I am surprised that you are surprised. I would assume the cost of the inflatable structure would be considerably less than that of a different type.

Mr. LOFTIN. I would like to make a comment on that. I can't answer your question with regard to the numbers.

One thing that I want you tokeep in mind on——

The CHAIRMAN. Could you talk a little louder?

Mr. LOFTIN. Yes, sir.

I can't answer your question as to the comparative costs. I would make this comment, that in the development of any new system, whether it be an inflatable space station or reentry vehicle or what have you, a very large part of the cost is in the R. & D. that has to go into the thing.

Although, again, I can't give you numbers, I would guess this is relatively large as compared to the cost of the actual metal or fabric or what have you that is cut to make the thing out of.

Mr. HECHLER. I would suggest maybe that Goodyear might want to volunteer to help you out on the R. & D. cost.

The CHAIRMAN. Mr. King, I recognized you.

Mr. KING. I will pass. I don't want to cut into Goodyear's presentation.

The CHAIRMAN. Unless there is an urgent question, let's ask these two witnesses to stand aside for awhile while we give Goodyear an opportunity to put on its case.

Goodyear has a motion picture.

Mr. KARTH. For a matter of comparison, from the witnesses in the communications industry who were here, they estimated all the way from $400 to $600 million for a 25 or 30 active satellite communication system.

Could you estimate the cost for approximately that many passive satellites at the 2,000- or 3,000-mile level so their duration would be from 5 to 10 years; could you give me a figure on that or could you not at this time?

Mr. O'SULLIVAN. I am sorry that I am not in a position to try to give you a figure on that.

Mr. KARTH. Would you try to prepare one and give it to the committee for the record?

Mr. O'SULLIVAN. I think we could do that.

The Naval Air Materiel Center, Naval Air Development Center, Naval parachute facility and Naval medical units all have given substantial support to NASA. In addition, the Pacific Missile Range, under Navy management, is aiding in the operation of the Canton Island, Hawaii, and southern California tracking stations.

Supports by units of the Department of Defense has, in general, been formalized through a series of agreements between NASA and the particular military service concerned. As a rule, these agreements call for reimbursement by NASA for any support or services rendered over and above normal military operations. Estimated costs of DOD support are contained in table IV.

TABLE IV.—*Estimated costs of DOD support of Project Mercury (through MR-7 and MA-8)*

[Thousands of dollars]

DOD unit/command	Estimated total costs	Portion reimbursed by NASA	Balance absorbed by DOD [1]
AFMTC	3, 188	1, 500	[2] 1, 688
AFBMD	54, 350	[3] 53, 900	450
APGC	130	8	122
ACIC	185	[4] 185	----------
WSMR	660	560	100
PMR	1, 552	1, 192	[5] 360
Air Rescue Service	1, 394	[4] 1, 394	----------
Navy recovery forces	18, 333	5, 135	[6] 13, 198
Bioastronautics:			
Operational	560	100	460
R. & D	1, 425	496	929
U.S. Army, LARC Supply	114	34	80
GEEIA	166	----------	166
NASA space task group	290	290	----------
Total	82, 347	64, 794	17, 533

[1] These estimated costs are not supported by or obtained from any accounting system. They are assembled by estimating the cost of effective man-days effort which is applied to Project Mercury by DOD personnel who would have been employed by DOD whether or not Project Mercury were supported.

[2] Includes $325,000 to construct a building to replace Telemetry-3 Building, which is being used as Mercury control center. Includes estimated cost of range support of Mercury.

[3] The AFBMD reimbursable costs are based on a 14-booster, 13-launch Mercury program. These estimated costs were prepared as of July 31, 1960, in conjunction with the development plan covering AFBMD support of Project Mercury. As such, they are subject to current and future negotiation, refinement, and/or approval by NASA. This is a continuing process as the program develops and as the requirement for boosters and/or launches changes.

[4] Appropriate action to obtain reimbursement is in process of negotiation.

[5] Includes nonreimbursed cost of Navy Construction Battalion work at Canton, and cost of general purpose range support of Project Mercury.

[6] Cost of operations and maintenance of Navy Recovery Forces are being reimbursed by NASA in accordance with agreement between CNO/NASA (STG) dated Mar. 23, 1960.

Overall coordination of Department of Defense support for Project Mercury operations is arranged between Maj. Gen. Leighton I. Davis, USAF, Department of Defense representative for Project Mercury operations, and Mr. Walter C. Williams, Associate Director of Project Mercury.

Project Mercury funding summary

Initial funding for Project Mercury was provided in fiscal year 1959, when $46,416,330 was obligated for Mercury research and development, and $2,425,000 for construction and equipment.

In fiscal year 1960, the obligation for research and development totaled $84,328,370, and for construction and equipment, $35,795,000. The fiscal year 1960 figures include supplemental funding of $12,200,-

(The information requested is as follows:)

The question was asked for the comparative cost of a 25 to 30 passive communications satellite system to a system incorporating an equal number of active communications satellites.

NASA has engaged the Rand Corp. under contract NASr–21, a copy of which is attached, to study passive and 24-hour active communications satellite systems. The Rand Corp. will develop information which will help determine the practical and economic benefits and the cost consideration related to satellite communications systems. When the information is developed we shall be happy to make it available to the committee.

ECONOMIC AND TECHNICAL STUDIES ON COMMUNICATIONS SATELLITES FOR THE YEAR DECEMBER 1, 1960–NOVEMBER 30, 1961

The studies described below are proposed to be initiated during the coming year. It is expected that the study of passive systems can be essentially completed during the year and a good start made on the study of 24-hour active systems.

We expect, however, that during the course of these studies other technical problems will arise which cannot be foreseen now or may become of special interest as the development of the communication satellite technology progresses. We propose that study of such problems be undertaken when deemed desirable after appropriate consultation between NASA and Rand.

I. Passive Systems

As a first step, a parametric study of those systems containing spherical reflectors as orbiting elements will be made for the purpose of evaluating their economic potential. The main variables are:

A. *Reflector.*—The size, weight, and useful lifetime of the reflectors are of importance. The lifetime as a function of weight is presently least understood. Therefore, at first, it will be necessary to assign a range of reasonable lifetimes for a given weight. As the study progresses we should be able to refine this. Close contact will be maintained with groups studying the problem of stiffening the reflectors and consideration will also be given to reflector shapes other than spherical.

B. *Orbital altitude and configuration.*—The orbital configuration influences the capacity of the system, the circuit outages in terms of total fractional outage time and also the duration of outages. Other important factors are the number of reflectors and the launch vehicle. Tradeoffs among system capacity (desired to be large), outage time, and the number of launches required to place the system in orbit (both desired to be small) will be investigated. These tradeoffs depend in part on the great circle distance between terminals and on their locations relative to the poles. As a consequence, it will be necessary to make assumptions about the locations of the ground terminals.

C. *Ground environment.*—It is necessary to develop solid information on the present state of the art of high effective radiated powers and the projected state of the art a few years hence, including the properties of large tracking antennas. In the course of the Echo experiment, certain tracking difficulties were encountered. This raises the question whether in an operational system each ground terminal would catalog the orbital parameters of each individual reflector, whether a central station could perform this function, etc.

Variations in the parameters mentioned above will be studied to determine their effect on costs, and to see what general system design now appears most promising.

For the same antenna size, receiver temperature, and transmitter power at the ground installation and equal payload in orbit the number of channels in an active system is much higher than in a passive system, when a single link is considered. However, in a passive system the number of participating ground stations can be increased, subject only to the restrictions imposed by the availability of frequencies. Thus, a passive system may become competitive with active systems when the number of participating stations becomes large, particularly if the stations tend to concentrate in some geographical areas. This possibility will be examined as part of the passive satellite study.

II. Active Systems

A thorough analysis of 24-hour communications satellites will be undertaken. While results of some aspects of this analysis will be reported during the coming year, it is currently anticipated that this study will extend beyond November 30, 1961.

As noted in the special advisory report, by using a more advanced repeater design a capacity increase of a factor about four seems quite feasible over what is now planned in the Advent program. A different approach to the 24-hour system is a smaller (lighter weight) satellite which could be launched by a smaller vehicle than Atlas-Centaur or several smaller satellites launched simultaneously by a large vehicle. A study will be made of the economic potential of such a 24-hour system based on the following technical studies:

A. *System implications.*—The system implications of a few small 24-hour satellites as contrasted with a single big satellite will be investigated. The frequency requirements in the two cases differ drastically provided the smaller satellites are separated in excess of one beamwidth as viewed from the ground. Also, replacement considerations are different as are a number of other system characteristics.

B. *Booster possibilities for 24-hour orbit.*—Booster data will be needed as background information in varying the other parameters of 24-hour systems.

C. *Orbital and attitude control subsystems.*—The principal objective of this investigation will be the determination of the relationship between fuel requirements and useful lietime in orbit for a specified payload or payloads. Possible byproducts might be performance specifications for the orbital and attitude control systems and a discussion of possible system mechanizations. The study will include investigation of orbital perturbations, orbital control, and attitude control.

The orbital perturbation analysis will include, for example, investigation of the perturbations of the orbit due to gravitational effects of the Sun, Moon, and the Earth's bulget to determine the length of the time permissible between orbital corrections. If a sizable antenna is involved the effects of disturbing forces due to radiation pressure from the Sun on orbital and attitude control processes may become significant.

The orbital control investigation will include, for example, investigation of the accuracy with which the desired orbit could be established, single and multi-stage orbit correction processes from the standpoint of fuel economy and accuracy, the effect of the attitude reference performance on the orbit control process, and probable fuel requirements to compensate for gravitational perturbations of the initial orbit.

The attitude control investigation will include, for example, consideration of possible attitude reference system mechanizations, performance specifications of the attitude reference system based on antenna and orbital control requirements, and energy requirements for attitude control systems.

D. *Repeater electronics.*—A 24-hour satellite may use a single high power output tube, a number of lower power tubes or a still larger number of low power solid state devices. The satellite antenna system may consist of only a pair of Earth coverage antennas or may include a number of highly directive antennas. The amount of directivity desirable depends on such factors as ground station distribution, the degree of attitude stabilization, and the type of power output device. The state of the art in output devices, antennas, and other satellite components as well as the interrelationships will be examined to define advantageous systems, e.g., choice of frequency, output device, number and type of antennas, design techniques.

Out of the voluminous work being carried out on auxiliary power systems, space environment and reliability, items of particular significance to active communications satellites will be studied.

E. *Quasi-fixed ground antennas.*—Only relatively small diurnal motions of the antenna beam directions are needed in 24-hour systems, so that the necessity for tracking antennas is eliminated. We propose to investigate what antenna arrangements might be most attractive.

Cost estimate, economic and technical studies on communications satellites—Estimated costs and fee for the year Dec. 1, 1960–Nov. 30, 1961

Direct salaries	$77,700
Overhead, at 85.68 percent	66,600
Publications	2,500
Staff travel	9,250
Consultants, fees, and travel	7,000
Computing machine rental	10,200
Total estimated cost	173,250
Fixed fee	10,400
Total estimated cost and fixed fee	183,650

ECONOMIC AND INTERNATIONAL POLICY QUESTIONS ASSOCIATED WITH SPACE ACTIVITES FOR THE YEAR DECEMBER 1, 1960–NOVEMBER 30, 1961

Studies planned on the economic and international policy questions associated with space activities fall into three broad areas: those dealing with communications satellites, those dealing with meteorological satellites, and consideration of the impact of the "space race" on other countries. Proposed programs of research in each of these areas are described below. The studies described are proposed to be initiated during the coming year and it is expected that substantial progress can be made on all of them. However, during the course of thesse studies, other problems may arise which cannot be foreseen now or may become of special interest. We propose that study of such problems be undertaken when deemed desirable after appropriate consultation between NASA and Rand.

1. Communications Satellites

Three studies are planned on the economic and international policy questions associated with communications satellites: a study of economic and social benefits stressing possible growth of new kinds of demands for long-distance communications; a study of economic policy issues; and a study of the pros and cons of internationalized development and operation of communications satellites.

A. *Economic and social benefits.*—Though most of our future work in connection with analyzing the economic benefits of communications will be done in close connection with the technical studies described separately, one aspect of these studies is of general interest, and is proposed to be continued more or less independently of the detailed economic and technical analyses. This study will further examine the new kinds of demands for long-distance communications that may emerge in the future; especially demands for data transmission, facsimile devices, closed-circuit TV, and commercial TV. The economic promise of communications satellites undoubtedly will be substantially affected by how rapidly these new types of demand emerge.

B. *Economic policy issues.*—The study of economic policy issues will involve three considerations: a short-term study (several months) of licensing the use of Government launching facilities and two longer term studies (something like a year), one dealing with the frequency allocation problem and the other with the ratemaking problem.

The analysis of the economic policy problems involved in working out a scheme for licensing private contractors to use government launching facilities will include consideration of the kinds of licensing arrangements the AEC has worked out and an examination of alternative formulas for determining what rates should be charged for the use of government launch facilities as well as for the launching vehicles.

The study of the frequency allocation problem will be directed to finding ways for insuring efficient utilization of the frequency spectrum in the light of increased demands on spectrum space brought on by communications satellites. The study will include, for example, consideration of the following items: (*a*) An examination of prevailing practices in allocating and assigning frequencies, and how these practices will affect the availability of spectrum for space purposes; (*b*) an examination of the effectiveness of the current procedures for allocating frequencies. How well do they take into account the value of the rights that are assigned for particular purposes? How well do they insure that adequate attention will be given for finding ways for conserving on the use of the spectrum? How well do they facilitate adjustments in spectrum use as technology advances?; (c) an examination of the proposals that have been made for improving the efficiency of the allocative process. Among those that will be seriously examined from a practical viewpoint is the suggestion that a market be established for the purchase and sale of frequency assignments.

The analysis of the ratemaking problem will include, for example, consideration of the following subjects: (a) A systematic examination of how communications rates are presently determined with the view of developing an explanation in terms understandable to the layman; (b) an inquiry into how international rates are determined both in the communications field and in the airlines field; (c) an analysis of the consequences present policies are having in allocating resources; (d) a discussion of the kinds of changes in ratemaking policies that appear necessary if the benefits of communications satellites, or other kinds of new technology, are going to be fully exploited.

C. *Internationalized development or operation.*—A communications satellite system is by definition "international" in that it provides a communication service between countries and probably on a global scale. Ground links would be located in various countries and international arrangements would have to be made accordingly. The United States may decide to develop and operate the system *essentially* as a U.S. enterprise (public or private) and to work out political arrangements and technical details on a bilateral basis with the user-participants. The Special Advisory Report of September 15, 1960, recommended such an approach, for reasons cited on pages 73–75.

However, insufficient analysis has been given the question already raised by U.S. officials and businessmen: Why not develop, or at least operate the system under some sort of international auspices? Development, ownership, or operation might be vested in a specialized agency of the United Nations; or in some international technical group; or in a consortium; in a public or private corporation in which shares are held by governments, private concerns, or other groups; etc.

We propose to study this problem to identify and assess the worth of a *variety* of possible "internationalized" arrangements; their advantages, risks, and drawbacks, and the longer term implications and consequences for U.S. national interests. Several case studies of analogous or pertinent international ventures would be undertaken (e.g., International Atomic Energy Agency) in order to assess the precedents and to establish a factual footing for future projections.

This study will follow through on present Rand work for NASA, nearing completion, on some of the political problems and opportunities in the field of cooperation and international regulation and control of space activities. It will be pursued in close association with the planned project on "The Impact of the 'Space Race' on Other Countries" (see description below).

II. Meteorological Satellites

Two studies of the economic implications of meteorological satellites are planned. The first treats the value of improvements in storm warning and the second considers how information derived from meteorological satellites might be used to improve the hurricane warning system.

A. *Economic value of improvements in storm warning.*—Over the next few months, work on the economic and social value of better weather information will focus on the problem outlined in section V of RM–2620–NASA: the determination of the value of improvements in storm warning, particularly hurricane warning. A model of the sequential decisionmaking problem involved in the efficient use of storm advisories is being developed. When it is completed, which is expected to be in the near future, an attempt will be made to apply it in some situations where the economic significance of better warning may be expected to be considerable. One particularly interesting opportunity for a case study has come to our attention: when a hurricane threatens at Cape Canaveral a decision must be made as to whether launching vehicles should be taken down and gantries secured against the high winds. Such action may be costly both in terms of the direct costs of taking protective action and the resulting delays in the testing program; on the other hand, failure to take such action when it is needed will result in expensive damage. It is hoped that the analysis will both point the way to optimal use of the existing possibilities for warning and indicate what sorts of improvements might have the greatest value. Subsequent to the analysis of the Cape Canaveral problem, we propose to undertake other case studies of the use of hurricane warning, but the particular situations to be studied have not yet been decided upon.

B. Possible improvements to the hurricane warning system.—A study is planned to indicate specifically some improvements in the hurricane warning system which might be obtained by using meteorological satellite observations. In particular, we will seek to determine what improvements would result simply from having the information on the position of the hurricane which the satellites would make available, and compare the costs of obtaining position data in this way with the costs of obtaining it by aircraft reconnaissance. Because the long-range contribution of the weather satellite program to improvements in forecasting techniques and to the science of meteorology cannot be estimated with precision, our conclusions in this area will have to be regarded as providing lower bounds to the benefits obtained rather than expected value estimates.

III. Impact of the "Space Race" on Other Countries

Currently nearing completion is a study of Soviet cold war objectives in space, and the Soviet conception of U.S. objectives and space programs. The impact of the Soviet technical program and political strategy, and the impact of U.S. efforts need to be assessed for their effects on in-between nations. Such a study is proposed, on a limited scale, in order to provide an empirical basis for positive proposals and initiatives which the United States might undertake in the future—initiatives for consolidating and building international support for U.S. space activities, both technical and political.

In order to make realistic assessments of the support the United States can expect from other countries and to guide future U.S. actions, an analysis will be made of the views and positions already entertained in key countries as expressed in their own space programs and interests; in their stand at the United Nations, COSPAR, ITU; their attitudes toward space aspects of arms control negotiations; etc. Much of the present knowledge on the impact of the space competition is based on casual impression or episodic public opinion polling. The proposed study will attempt to develop a more objective synthesis of existing source materials and might be followed up with field studies on a pilot scale.

Cost estimate, economic and international policy questions associated with space activities—Estimated costs and fee for the year Dec. 1, 1960–Nov. 30, 1961

Direct salaries	$133, 300
Overhead at 85.68 percent	114, 200
Publications	4, 900
Staff travel	15, 900
Consultants, fees, and travel	63, 650
Computing machine rental	3, 800
Total estimated cost	335, 750
Fixed fee	20, 150
Total estimated cost and fixed fee	335, 900

Mr. O'SULLIVAN. In regard to a question I believe you asked a moment ago, I have some further information; namely, to the effect that RCA was selected yesterday to conduct notions to construct an experimental active communications satellite. That is a relay type. It is to test out the satellite components in the space environment. We are proceeding in that direction.

The CHAIRMAN. $3 million?

Mr. O'SULLIVAN. I think so.

The CHAIRMAN. If there is no objection, we will go ahead now and hear the witnesses from Goodyear.

Mr. Richardson, you are vice president of Goodyear Aircraft Corp. Could you take over your presentation, and you can introduce the witnesses, Dr. Ross and Mr. Madden, and you can put your motion picture on at the proper time and place in the testimony.

Mr. RICHARDSON. Thank you, Mr. Chairman.

STATEMENT OF ROBERT W. RICHARDSON, VICE PRESIDENT OF GOODYEAR AIRCRAFT CORP., AKRON, OHIO, ACCOMPANIED BY DR. ROBERT S. ROSS AND ROBERT T. MADDEN, OF GOODYEAR AIRCRAFT CORP.

Mr. RICHARDSON. We are very pleased to be here today.

We think the subject of inflatable structures or, as we call them, expandable structures, I think to put it in context, we all mean the same thing. So when you hear the difference in words, we are all talking about things that you make small on the launch pad and make large as you get into orbit.

We are very delighted to be here, primarily to acquaint you with a new technology.

I think Mr. Loftin and Mr. O'Sullivan have done a good job, and NASA is to be commended on the Echo and the communication satellite programs.

We would like to carry the discussion into some other areas that haven't been covered, which I hope you will find of interest.

It is obvious, as pointed out by Mr. Loftin, that in an expandable structure you can fold it up on the launch pad. It basically has light weight, and through that utilizes only medium size or smaller boosters therefore not requiring the large boosters to put large structures in space.

At Goodyear Aircraft we have been interested in this subject and have done active research work for a number of years.

The state of the art is coming along well. We don't know all the answers as yet, but it is all very feasible, and there is very definitely a big world ahead of us in this country in the use of expandable structures for many space applications.

I think in the interest of conserving time, we should get ahead with our presentation.

We are going to have to ask you, Mr. Chairman, to bear with us. We have some slides and motion pictures. We have a blackboard and we are going to try to work between them so we may have a little problem of turning lights on and off this morning.

The CHAIRMAN. We will help you. We have until noon. That will give you 40 minutes.

Mr. RICHARDSON. We will do the best we can to be finished by noon.

There are two gentlemen with me from our organization, Dr. R. S. Ross and Mr. Robert T. Madden, who are going to participate in our presentation this morning. I hope you will find it very interesting.

We will be most happy to answer any questions when we are through.

With your permission, I would like to turn our presentation over to Dr. R. S. Ross.

STATEMENT OF DR. ROBERT S. ROSS, MANAGER, AEROMECHANICS RESEARCH AND DEVELOPMENT DEPARTMENT, GOODYEAR AIRCRAFT CORP., AKRON, OHIO

Dr. Ross. We are going to show you a few slides of some of the subjects that we think we can make out of the inflatable or expandable structures. I have some movies here——

The CHAIRMAN. Just a moment. Some of us can't see the slides.

Dr. Ross. Some call them inflatable, expandable, erectable, or pliant structures. They all involve the same thing, the basic function; they can be folded up into a small compact package at one time and opened up into a very large one at another time.

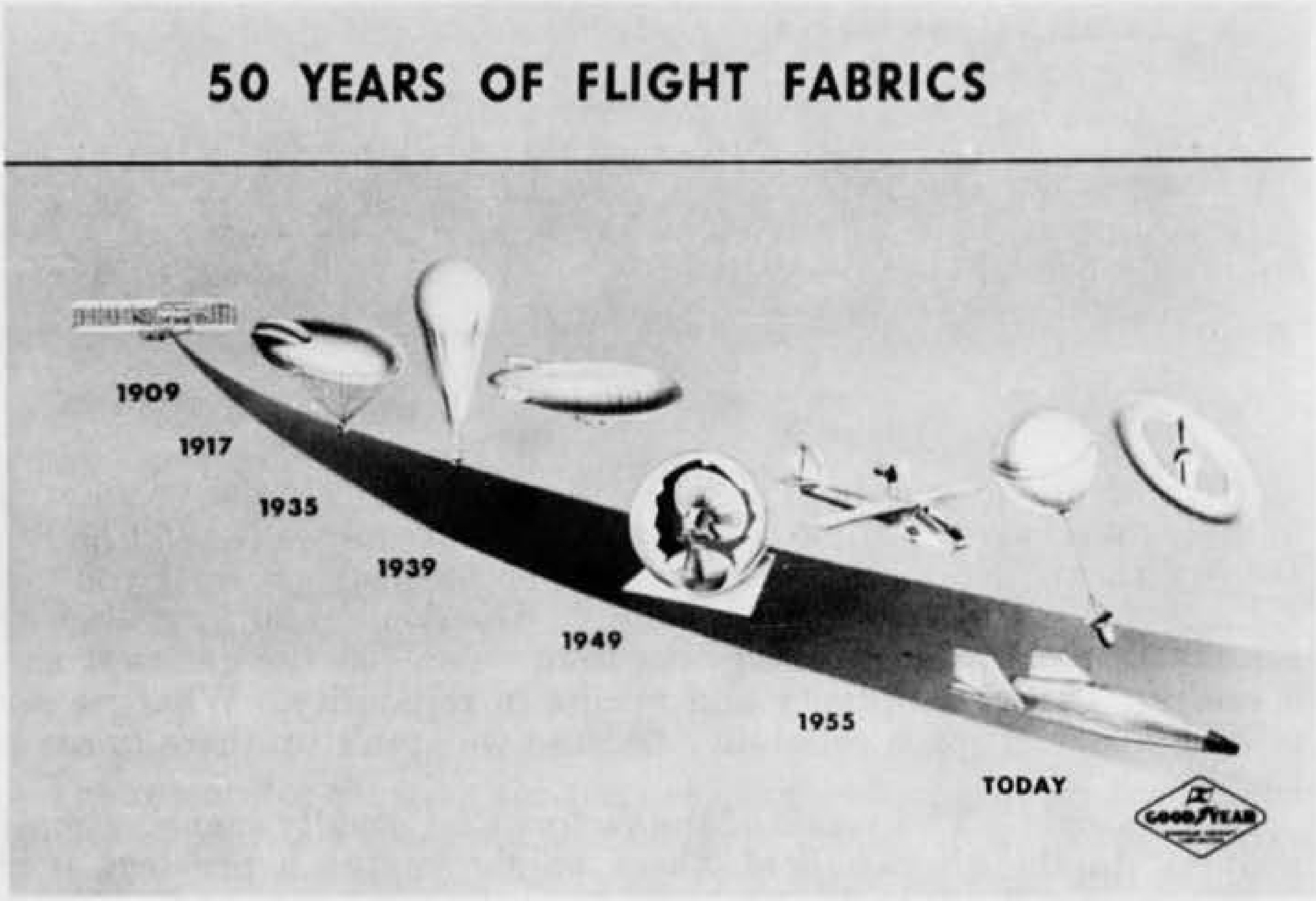


FIGURE 1

Figure 1 shows that what Goodyear has been doing for the last 30 years has been tied up with this type of structure. We can go all the way back to the beginning of, you might say, the Wright Brothers, way back in 1909, we started working with fabrics that went on airplanes. Actually the tires that went on the airplanes, too, and that we ride on today, are of that type of structure, up through the balloons and airships.

Back in 1949, we found we could see through some of this material with radar, and we made fabric radomes.

In 1955 we found we had a breakthrough. We built the inflatable plane at that time.

Today we are looking at space applications that could be space stations or different kinds of re-entry vehicles.

We will try to tell you about some of these today.

Why do we really look at expandable structures in the first place. There are four major advantages as shown on Figure 2.

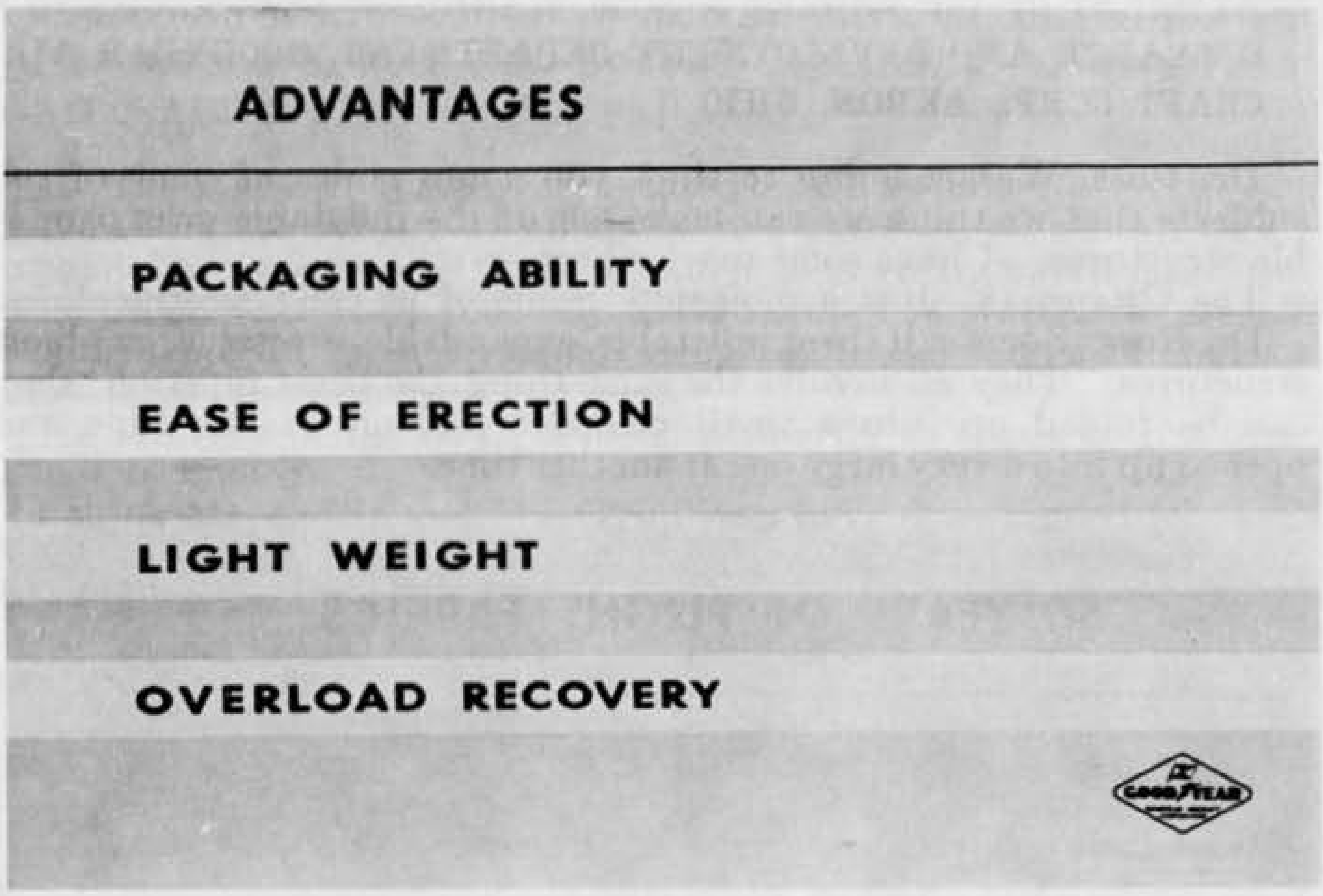


FIGURE 2

First of all, as has been mentioned several times, the packaging ability. We have a million hinges built into it and we haven't had to pay for them. Normally, when we make a hard structure, if you put a hinge in, it costs you extra weight. We don't need any kind of actuators or cams or anything like that. You put the gas to it and it erects. This is simplicity and results in reliability. What we are talking about is space reliability because we aren't up there to see it usually.

Light weight. This is one of the factors that usually surprises most people. In the aircraft field where weight is such a problem, it is usually very difficult to do anything that will save 5 percent in weight. In our applications sometimes we talk about saving 90 percent. This is a very large factor and an important one.

There is nothing magic or secret about it. We aren't varying any basic fundamentals. The reason that we can usually go to these extra light weights is that we can make practical structures of very very small dimensions which are not possible out of normal sheet metals. If you got the metals down to those dimensions, they would be foils so delicate that they would be hard to fabricate.

The last factor, overload recovery, is the kind of thing that is helpful to the engineer who works in this field. Any time a man designs a structure, he has to anticipate how big the loads are going to be that he is going to encounter. Nature doesn't always play in his favor, and once in a while he encounters a load that is greater than what he anticipates.

In normal structures, if you get a load that is too large, the structure will collapse. In an expandable structure what happens is, instead of collapsing, you get what we call an excessive deflection, it bends. When the load is taken off, it can straighten out and be as good as new.

These are our advantages with this type of structure.

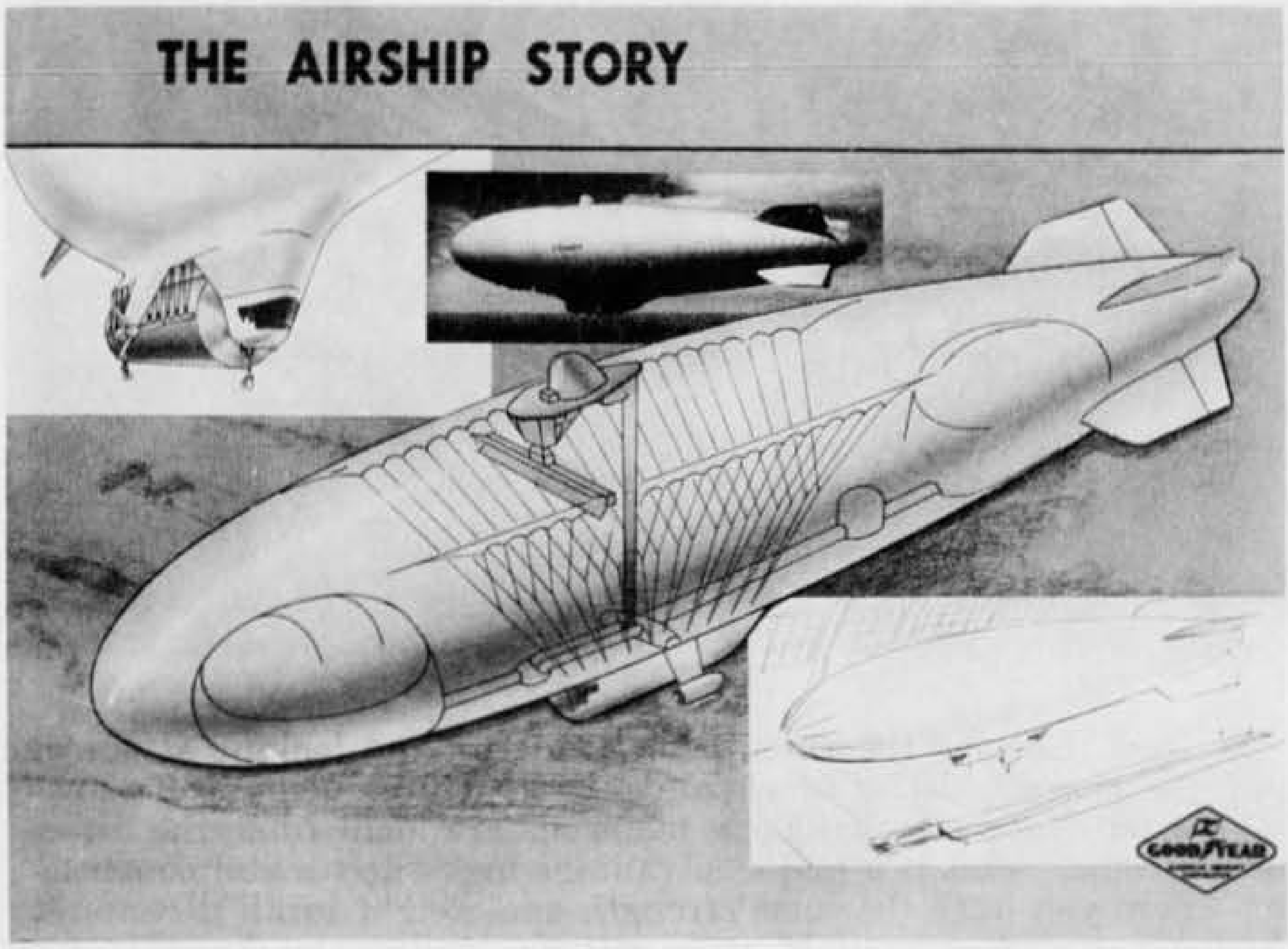


FIGURE 3

The reason for showing the picture (Figure 3) of the airship, which is not necessarily a space item but could be related to it in that we have already examined this for carrying very large boosters and find you can do this with an airship-type vehicle. Another reason for showing this is that size is not really a difficult problem with an expandable structure.

The car that you see underneath the airship is about the size of a good size airplane. You can see how much larger the envelope, which is an expandable structure, is.

When we talk about space, we are talking about applications that usually requires very large structures. And when we talk about an expandable structure, a large structure shows great advantages.

Let's show the movie here of a typical airship in flight. This will be the first of several brief moving picture examples of expandable structures.

(Movie shown of airship being moved from air dock and in flight.)

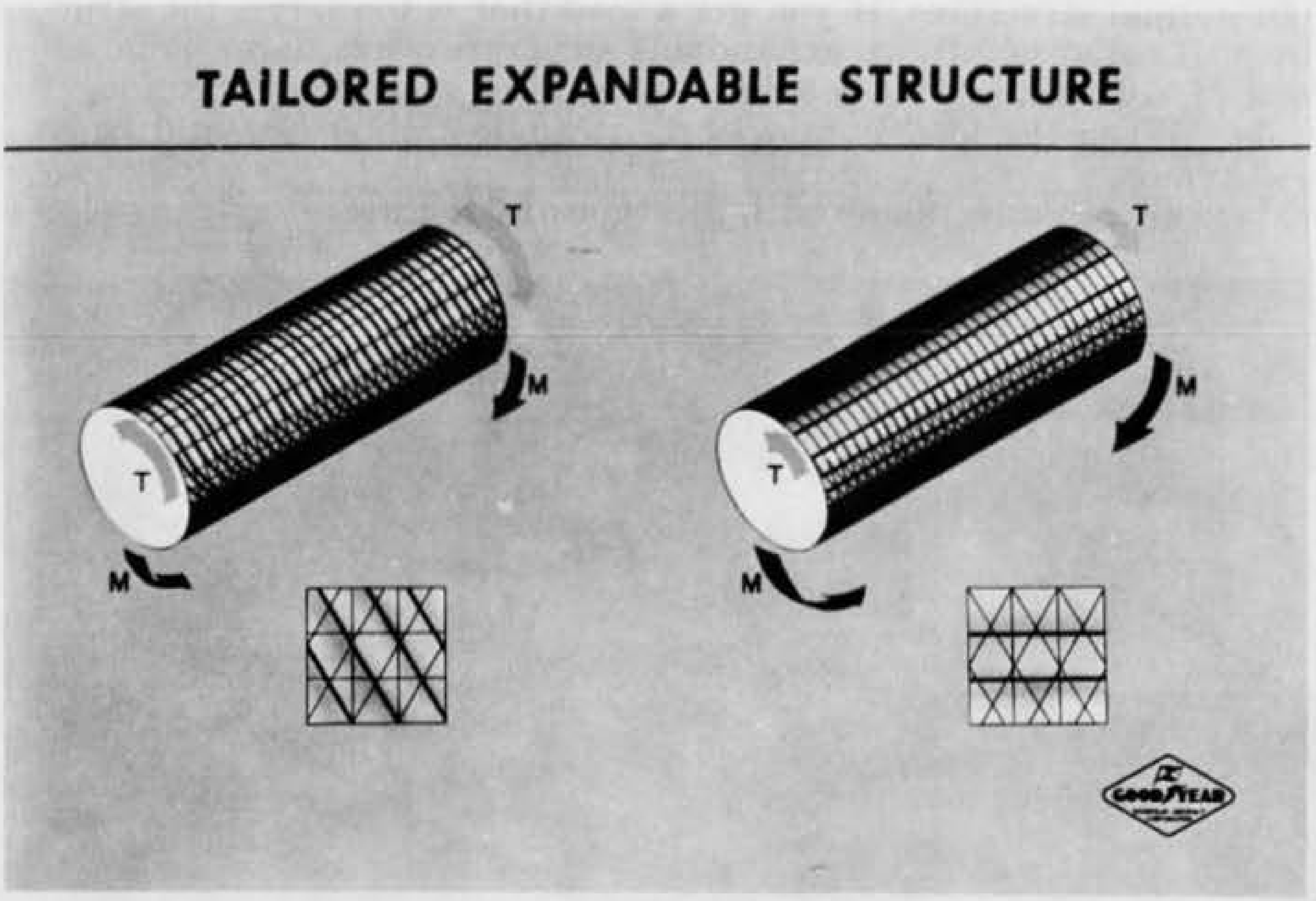


FIGURE 4

Dr. Ross. Leaving the airship for a moment and looking at one of the basic characteristics of expandable structures, Figure 4, shows that we put the cords that these materials are made of in the direction we want. This is a major advantage over sheet metal construction where you have the same strength and weight in all directions, whether required or not. If we have a big load in one direction, we can put lots of cords or heavy ones in. If we have a small load in this direction, we can put few cords. This gives us the advantage of only putting into the material the material you actually need to carry the load. Don't carry anything you don't need. It gives us the opportunity of making these light weights that we talked about.

Also, everybody knows if you make a sphere, a pressurized structure, where you have pressure in the center and carry all the material around the outside, this is one of the lightest structures you can possibly make.

The airship is a body of revolution of this type.

We attach the car to the bottom and distribute its load into the envelope by catenaries attached to the top. Actually, you will find that we have pulled down on the envelope in those areas to take the high load.

If we carried that over a wide span, you would find we could pull very hard on the top and bottom and get to the shape shown in the lower part of Figure 5, and have what you might consider a flat airship.

Let's consider that you might take this and put an infinite number of connections in there, and you obtain a pressurized structure that has what we call drop threads. This gives you flat structures so you don't have to be limited to round structures, cylinders, or torus-type.

000 for research and development, and $6,800,000 for construction and equipment.

Early in fiscal year 1960, Congress was advised that NASA intended to transfer $15 million from research and development appropriation to construction and equipment for construction of the Mercury network. The fiscal year 1960 figures reflect this funding transfer.

For fiscal year 1961, the current allocation of funds is $110,051,000 for research and development, and $15 million for construction and equipment. A request for $74,245,000 is currently contained in the NASA authorization request for fiscal year 1962. The section on Project Mercury funding projects a total funding requirement through fiscal year 1962 of $368 million. The validity of this figure is subject to the success of meeting the flight test target dates and could go as high as $500 million in the estimation of the committee staff.

Why man in space?

In the past, man's scientific and technical knowledge was limited by the fact that all of his observations were made either from the Earth's surface, or from within the Earth's atmosphere. Now, man can send his measuring equipment on satellites beyond the Earth's atmosphere, and into space beyond the Moon or lunar and planetary probes. The benefits to man that have been derived from these initial ventures into space are too numerous to be recounted here; but the exploration of space, in its truest sense, will begin only when man himself can participate directly in this exploration.

Man is destined to play a vital and direct role in the exploration of the Moon and the planets. In this regard, it is not easy to conceive that instruments can be devised that can effectively and reliably duplicate man's role as an explorer, a geologist, a surveyor, a photographer, a chemist, a biologist, a physicist, or any of a host of other specialists whose talents would be needed. In all of these areas, man's judgment, his ability to observe and to reason, and his decision-making capabilities are required. Only man can cope with the unexpected; and the unexpected, of course, is the most interesting.

The search for extraterrestrial life, for instance, is a problem of formidable difficulty for pure instrumentation systems, that is much more easily within the scope of man's abilities. Even in more prosaic endeavors such as photography, it is extremely challenging to duplicate man's ability to select pertinent subject matter and optimum photographic methods, to focus and choose the most profitable instant for exposure, to recognize that his view is obstructed, or even to note that the lens has become dirty.

Closer to Earth, man's special abilities would be employed in manned orbiting space laboratories, or space stations. Man's observational, analytical, and functional capabilities can provide an advantage in the conduct of a range of meteorological, communication, broadcasting, mapping, and search activities in orbiting vehicles. Orbiting laboratories will also permit the investigation and proof testing of vehicular components and operating techniques required for the development of other advanced space vehicles and missions. Of note in this area are the evaluation of micrometeorites and radiation damage to space materials, the development of space propulsion systems, the study of spacecraft erection and construction, the investigation of rendezvous

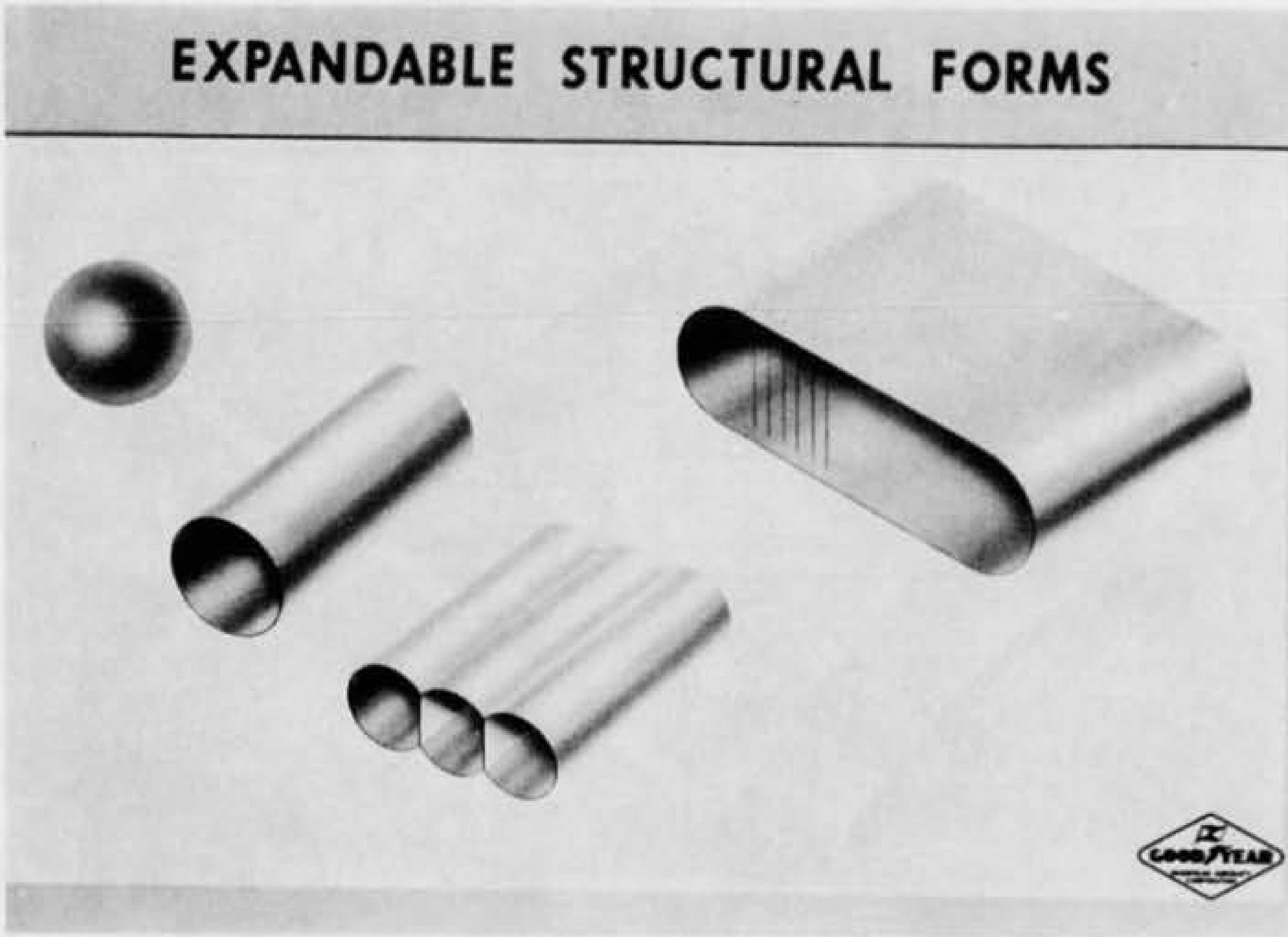


FIGURE 5

One of the breakthroughs we had was the development of a material called Airmat, which is made out of this flat structure as shown in the upper right side of Figure 5. This is a typical flat panel with the number of threads in between it. When you put pressure in it, it doesn't go to a sphere but is flat. We call this Airmat. When you put pressure into them, the threads prevent the pieces of cloth separating more than the dimension of the threads.

We were able also to take these and actually shape the structure, that is, change the lengths of the drop threads so when you inflated this body you would have an air foil-shaped device. See Figure 6.

This shows how we went from the catenary-type arrangement on the airship and to the drop thread.

Frankly, the samples we are showing you are nothing but pieces of carpet, made on a carpet loom and normally they make these outside surfaces very close together. To make carpet they cut the drop threads to make the plush surface. In our applications, we coat the surfaces to make them gas tight, seal the edges and pressurize internally to make a rigid structure. This is nothing more than an I-beam, if you might visualize it, as shown in Figure 6. With pressure, you get tension in the surfaces and you have an I-beam with the web of the I-beam essentially weighing nothing.

It is difficult to get material lighter than this. This is why we look at it as one of the world's lightest structural materials. It will remain still and hard as long as you maintain pressure in it.

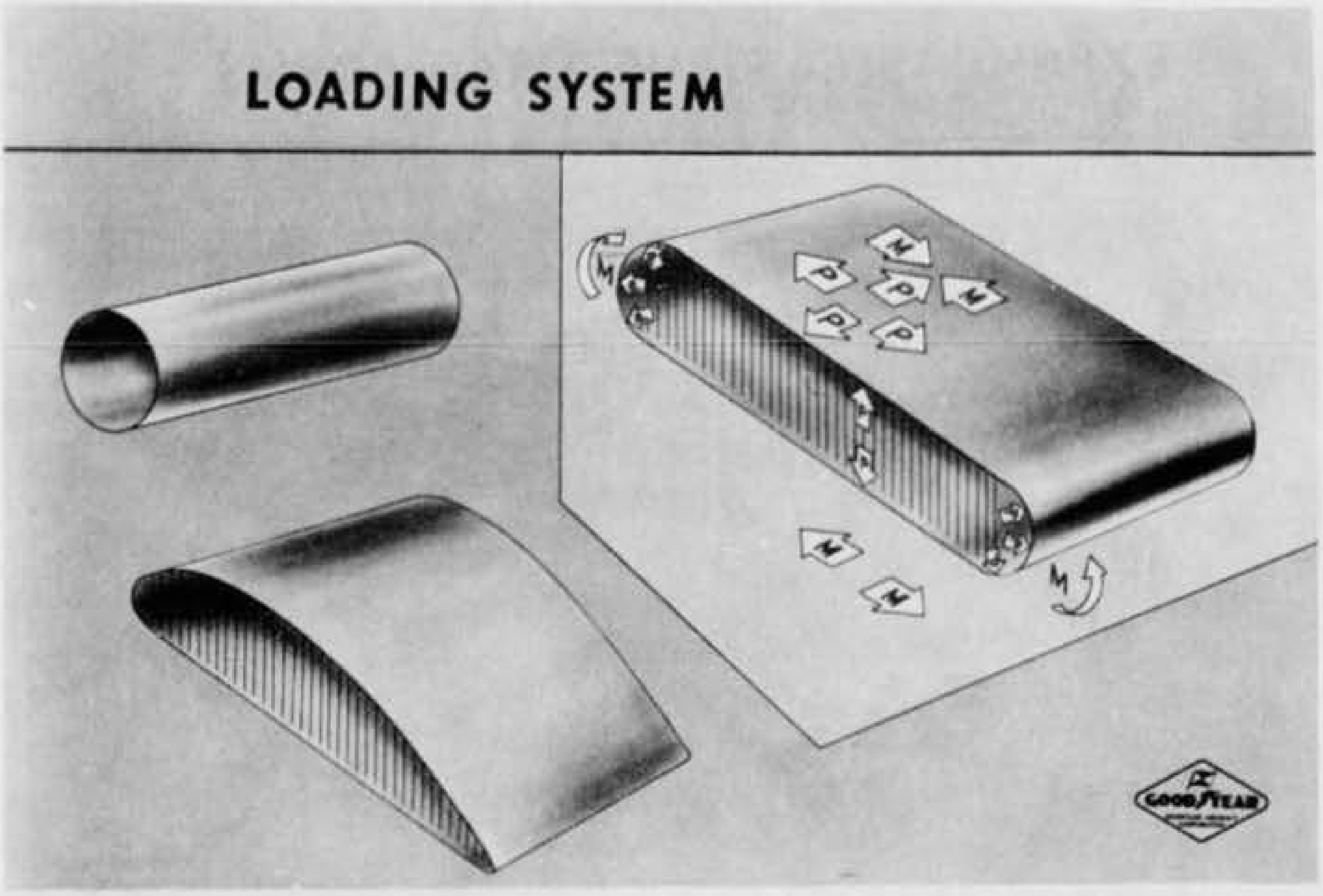


FIGURE 6

As I mentioned earlier, we actually were able to make an airfoil shaped body on these looms. We set the looms with special gauge blocks in them and instead of carpet, and we said, "We want a specified number of yards of NACA 0015 wing structure."

To show that we could do things and make them useful in this way, we actually, in working with the Navy, ONR, decided we would make a rescue-type vehicle as shown in Figure 7.

The idea behind this was that we would try to make it as small as possible. If a pilot is down in some hostile territory, you could fly over, drop this package to him, and some dark night he could turn a valve and he would inflate, start the engine and fly back to his own base.

To make an airplane like this, we had to make what you would call breakthroughs in the state of the art of structures. We were able to make wings of this airplane of one-tenth of the weight of a conventional structure.

We have a short movie now of one of these little airplanes so you can get some idea of its design and flight characteristics.

We made this one-place plane for the Navy. The Army asked us to make a two-place plane for them.

(Movie shown of Inflatoplane being unpacked and flown.)

Dr. Ross. The next slides cover some of our work on space stations. Since this field covers everything from underneath the sea to in the air and off into space and the space field is what we are talking about today, we have divided our expandible structures into three areas: Those that require large strengths-light weight, such as a space station, those items that encounter high temperatures such as some-

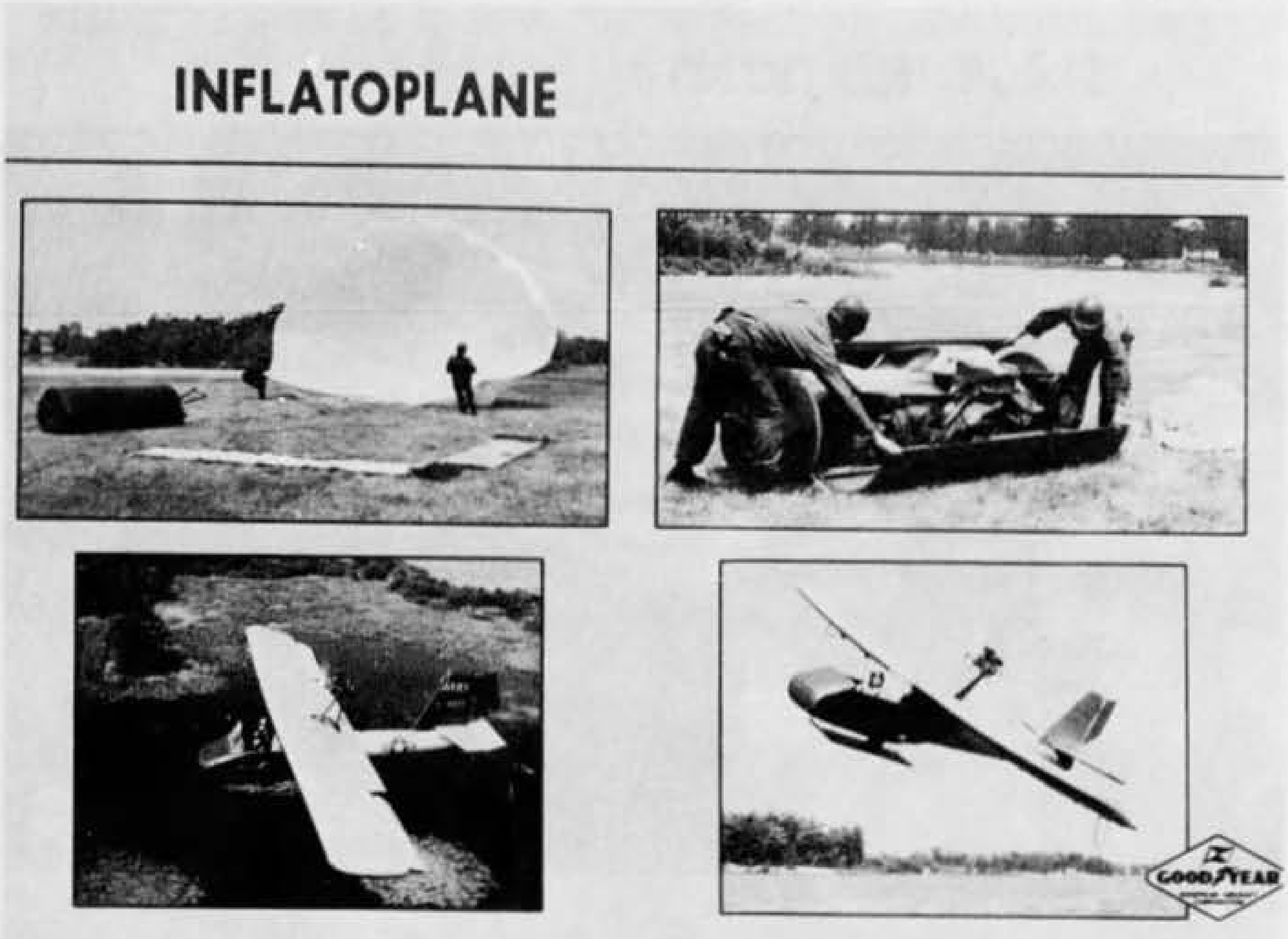


FIGURE 7

thing you would use for re-entry into the atmosphere, and finally those items that are very very light in weight, but don't have to take any big loads. Usually, you want the light weight structures very accurate in shape, such as a gigantic solar collector.

At this time, I would like to introduce Mr. Madden, who will give you a little discussion on this particular type of space station. Then I will return to cover the other two structures fields of applications.

STATEMENT OF ROBERT T. MADDEN, MANAGER, ASTRONAUTICS SALES, GOODYEAR AIRCRAFT CORP., AKRON, OHIO

Mr. MADDEN. Figure 8 shows what we might consider an advanced space vehicle, a large toroidal arrangement, three tier-type construction.

Figure 9 shows a configuration which is more representative of the type of work that we are doing today with the Langley Research Center, which Mr. Loftin reviewed earlier.

You can see here we have taken a look in our configuration evaluations at two possibilities of how expandable structures might be used in a space vehicle, and in the upper left hand side for comparison have shown a configuration which might be a metallic cylinder, possibly the final stage of a booster.

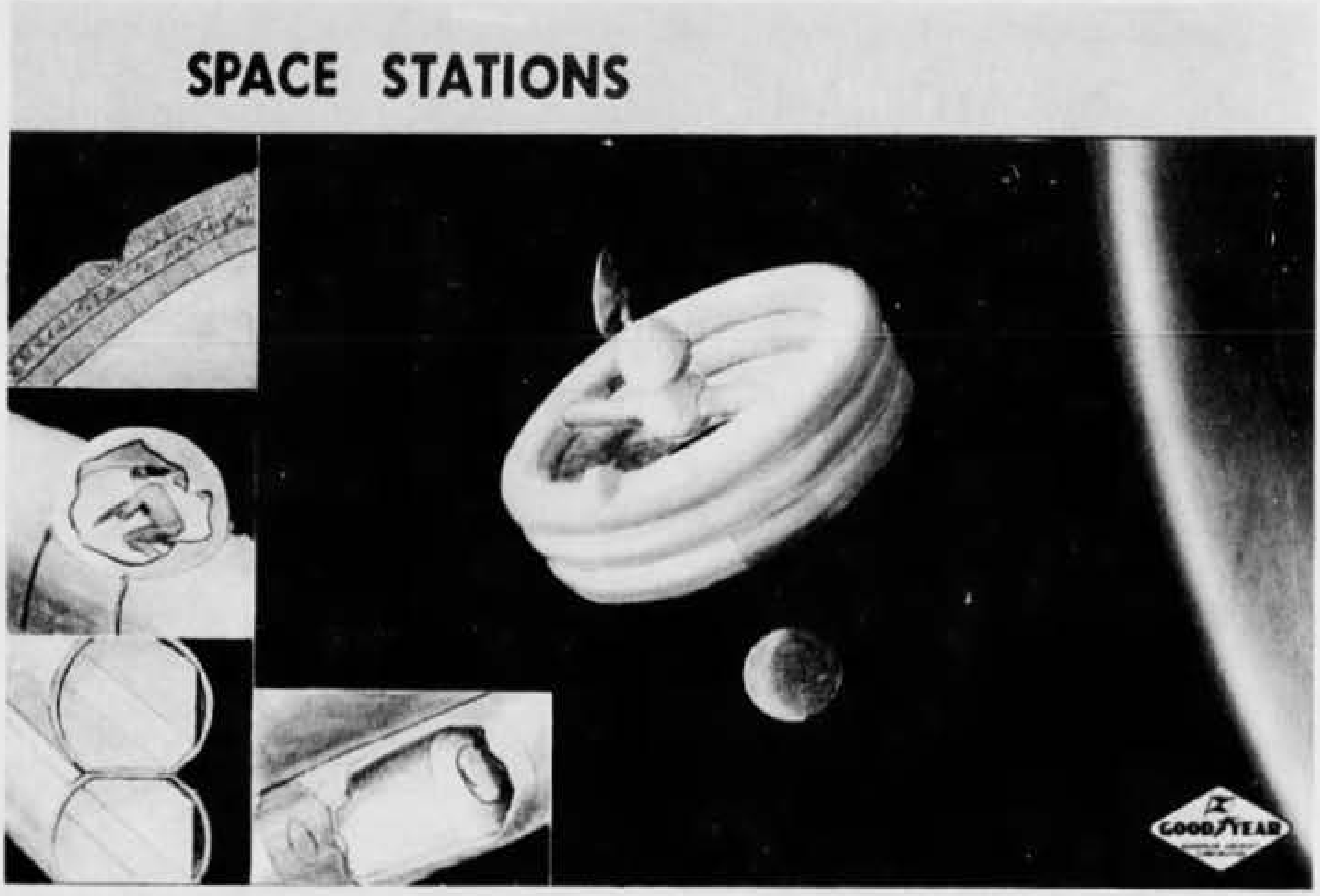


FIGURE 8

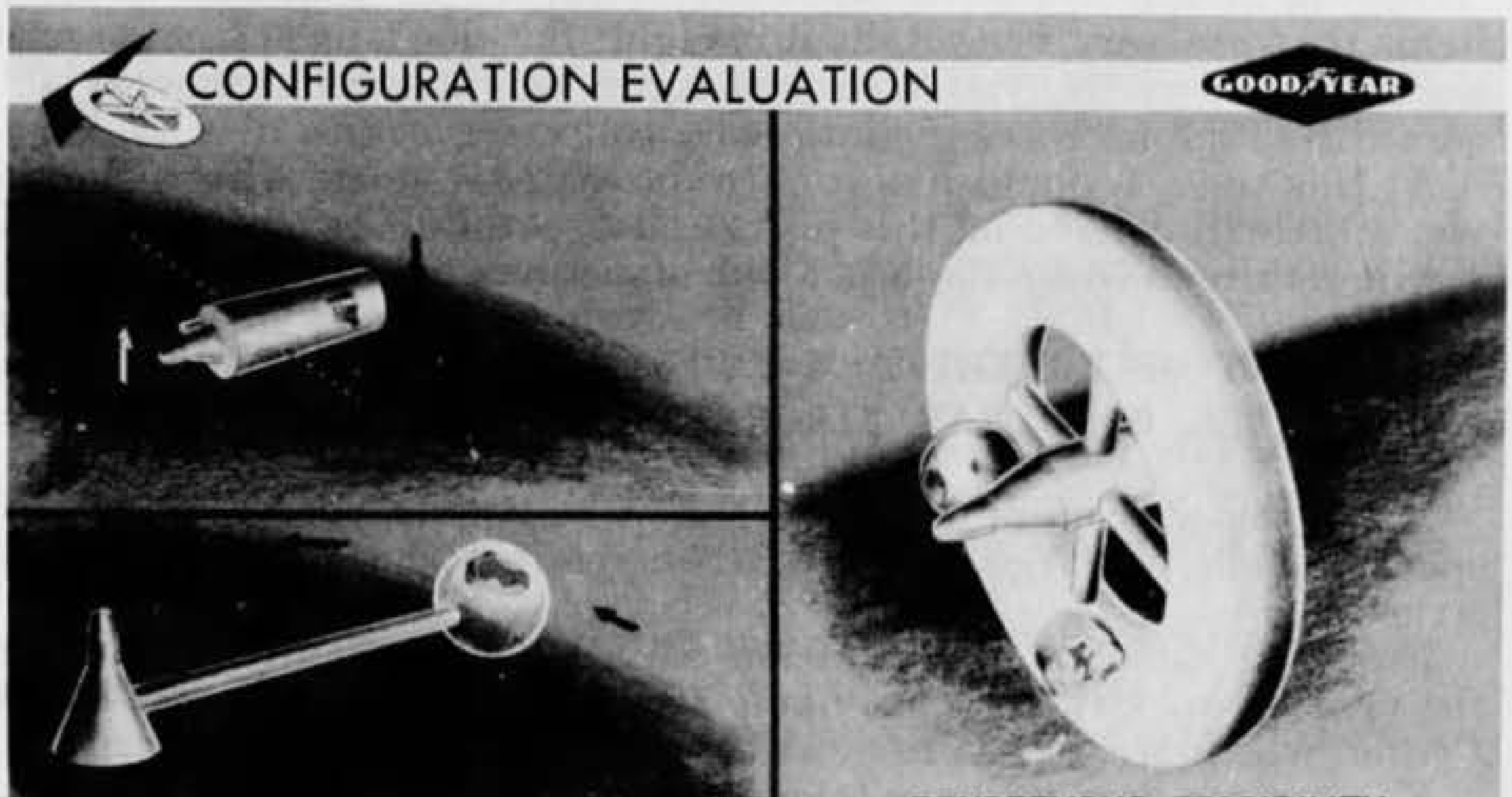


FIGURE 9

Our studies have shown that the problem of gravity simulation, if this is an area of concern, can probably be best handled with a toroidal arrangement and that this type of structure, using some of the principles that Dr. Ross explained, can be made a minimum weight for the desired volume. The research work that we are presently doing with the Langley Research Center is being directed at getting the optimum type of material for this type of configuration.

On Figure 10, we show a comparison of some of the expandable space station configurations that we have been investigating.

The first is a one-man 24-foot diameter configuration, identically that configuration that Mr. Loftin described and as represented by our model which I want to describe a little later.

BOOST WEIGHT DATA

GOOD/YEAR

STATION	MISSION (DAYS)	WEIGHT BREAKDOWN (LB) CAPSULE	TORUS *	POWER +	LAUNCH TOTAL
1-MAN (24 FT)	14	3,344	3,432	1,005	7,781
3-MAN (50 FT)	14	3,500	3,090	1,000	7,590
10-MAN (100 FT)	35	6,596	8,018	7,500 †	22,114
10-MAN (200 FT)	35	6,596	9,128	6,300 †	22,024
10-MAN (400 FT)	35	6,596	10,798	5,100 †	22,494

* INCLUDES MISSION, LIFE SUPPORT, AND ELECTRONIC EQUIPMENT.
+ INCLUDES LAUNCH AIRFRAME WEIGHT.
† 25 KW ELECTRICAL SYSTEM.

FIGURE 10

We have also looked at a three-man, 50-foot diameter space station.

I think an important thing to note here is that the total launch weight of these vehicles is of the order of 7,500 to 8,000 pounds, which is well within the anticipated capability of the Centaur booster.

The concept in the first instance would utilize the Mercury capsule as the re-entry vehicle, and you can see it is identified as a one-man station.

Looking at later capabilities, we also show 100-foot diameter, 200-foot diameter, and 400-foot diameter stations.

It may be of interest that for the exact simulation of gravity that we have here on Earth, a 400-foot diameter space station, rotating at approximately 4 rpm gives the one g simulation.

Figure 11 shows a concept of a three-man station, using again the same principles of an inflated torus.

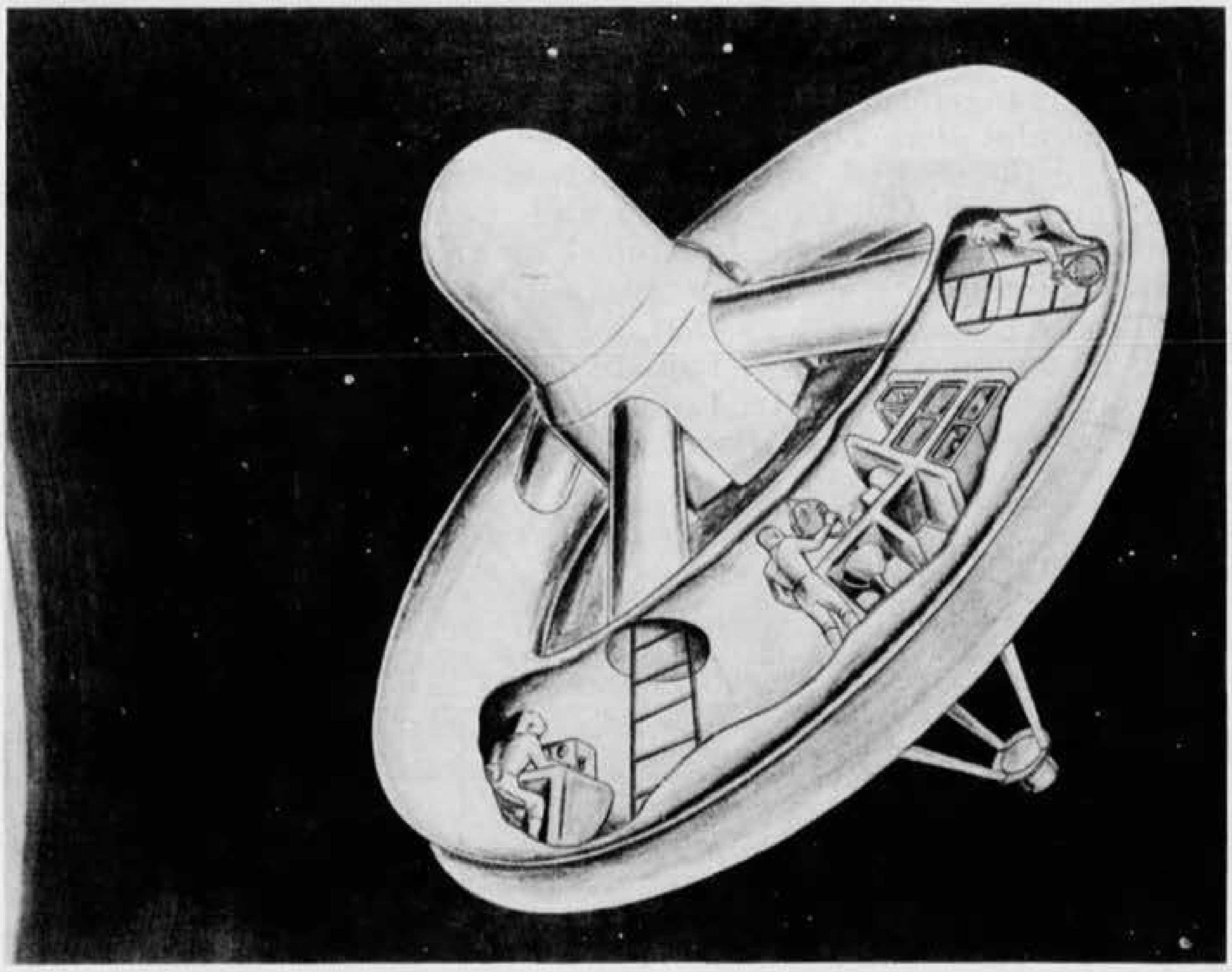


FIGURE 11

Here a ballistic-type nose cone and re-entry vehicle would also be the center hub and, as brought out in some of the earlier discussion, the space station would be boosted in the packaged configuration within the nose cone, as an integral unit. After deployment of the space station in the space environment, the crew could move out through the spokes into the working structure.

Figure 12 shows the typical deployment sequence for this type of vehicle.

As you can see, in the lower left-hand side, completely packaged, the inflatable components mate nicely with the booster configuration. After deployment, the pressurized space station assumes the toroidal shape. After completion of the mission, the capsule can be separated and programmed for re-entry and recovery in this instance, much like that recently accomplished with the Mercury capsule.

Figure 13 shows the launch configuration, which is perhaps better described by a movie which we can show now of the buildup of an expandable configuration.

(Movie shown of space station model launch and deployed configurations.)

Mr. MADDEN. Starting with the basic Atlas booster, as shown here, then comes an interstage fairing, the attachment of the Centaur stage, and finally on top of this the mission module, as we term it, which would enclose the packaged inflatable space station. This is attached to the Mercury capsule configuration, much as it is presently designed today.

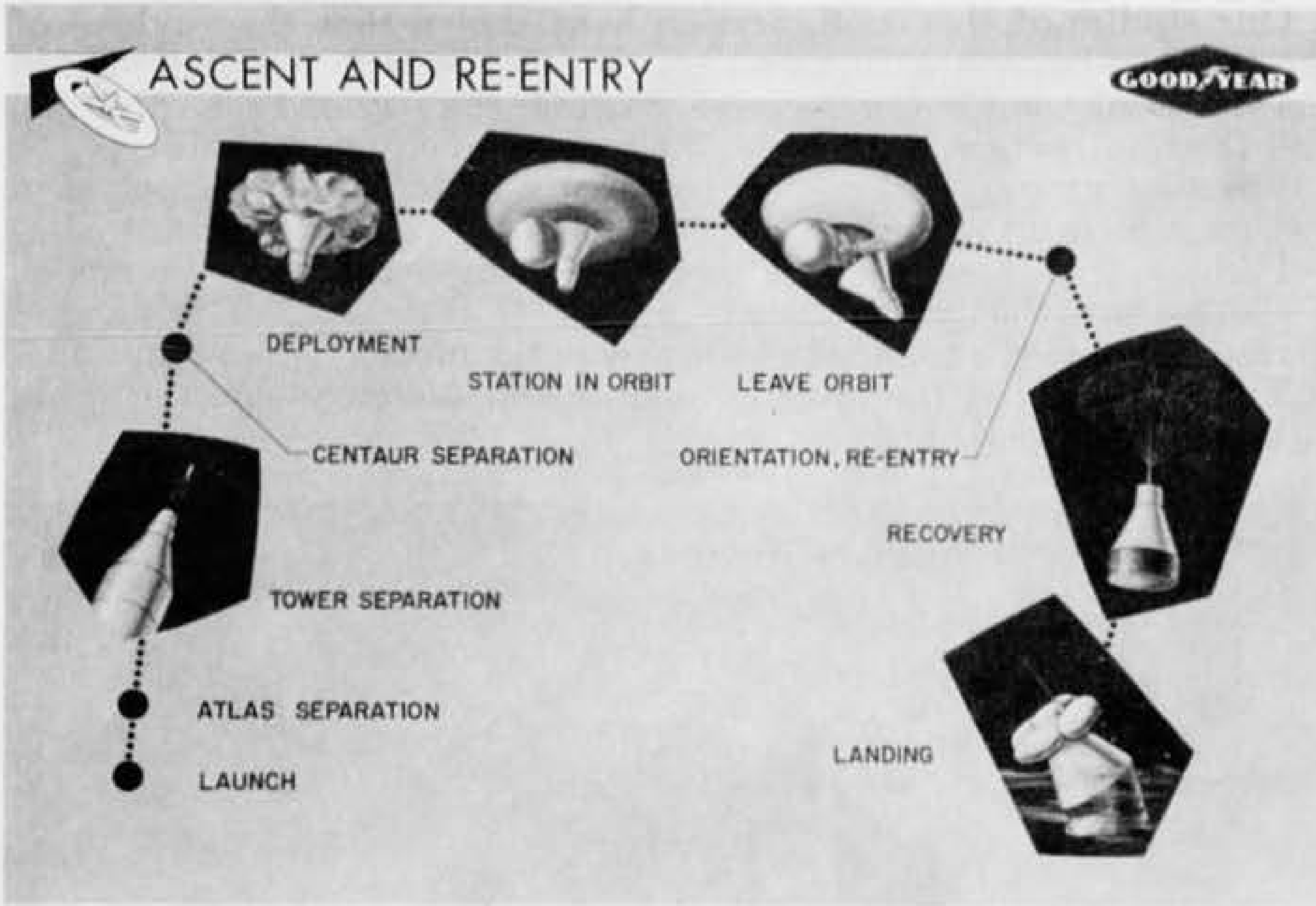


FIGURE 12

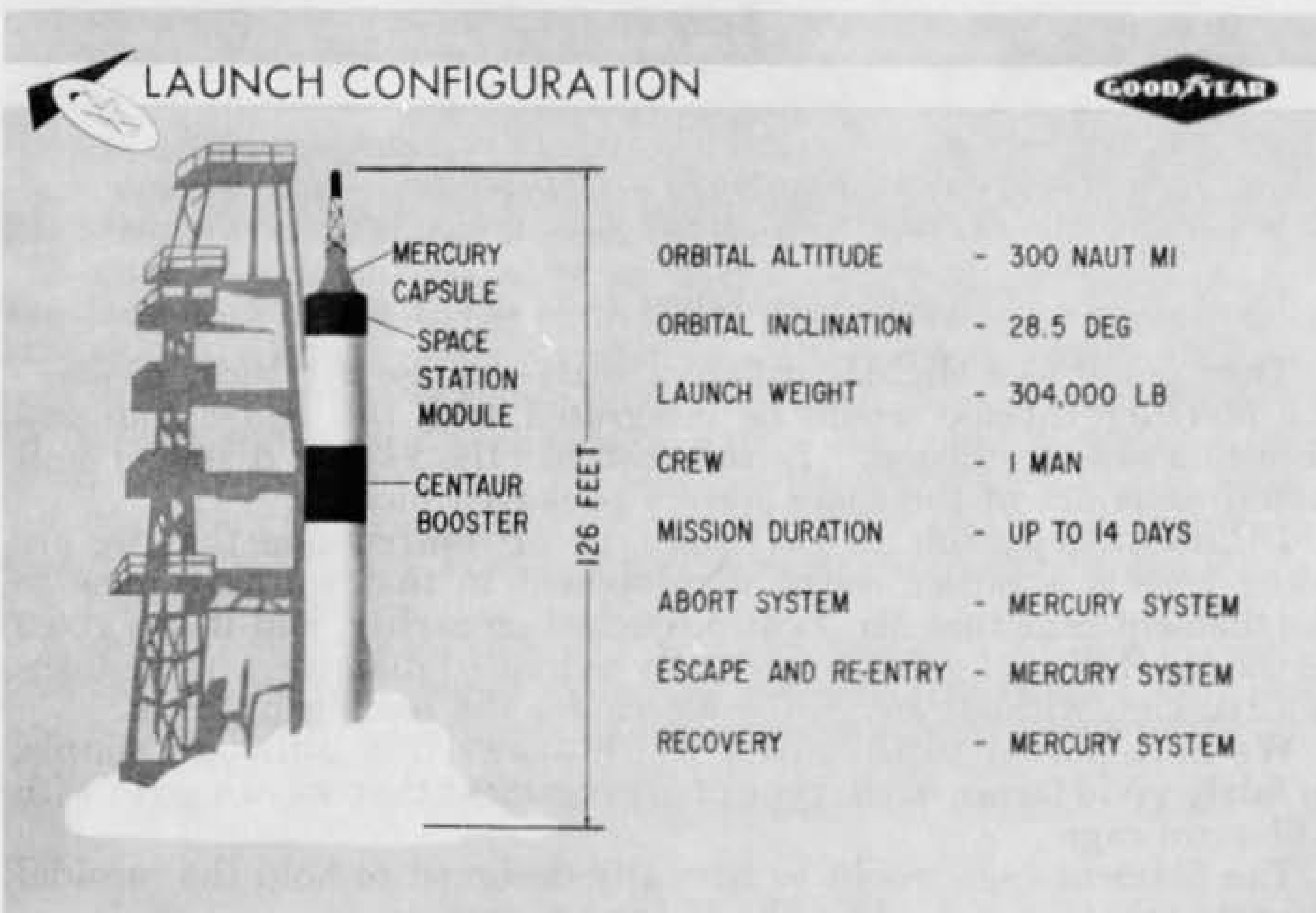
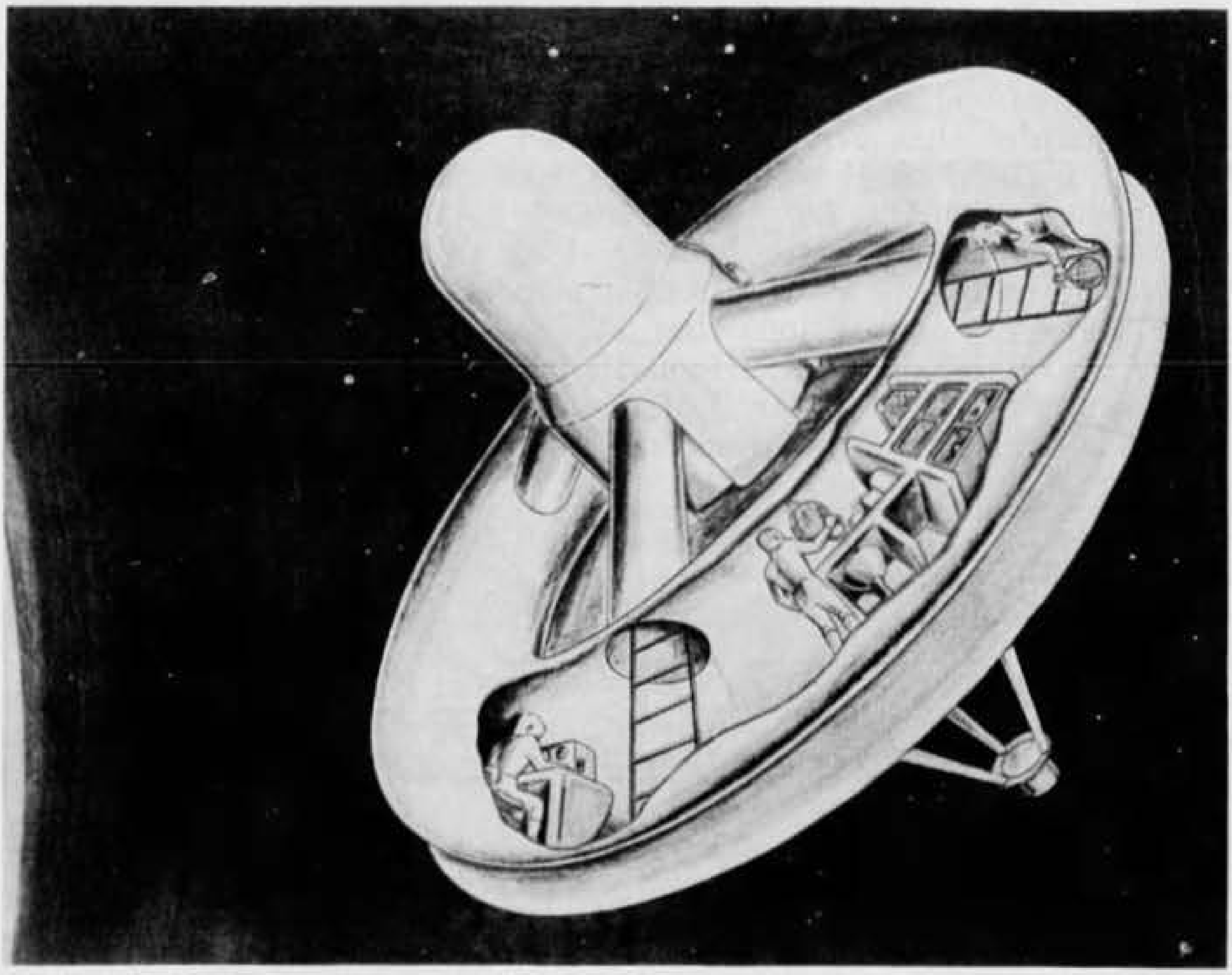


FIGURE 13



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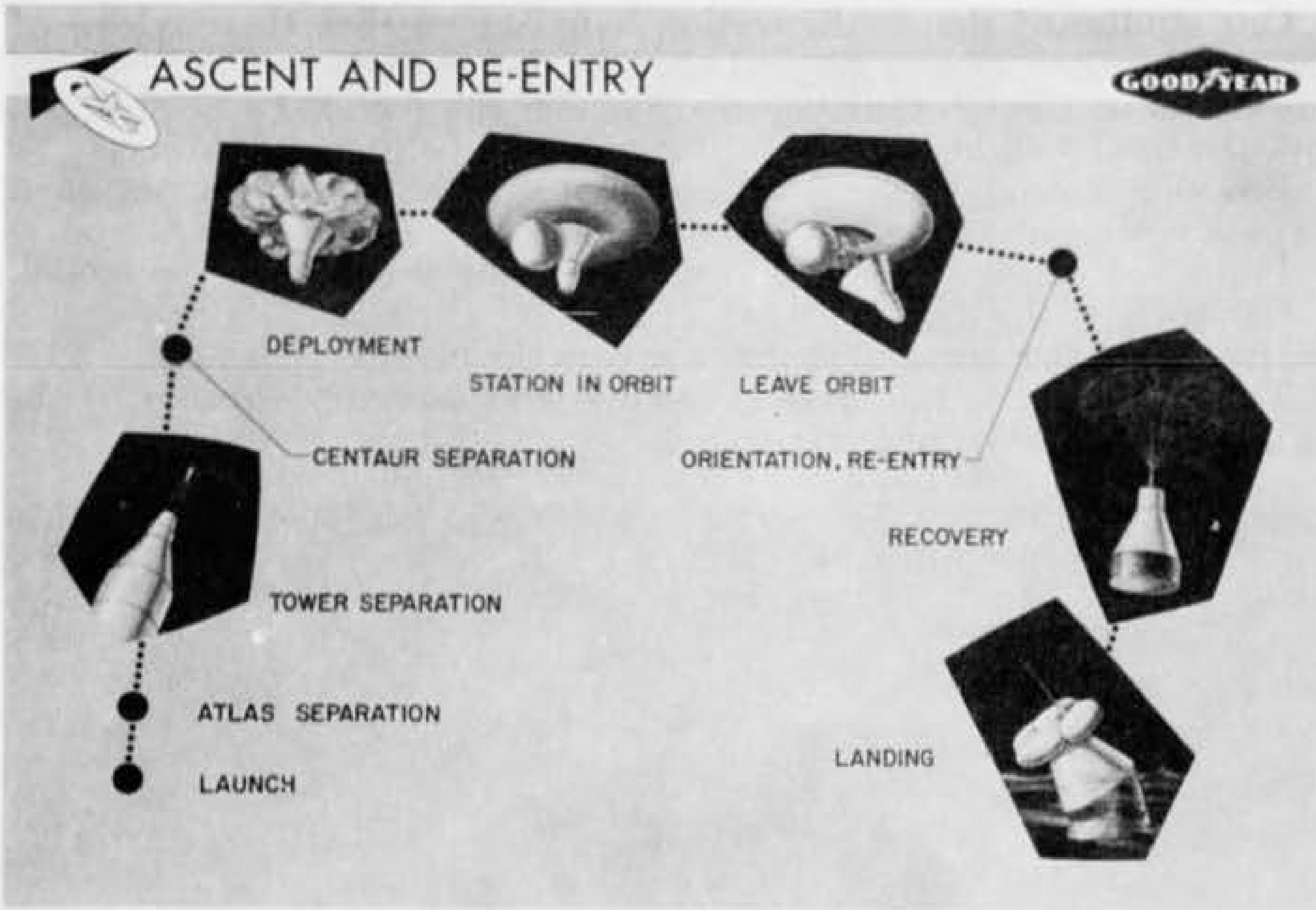

FIGURE 12

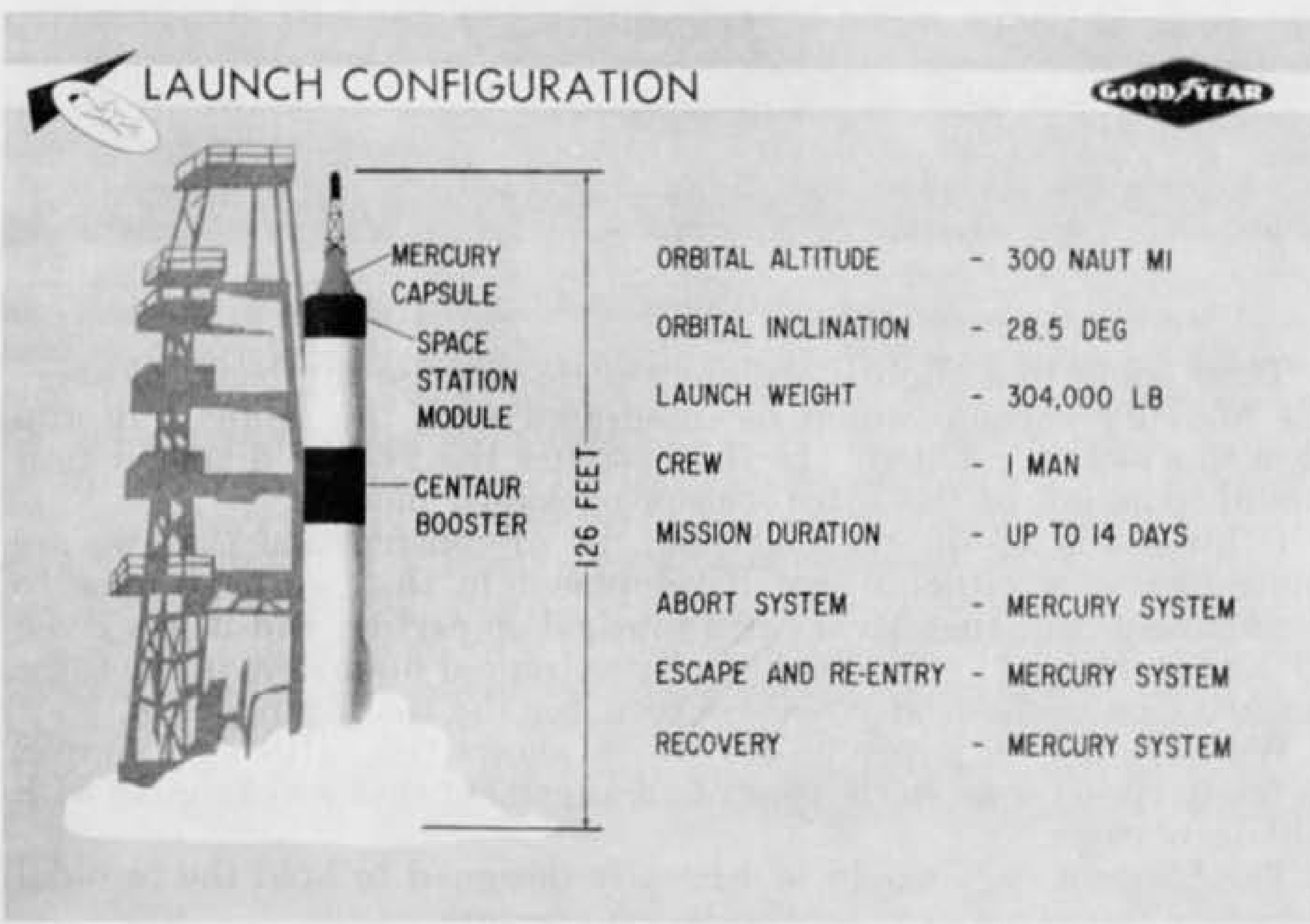

FIGURE 13

Our studies of this configuration have shown that the payload of the packaged space station and the re-entry vehicle are well within the limits of the Centaur booster, that is, the payload CG position, and the total weight are compatible with the booster capability.

For that reason we have no redesign on the booster to put such a space vehicle into orbit.

Perhaps I can describe this better by going actually to the model.

Can we have the lights, please?

Here we have the model that you saw in the movie. (See figure 14.)

You can see that the mission module and Mercury capsule would be launched in this configuration.

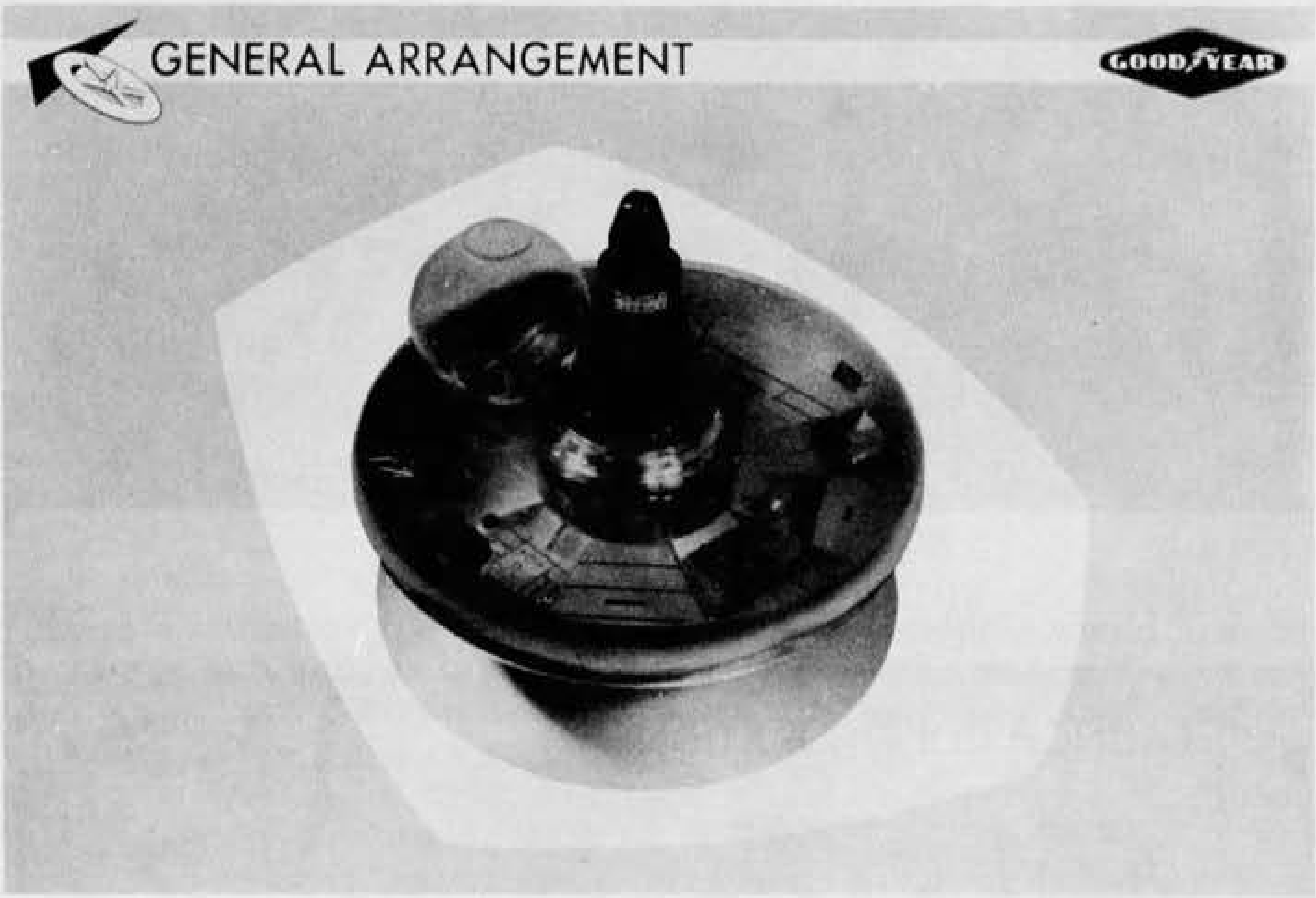

FIGURE 14

Then going to a slightly different scale—excuse my back, please—the Mercury capsule would be integrated with the center hub and then this section inflated. In this instance the 24-foot diameter unit would come out of the space station packaged module.

I think it is significant that the type of construction that we are using here is a rather recent development in that we have gone to the filament cage that Mr. Loftin touched on earlier, and it has given us the capability of going to virtually unlimited diameters in the torus construction without any real concern for the tooling problem.

We have here a paper model which shows this, although simple, in fairly vivid terms, in the type of arrangement that we can go to with a filament cage.

The filament cage would be basically designed to hold the toroidal structure that is required for the design pressure.

Figure 15 is a photograph of the bladder internal construction, which would be then the pressure-sealing member of the structure.

techniques, and the detailed assessment of the long-duration capabilities of man in a weightless environment.

The initial step in providing the capabilities for the manned exploration of space is Project Mercury. This project is designed to put a manned satellite into an orbit more than 100 miles above the Earth's surface, let it circle the Earth three times, and bring it back safely. From Project Mercury we expect to learn how man will react in a space environment, what his capabilities will be, and what must be provided in future manned spacecraft to allow man to function usefully. Such knowledge is vital before man can participate in other, more difficult, space missions.

But the determination of man's capabilities in a space environment is only one of the benefits that will be derived from Project Mercury. Of equal importance is the technical knowledge being gained during the design, construction, and operation of the first vehicle specifically engineered for manned flight in space. The accomplishment of Project Mercury will mark a tremendous step forward; man's venture into space will immeasurably extend the frontiers of flight. The speed of flight will be increased by a factor of eight over present achievements, and the altitude by a factor of five; the environment encountered in space flight will be one that heretofore has not even been approached. This extension of the flight envelope has required major technical advancements in many diverse fields including aerodynamics, biotechnology, instrumentation, communications, attitude control, environmental control and high-speed parachute development, to mention only a few. By its very advanced nature, therefore, Project Mercury has opened the door for future manned space-flight programs.

Origin of program

The genesis of the Nation's manned space-flight program dates back to research and study efforts carried out in 1956, 1957, and 1958. In those years, studies were made by the National Advisory Committee for Aeronautics, predecessor of the National Aeronautics and Space Administration, and by each of the military services. A detailed description of these early study programs can be found in House Report No. 1228, entitled "Project Mercury—First Interim Report, a Staff Report of the Committee on Science and Astronautics."

In August 1958, the President assigned the responsibility for the manned flight program to NASA, which by that time had been established by law, though it had not yet become an operating agency. At that time, the early work on the capsule concept, the painstaking analysis, design, development, and testing of shapes, had progressed to the point where on August 1, 1958, Dr. Hugh L. Dryden, then Director of NACA and now Deputy Administrator of NASA, was ready to present to the Select Committees of the Congress on Astronautics and Space Exploration, a program which he called technology of manned space-flight vehicles. Dr. Dryden's testimony included the following statement: "This program that we are talking about will lead to a man in space in something of the order of 2 to 3 years, depending on how much luck you have with it."

Although the responsibility for the manned space-flight program was assigned, in 1958, to the National Aeronautics and Space Admin-

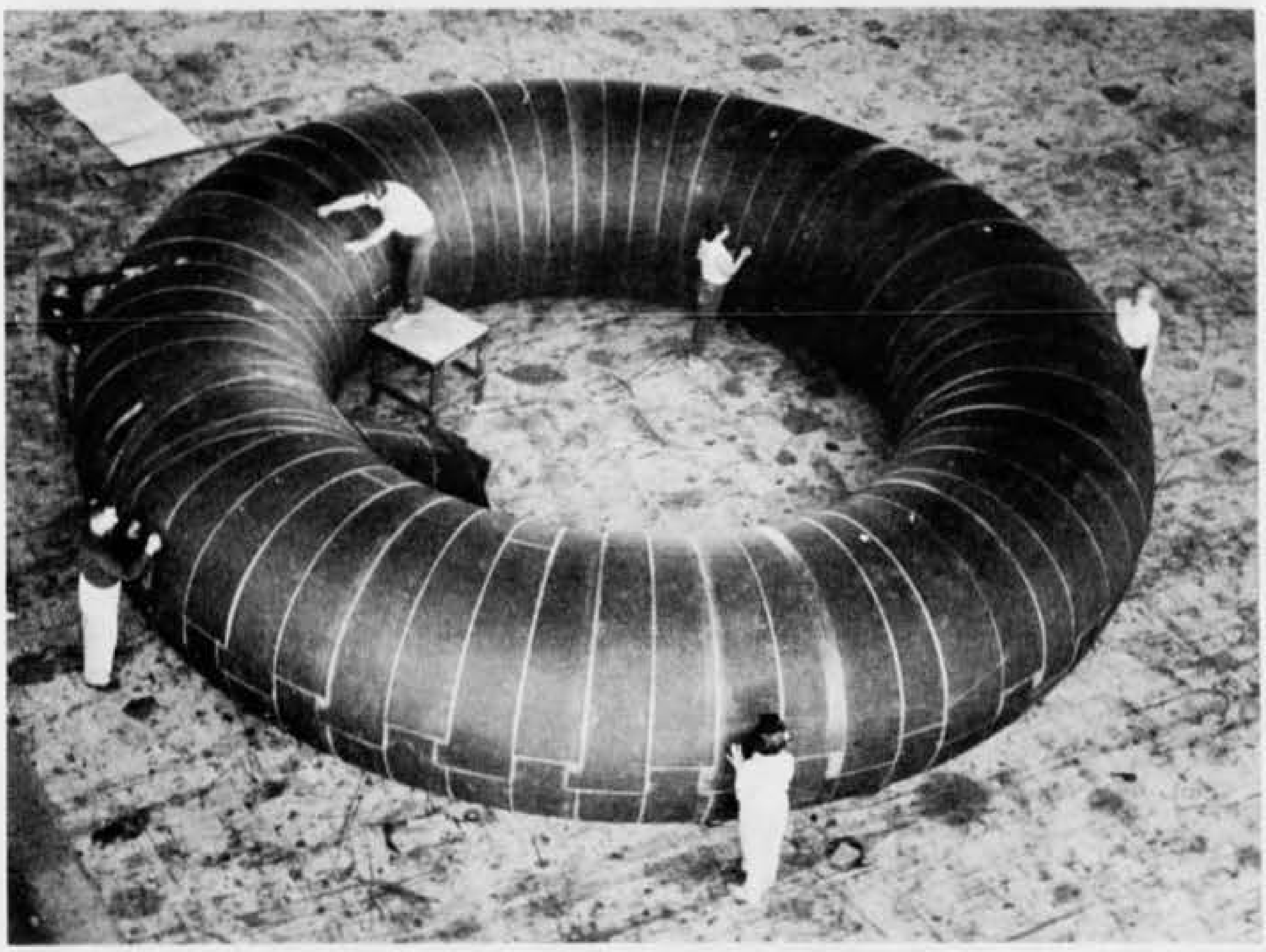

FIGURE 15

It is important to note in this configuration many of the components, such as bunks, and other required equipment; work tables, work stands could also be of the inflatable type of construction. And these then lend themselves to similar packaging and light-weight capability in the launch configuration.

Of course there is the question asked, what do we see in looking at the early availability of a space vehicle?

Figure 16 summarizes some of these. We feel the approach we are discussing here with the torus configuration lends itself directly to studies of artificial gravity simulation. It gives us a working laboratory where we can investigate, as on a test-bed basis, the performance of life-support systems, auxiliary power, attitude controls, and it provides a very natural test-bed for such programs as the earth orbiting laboratory that is one of the considerations in the Apollo planning, as well as the Military Test Space Station which the Air Force is now considering.

Figure 17 shows a picture of the center hub of a 30-foot diameter unit that we are building on corporate funds at Goodyear. This unit will be assembled with the 30-foot torus shown in Figure 15.

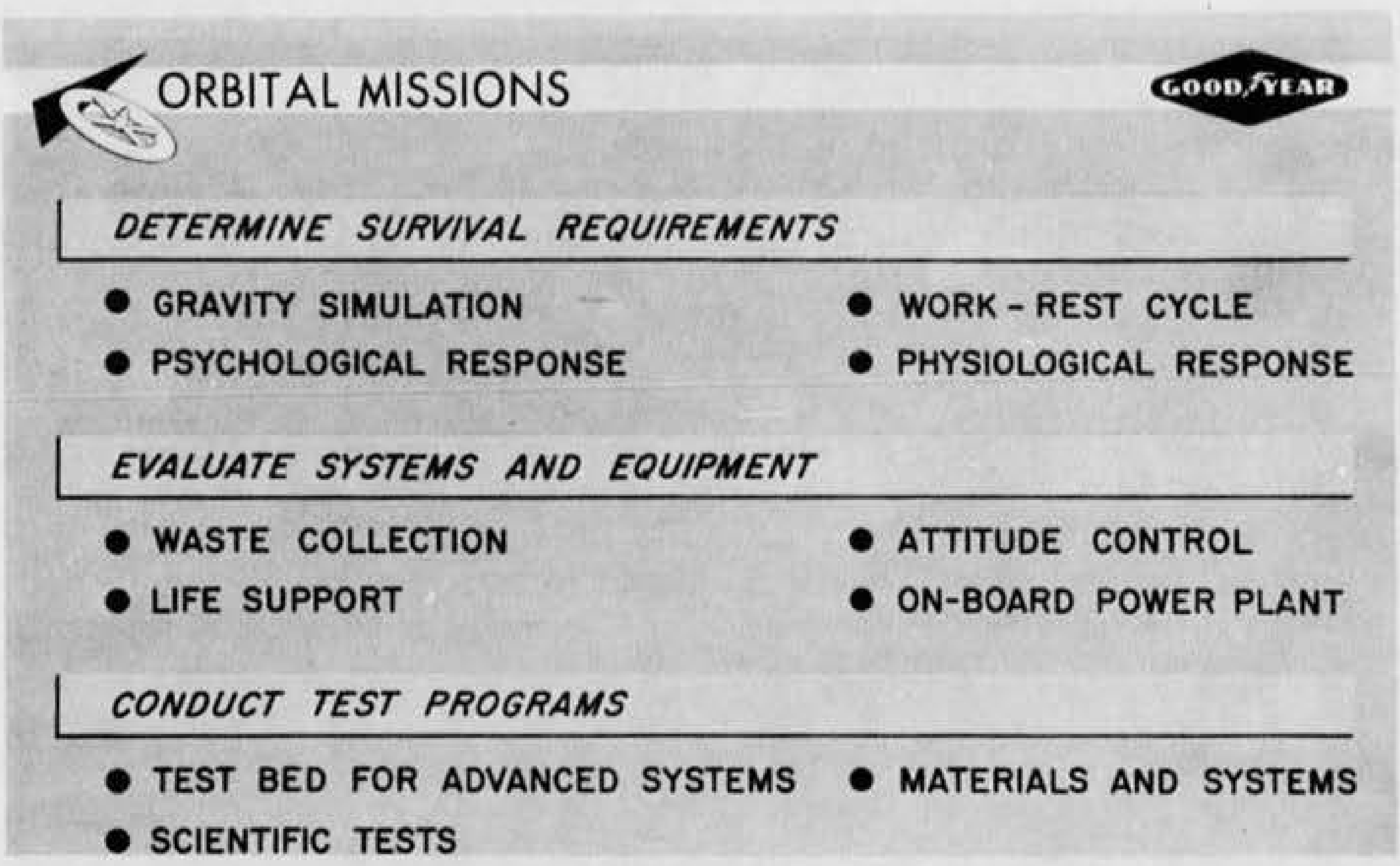

FIGURE 16

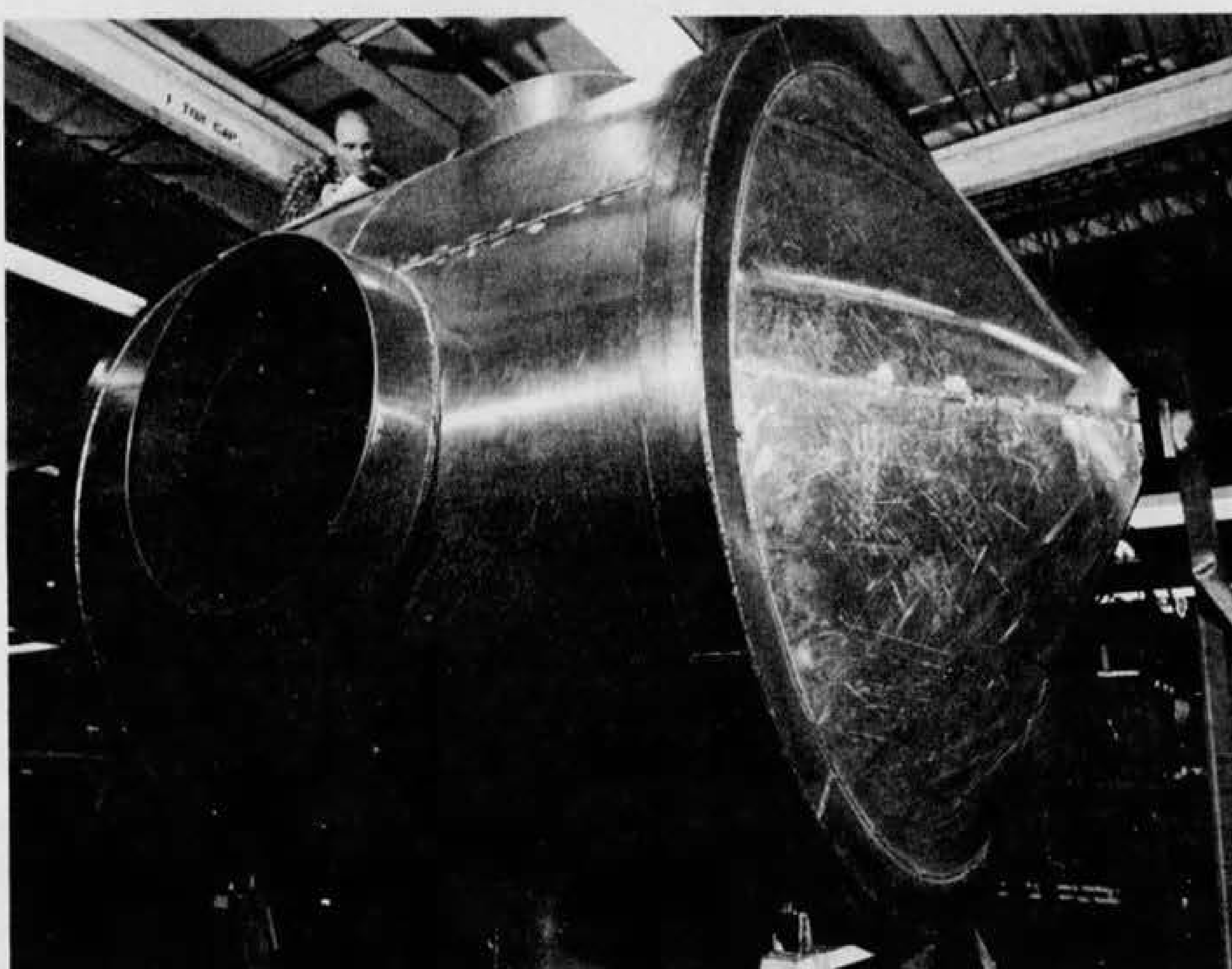

FIGURE 17

Figure 18 shows a development plan which we feel is feasible, based on our current work in house at Goodyear, and that with the Langley Research Center and with the Air Force.

As Mr. Loftin and Mr. O'Sullivan pointed out, we too agree that there are no major technical breakthroughs required to work toward an operational system of this type in approximately 3 years.

This is not to say certainly that we have the answers to the coating problems in terms of radiation, thermo-balance and a number of other areas, but we do feel the education we are getting now in the structural design of these full scale units does give us a firm basis in this area.

Our plan here would be to work toward vertical shots and then the fabrication of three orbital full-scale prototype units, two of which would be unmanned, the third manned, and as previously mentioned, would utilize the Mercury capsule for the re-entry of, in this instance, a one-man crew.

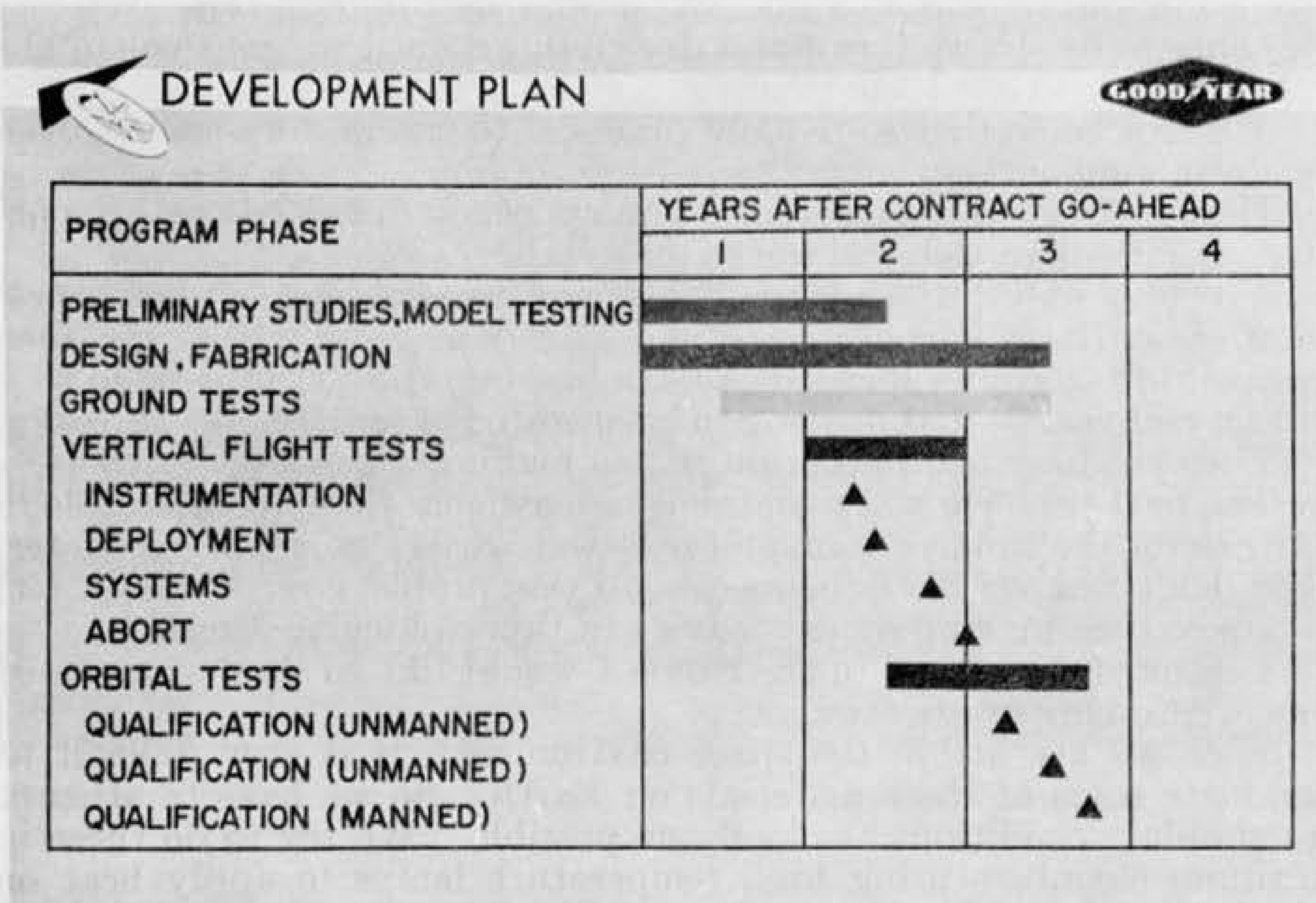

FIGURE 18

This completes my portion of the presentation.

Mr. RICHARDSON. One other thing I would like to point out, that I think Mr. Madden overlooked, is it allows the man to get out of his space suit, to take it off after he comes out into the space station, and to work in a normal atmosphere in the space station.

Things like this we have to learn as we go on into space.

STATEMENT OF DR. ROBERT S. ROSS, DIRECTOR, AERONAUTICAL RESEARCH AND DEVELOPMENT DEPARTMENT, GOODYEAR AIRCRAFT CORP., AKRON, OHIO (Continued)

Dr. Ross. I think the next things we want to tell you are as we got up into space, we started to realize there are other problems such as high temperature. We wanted to find out if we could make these materials that normally go to 200 degrees Fahrenheit, so they can take the high temperatures.

Looking through all the different types of metals that are available, we found that materials like some of the stainless steels or René–41, for instance, as one sophisticated type of material, has a very good temperature strength curve. Actually, you can get up to 1,500 or 1,800 degrees Fahrenheit and still retain strength.

The problem was to get this material drawn down into fibers so we could weave it into cloths. We found we could do this. We had it continually drawn down and drawn down until we got some of the fibers to a third of a human hair.

We took some that were more practical to use, and we made woven materials out of them.

Here are some samples of stainless steel drawn down to one-thousandth of an inch and woven into cloth.

You may find it difficult to get some of these materials in flat sheets that are uniform in characteristics. If we can get it to wire and then weave into cloth, we find it is a flexible sheet, and it can be used as a structural vehicle that is going to be operated at high temperatures.

Then you have to do something about making it gastight.

The next problem was to develop an elastomer that would be able to withstand the kind of temperatures that we are going to encounter. We don't feel we have the answer to this problem yet. We do feel we have been making some headway in this particular direction.

I think if we can go to the movie I would like to show you one of our high-temperature tests.

Since we are not in the space environment, it is very difficult to evaluate some of these materials on Earth. So we have to attempt to simulate conditions as closely as possible. We try to do these in altitude chambers using high temperature lamps to apply heat on these materials. Such tests do not show the problem as you come through the atmosphere and have the air rushing over the material, itself, so we developed a little hydrogen and oxygen rocket. We put a little material in the blast of this rocket and try to evaluate what takes place here.

(Movie shown of High Temperature Material Test.)

Dr. Ross. We have this piece of material, similar to what you have in your hands, in a frame in a hydrogen-oxygen rocket blast. You will notice when the hot gas hits the piece of material, it will start to glow and it will actually get red hot there. It still retains most of its properties.

This is just a simulated type of test. As I say, it is the type that we are using to try to screen the different kinds of materials that we would need for high-temperature re-entry.

There are two basic types of re-entry that we can encounter. One is the ballistic type, where you have some type of vehicle to let you use drag.

The second type is the lifting type, where you come in with wings and can fly in the atmosphere.

With these expandable type of structures, we find both of these types of units can be put on a launch pad in a small package.

Figure 19 will show you what we call our Ballute, which is a combination of balloon and parachute.

Working with the Air Force and NASA, using their laboratories, we found that you can make a balloon-type vehicle, which you can see at the left here, with a torus-type ring around it, which can be attached to a re-entry vehicle or escape capsule.

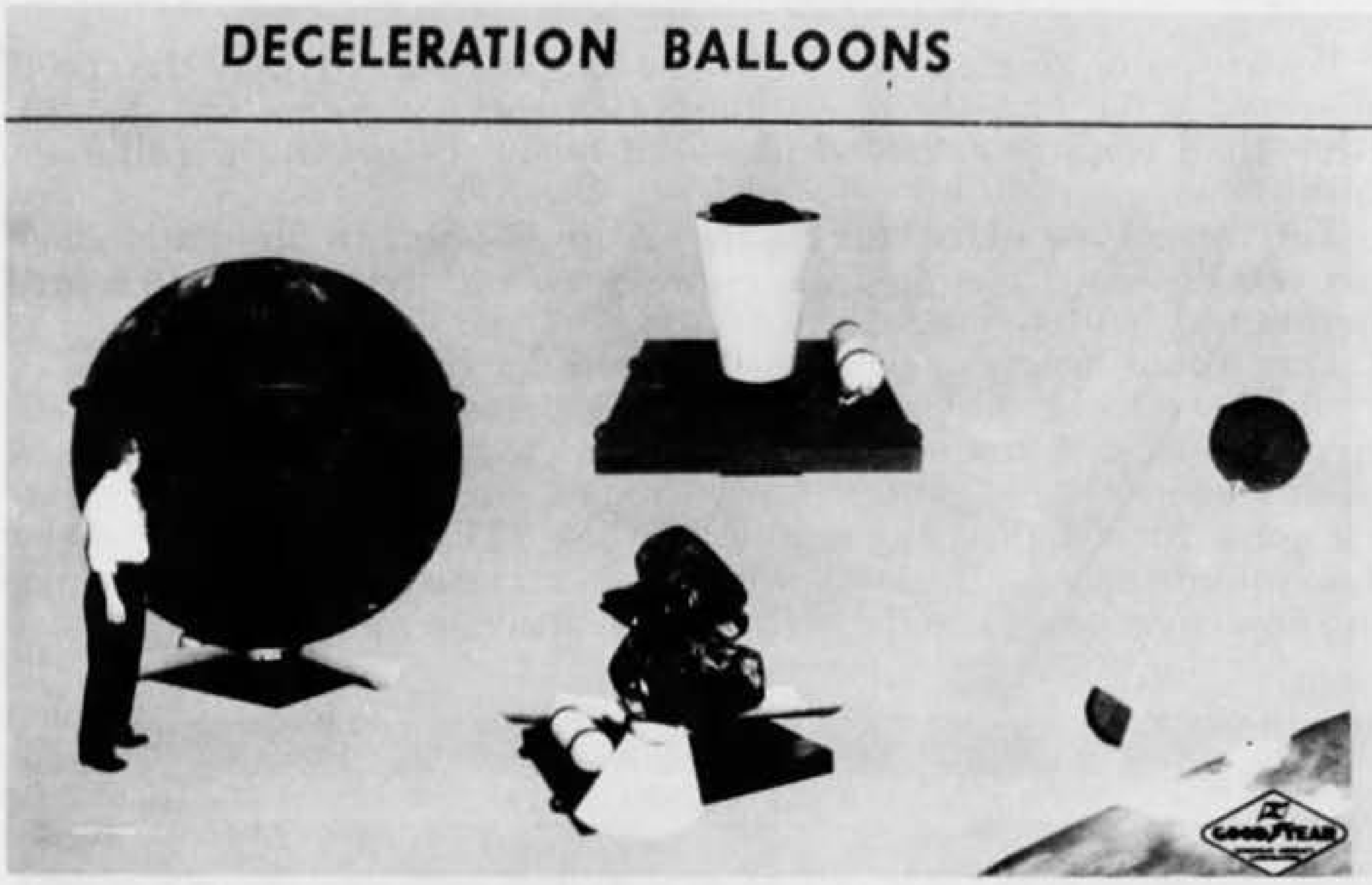

FIGURE 19

This item, when opened up in the high altitudes, is actually positively inflated by the gas inside so we don't have the problem of a parachute, trying to open when there is no air. As it comes through the atmosphere it has to go through the speed ranges, and this particular type of vehicle can do it.

It inflates behind the body, makes it act like a shuttle-cock, and comes down through the atmosphere.

This is used on the Cree missile to bring back about a 500-pound weight.

I would like to show some movies of this in the NASA tunnels at 3½ times the speed of sound.

(Movie shown of Ballute in supersonic wind tunnel.)

Dr. Ross. You will have to watch it closely. It inflates in two-tenths of a second.

This is 3½ times the speed of sound.

After it is opened, we let it reel aft on a cord, and this changes the drag again. It increases it by getting it beyond the interference of the body in the front.

The trailing string that you saw was the means of preventing it going down the tunnel if anything broke loose.

Notice how steady it is.

This is the Cree missile that this unit was put on. The Ballute is folded in a package between the missile and the booster. When this booster is fired after the booster is dropped off, this Ballute, about a 9-foot diameter balloon-shaped body, comes out and decelerates the body and lets it come back to Earth.

This was the first of two shots on that particular project.

As far as we can tell, everything was successful. We don't know what to change on the next one. This has been a very successful program.

We are going to make some of these to operate at 10 times the speed of sound. We have been working with the Air Force and NASA using their equipment to test these out before we get to the full-scale unit.

The other type of re-entry that we might want to discuss is what can you do about coming from outer space and flying down to a predetermined landing space?

This would mean we would have to build a vehicle up in space. It would have to be all packaged into the launch nose. When it gets up into space, it would have to open up to the vehicle that we are talking about.

Figure 20 is a typical example of this. The booster would carry it on up into space. There it would open up into a vehicle with wings and now come down and fly in from outer space.

FIGURE 20

Why do we think we can do this now?

I think if we can go on through the slides, I think I can show you a little bit of what we can do.

Figure 21 shows how the entire thing could be packaged into a small 5-foot by 10-foot nose cone.

These parts that you see here, that are indicated by cylinders and spheres, show the approximate volume of the hard structures, the instrumentation, the gas supply, the controls, and so on, as they would fit.

The space around here is taken up by the flexible structure. When you get that into space, it opens to this size vehicle.

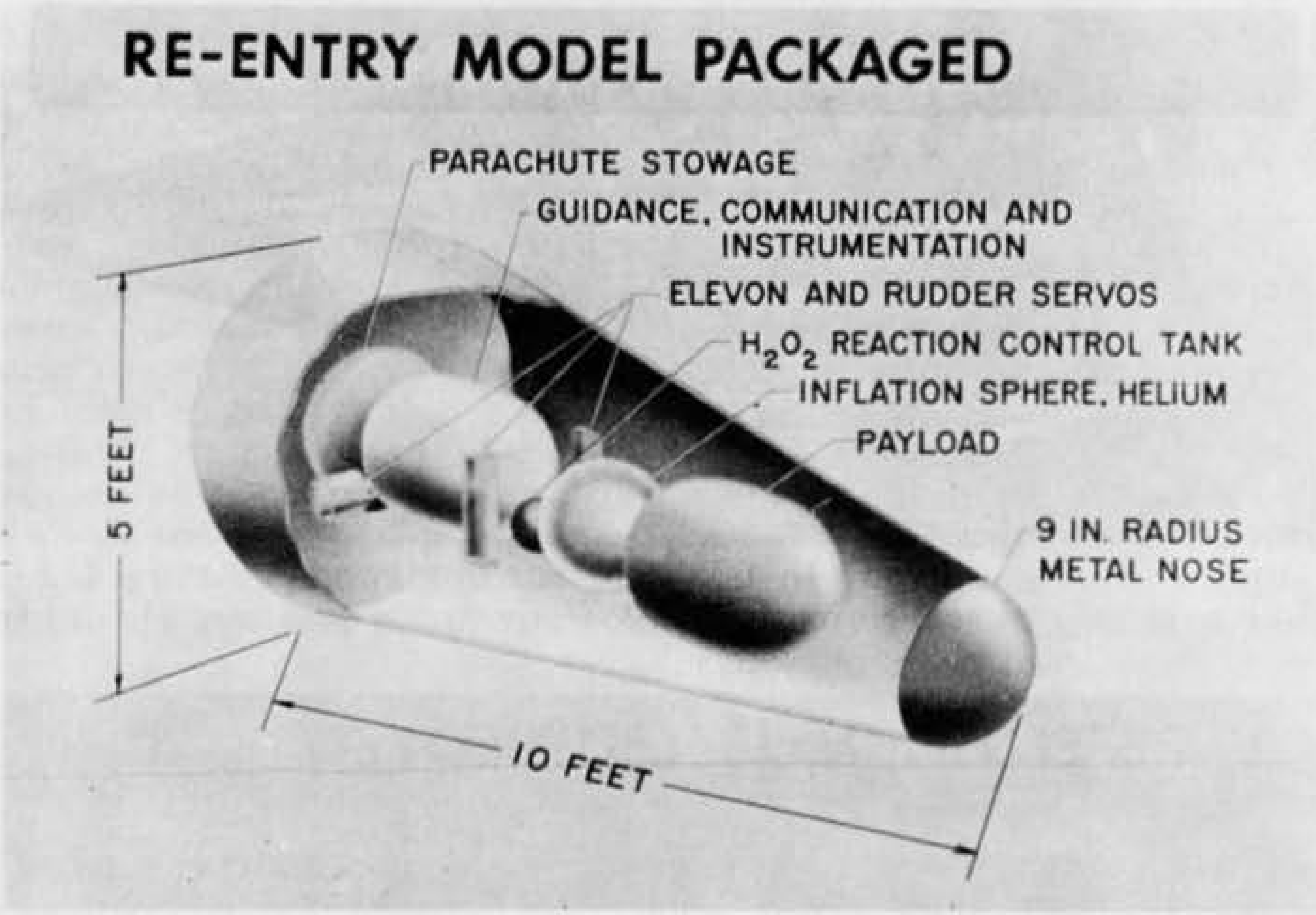

FIGURE 21

Figure 22 shows how small it is when it starts and how large it is when opened up. You notice the little parts in here are the same parts that we had on the package and how they are distributed to where they are needed in the vehicle.

Figure 23 is another view of the flight configuration.

This is a typical type of re-entry ship. It has the same aerodynamics as any other hard structure. The inflated structure material is made out of a metal and has the same kind of properties as any hard structure.

I believe this slide will show it as clearly as any the reason we think we can do more things with this approach than with some of the hard structures; that is, we can go to a lighter weight vehicle that could fly in the atmosphere at high altitudes.

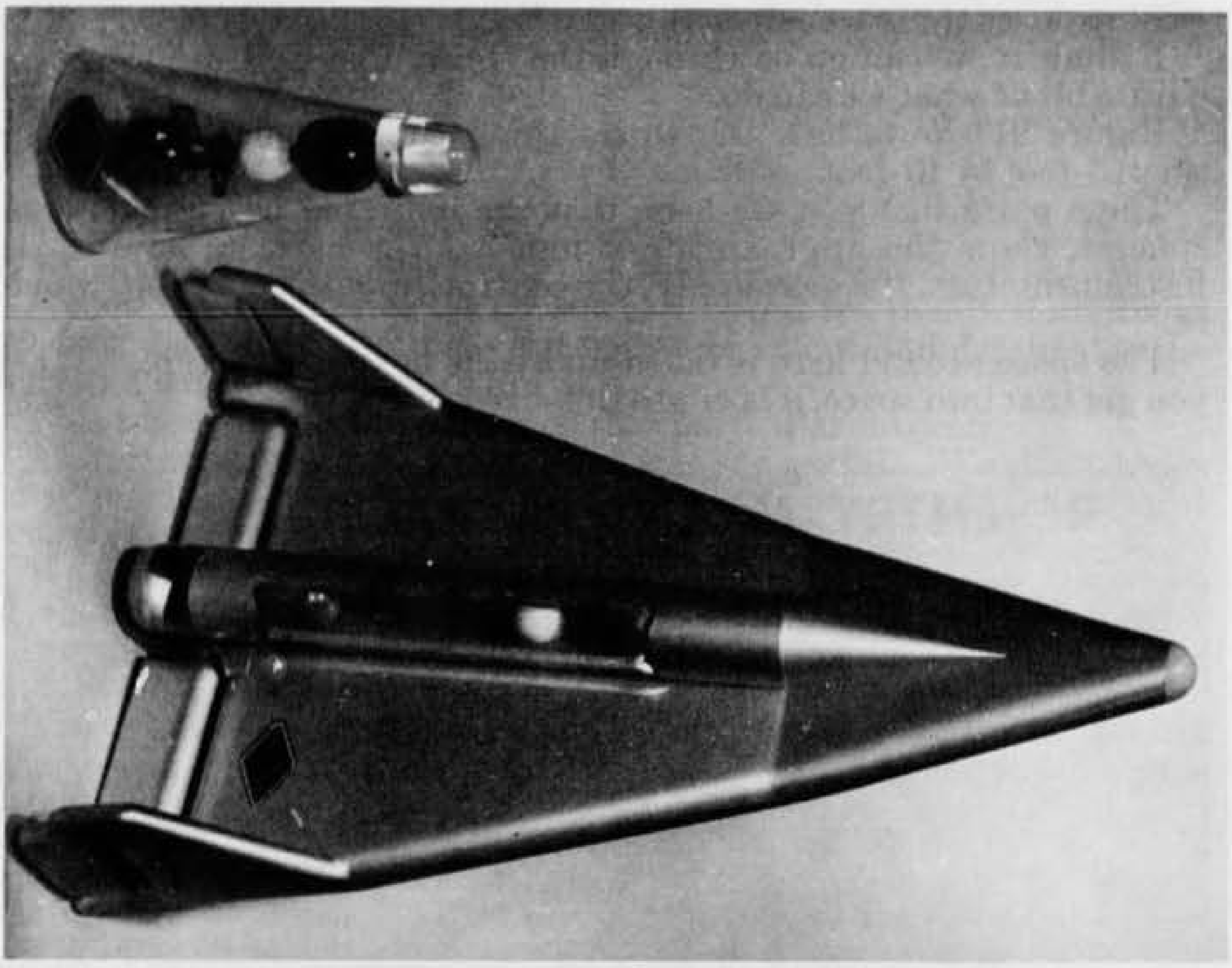

FIGURE 22

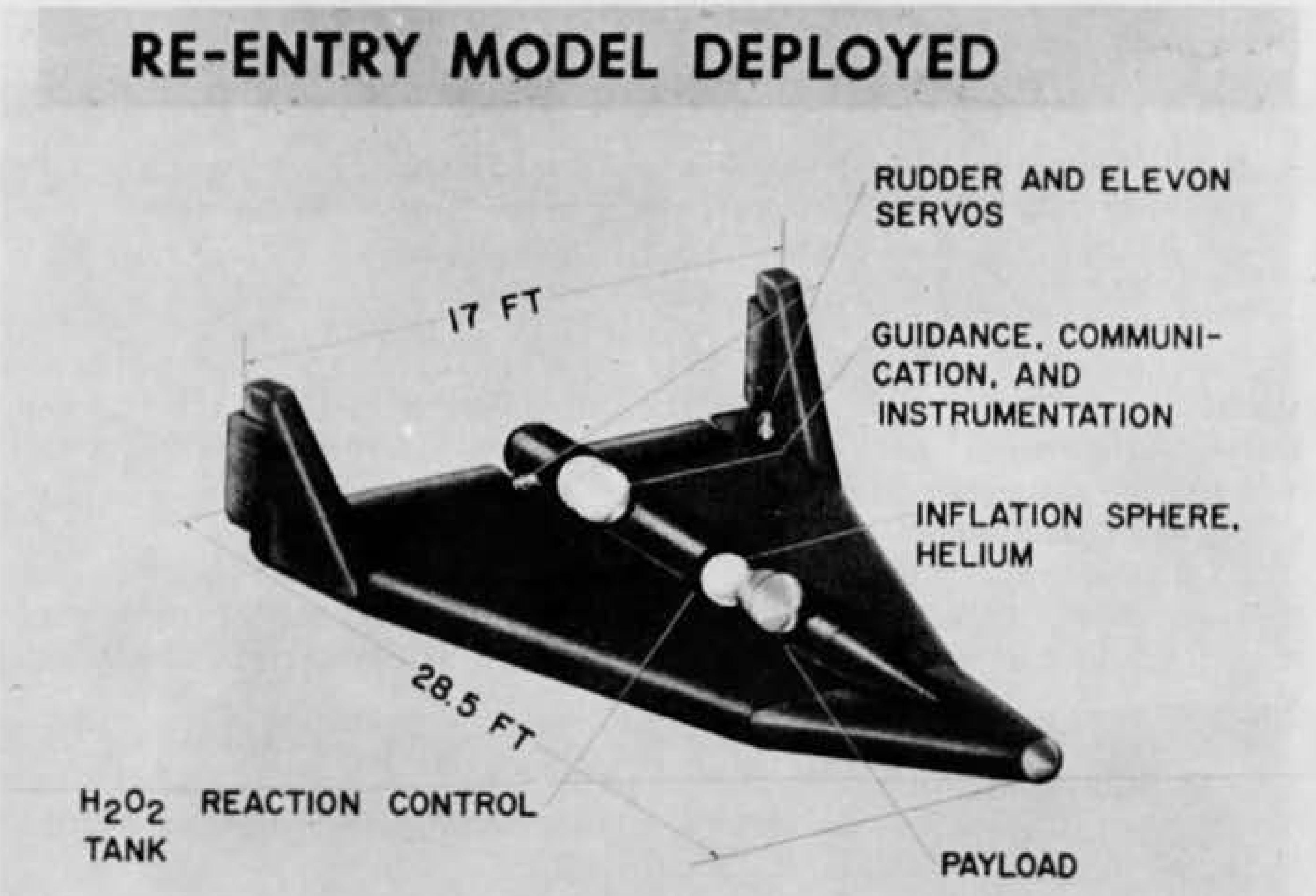

FIGURE 23

Figure 24 is a typical curve that shows the altitude and velocity. And this shaded area that you see is what we call the re-entry corridor. This is where most vehicles will have to fly when they come in from outer space.

Normally, each square foot of the wing surface must carry somewhere around 25 pounds per square foot. By going to this inflatable, light weight structure, we can probably divide that by 10 and have each square foot take maybe only 2½ pounds per square foot. This means you don't have to come down to the dense air to fly. You can actually come in and fly at the high altitude.

These upper lines here indicate the altitude at which you could probably fly with this vehicle and the lower region of this plot is where a conventional hard structure would operate.

These lines drawn on here are basically temperature lines. The bottom of this curve is the temperature through which you cannot carry a hard structure because it would burn up.

The upper line is the aerodynamic line. With our vehicle, you can see we would have lower temperatures.

So you see the whole thing is raised up. We can come in and fly at higher altitudes. Because of that, we do not have the high temperatures. This temperature may be around 1,500 degrees, where with conventional structure this is 3,000 degrees. We don't have to develop materials to go to such high temperatures as a hard structure. This is why if we can develop coatings and finishes to take 1,500 degrees, you can have a winged vehicle to fly in to a predetermined landing site. If you were just going to make a suborbital flight from Canaveral, Figure 25 shows you the footprint of your maneuvering capability. If you sent it up, you could pick any place in that area and

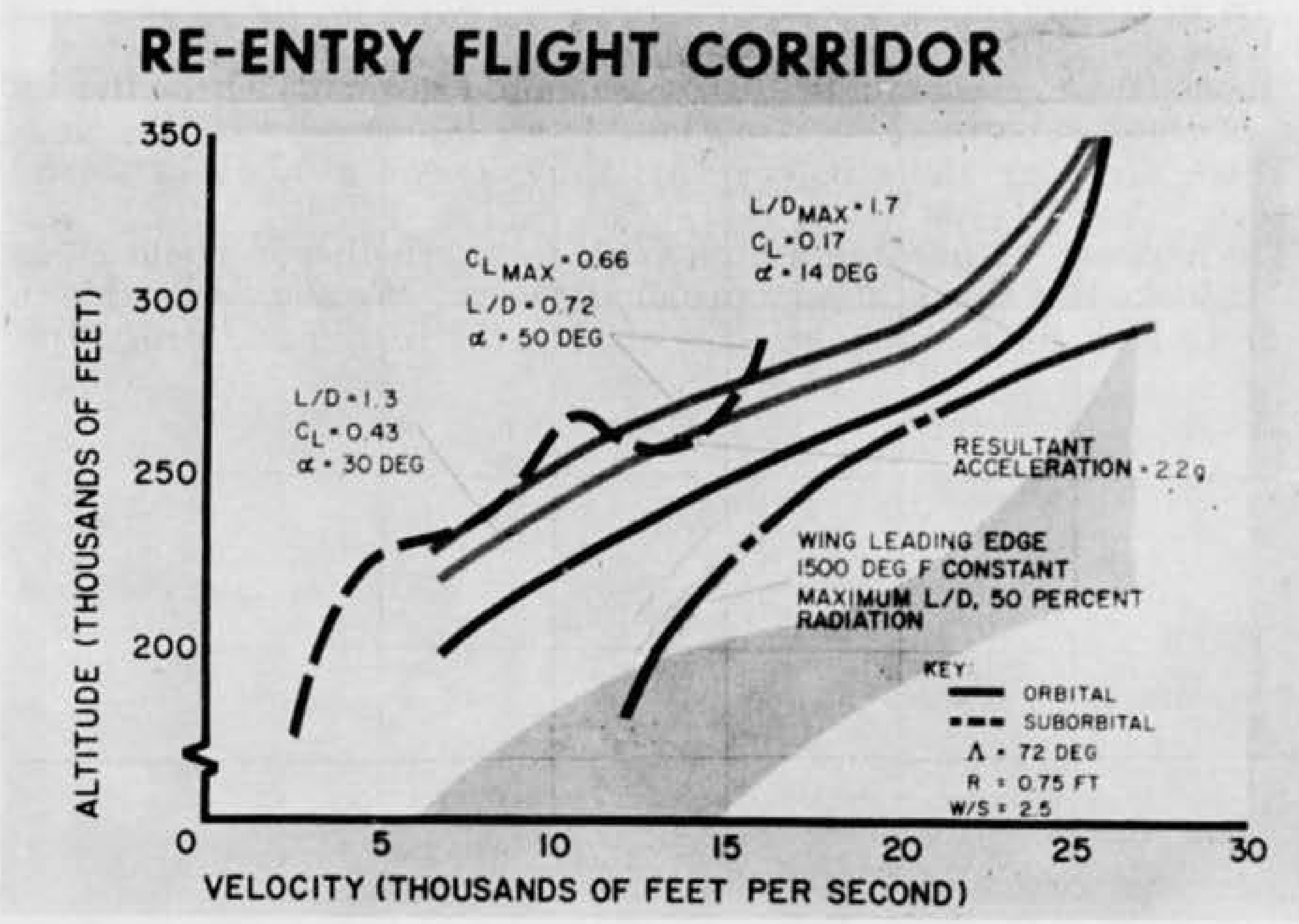

FIGURE 24

land on it. You might say, "I want to land on Island 9–A." and you would fly in as a conventional airplane. When it gets to the low altitudes, it is traveling at such a low velocity that it would operate much like a Piper Cub.

If you were going to put it into orbit, Figure 26 is looking down on the top of the world. This is firing out of some place like Vandenberg. You see, if this is the footprint of its maneuvering capability, you could pick almost any place in the United States and land there. You do not have to pick a particularly large field. Because of the light wing loading, you don't need a very large field to land in.

I think now I might show you a movie of one of these units assuming that this is the unit on the launch pad. This would normally be standing this way. The entire inflated structure is in this hard cover, and you can see the way it opens.

(Movie of Inflated Re-entry Glider.)

Dr. Ross. It opens up and goes to the predetermined shape. When it opens, it opens to that shape and you now have a lifting type of vehicle. It doesn't go to a sphere. It goes to the aerodynamic shape to which it was fabricated.

Then it can maneuver just like any other type of vehicle. The work that we are doing in our house now is to try to develop the materials that are needed to withstand the re-entry conditions that we will encounter on that kind of vehicle. As soon as that is done, we will be able to fly in from outer space.

(Movie shown of wing structure opening in tunnel.)

Dr. Ross. Here is an example of what would happen—you know in the suborbital shot we showed you, there might be some thought of it coming in where there was some atmosphere and you would have to open the wings in that atmosphere.

The next shot is in a wind tunnel and trying to open the wings with air going by. You will find that this thing is going to be tested at about 50 times the air load that we would normally encounter on one of these suborbital shots. There is air blowing by at this time.

There are four shots here. This thing opens in about a second or so.

The next one we put it at a high angle to see whether it would affect it. It looks like this is a very promising area. We should be able to go on to look for re-entry vehicles of both the lifting and drag type.

istration, the project has continued to be a team effort on a national scale that involves, in addition to NASA, facilities and personnel of all the military services, U.S. industry, and research institutions. The degree of cooperation between NASA, DOD, industry, and other institutions will become apparent in the body of this report.

In September 1958, a joint NASA–ARPA Manned Satellite Panel was established. This panel, with the aid of detailed studies by staff members of the NASA Langley and Lewis Research Centers, and with the advice and assistance of the military services, formulated specific plans for a program of research leading to manned-space flight. The specific plans derived by the Manned Satellite Panel were presented to the Director of the Advanced Research Projects Agency and to the Administrator of the National Aeronautics and Space Administration on October 3 and 7, 1958, respectively. Upon the approval by the Administrator of the NASA on October 7, 1958, a space task group was organized from personnel of the NASA Langley and Lewis Research Centers and immediately began operations at Langley Field, Va. The space task group was given direct responsibility for implementing Project Mercury.

Summary of progress to date

In January 1959, McDonnell Aircraft Corp. was selected as the prime contractor to design and construct the Mercury capsules. The selection was based on an industrywide competition; 12 firms submitted proposals based on NASA specifications for the satellite capsule. After a thorough evaluation of these proposals, the contract was awarded to McDonnell.

The compressed time-phasing of the project, between inception and scheduled flight, has required that research, development, design, and fabrication be undertaken simultaneously. Thus, while the McDonnell Aircraft Corp. was implementing the initial design phases of the Mercury production capsules, a broad research and development program was being carried out. This program included scientific and engineering investigations using a wide variety of technical equipment to determine a suitable shape for the manned satellite capsule.

Following these investigations, a flight program was initiated to develop and qualify the various components of the capsule. This flight program included airplane drop tests in which full-scale capsule models were dropped from large cargo aircraft at high altitude. The tests were used to develop a highly reliable parachute system and to determine procedures to be used in recovery operations. In other tests, vehicles were released from fighter aircraft at supersonic speeds to develop and qualify the capsule's drogue parachute. The escape system was perfected by launching full-scale capsules with the escape rocket as the only means of propulsion.

Rocket-boosted flight tests were required to check the capsule and its components over a range of speeds and altitudes. A solid propellant rocket booster, nicknamed "Little Joe" was designed and fabricated especially for Project Mercury. This booster, which develops one-fourth million pounds of thrust at takeoff, was used on a number of occasions to further aid in the qualification of the all-important emergency escape system.

FIGURE 25

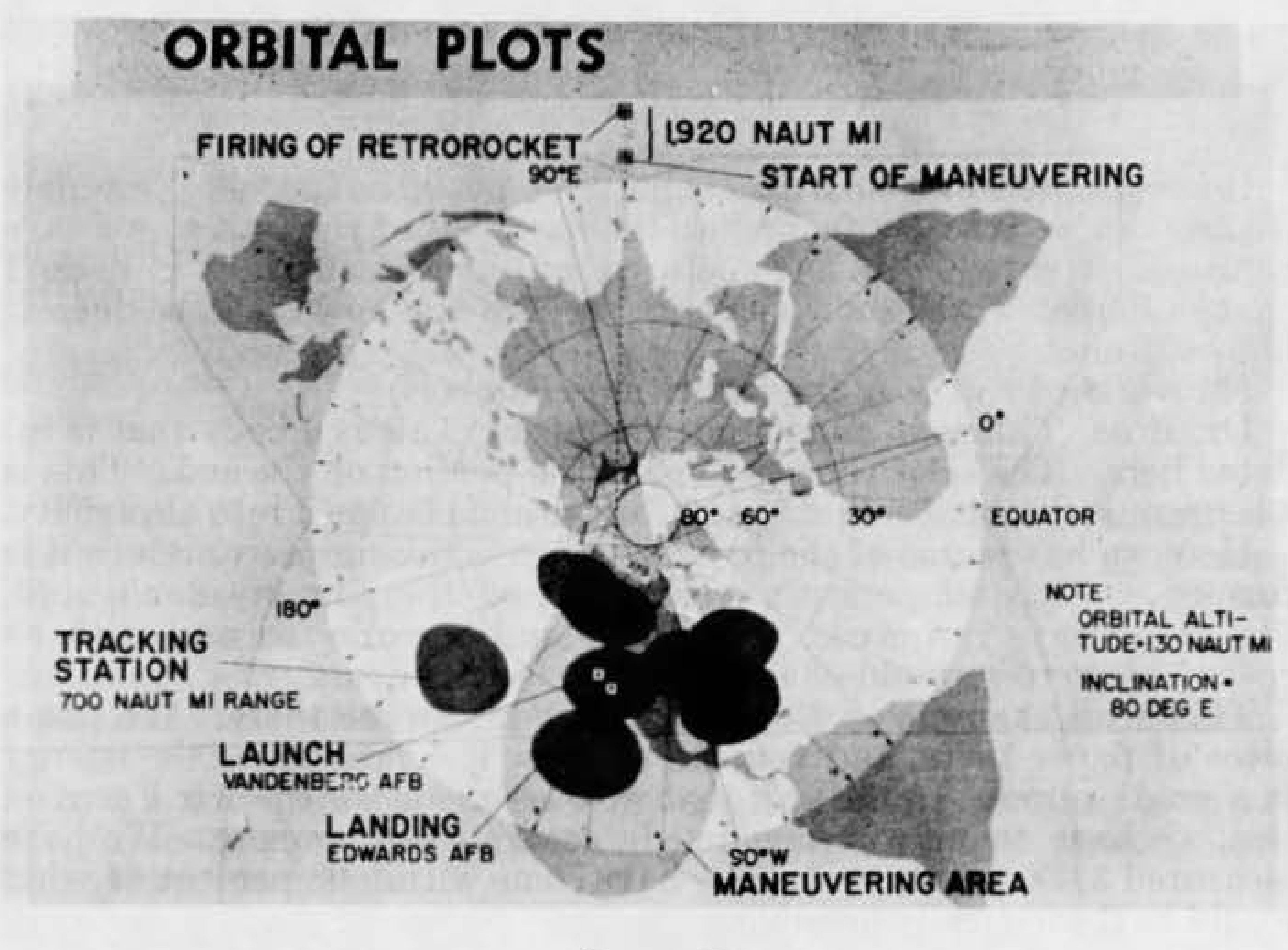

FIGURE 26

I mentioned there was one last type of structure that you might be interested in. That is one that we might want to have as a very large structure, but it doesn't have to have a high load-carrying ability, such as for instance a solar collector. Figure 27 illustrates here a typical example of how this is done.

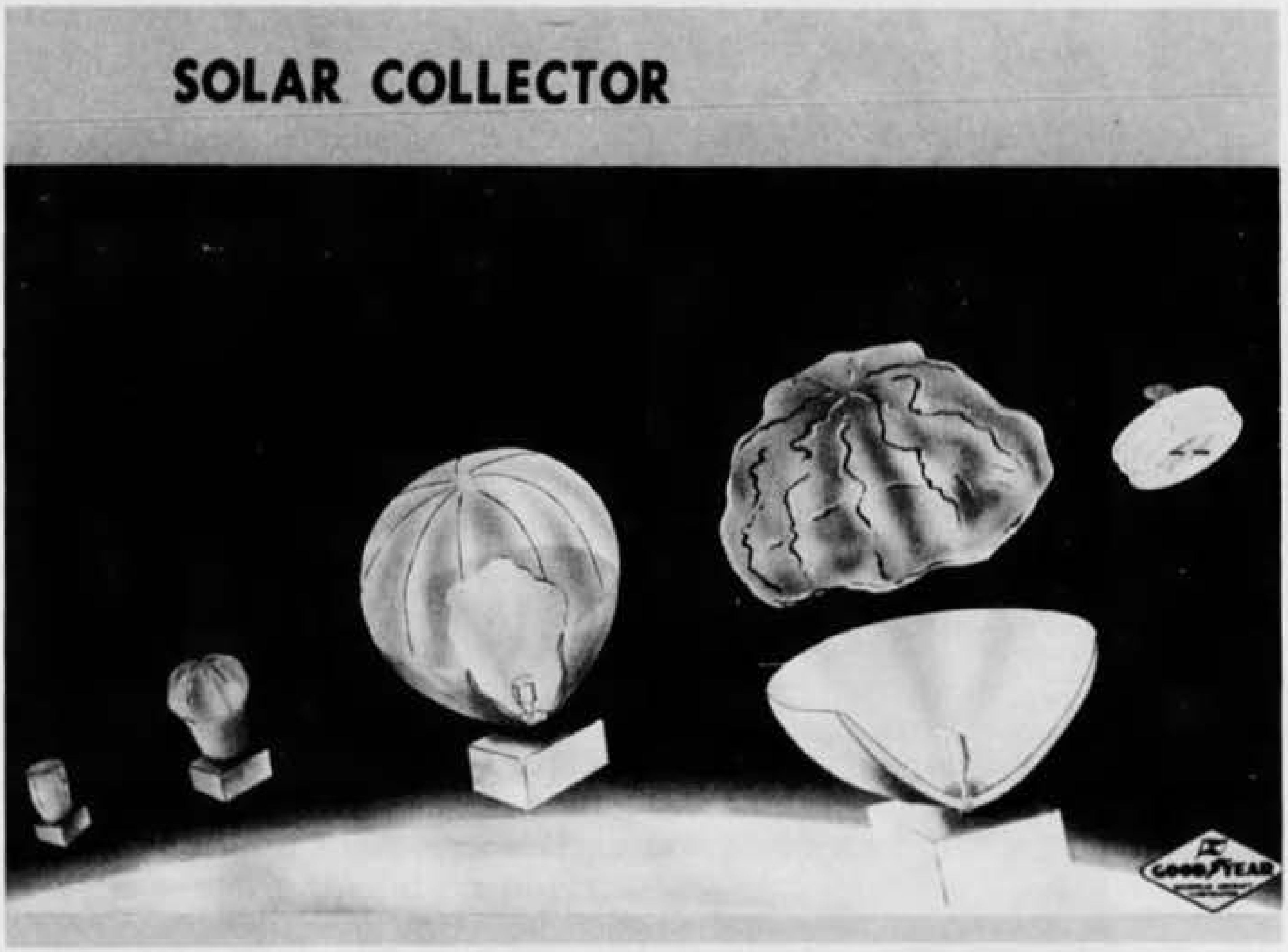

FIGURE 27

It is collapsed in a small package. We put it in space. We inflate it and then we actually foam onto the back end of the unit so we have rigidized it so when it is punctured by micro-meteorites it doesn't change shape. I will show you a movie here and how it can be done at high altitudes.

(Movie shown of foaming in altitude chamber.)

Dr. Ross. This is in an altitude chamber. This is a body that is inflated here. The solar concentrator is the portion on the end. This is a large unit that will collect the sun's rays and change it into electricity.

Here we have some of the foaming process taking place. Once it is foamed, a high temperature wire burns off the part we don't need. The Sun's rays can strike the mirror and be collected and with an energy converter would change it into electrical energy.

This is an example of a typical unit you can see there. We put a piece of paper there, and you can see how it concentrates the energy in a small source. In the unit that we have made for the Air Force on this, we have found a tremendously accurate ability here. We have measured 3,600 points on it. We have come within 98 percent of what would be theoretically possible.

It looks like this system could go into extremely large structures and make them into a reliable dimension that can do a job for us in space. This thing of course is made out of films and foils and can also be used for Earth applications.

(Four foot diameter collector model displayed.)

Dr. Ross. This was in a little package that was inflated and rigidized in space. I think this gives us an idea of the things we can do. If we go back to the slides now, I will show you what we are basically doing in-house.

Figure 28 shows that in order to use this material you have to consider everything from the basic material and coatings all the way down through to the actual application. Each one of these things as I mentioned before, have to be considered in designing the final vehicle. You can't just take a piece of material off the shelf. You have to design each of the structures for the specific application.

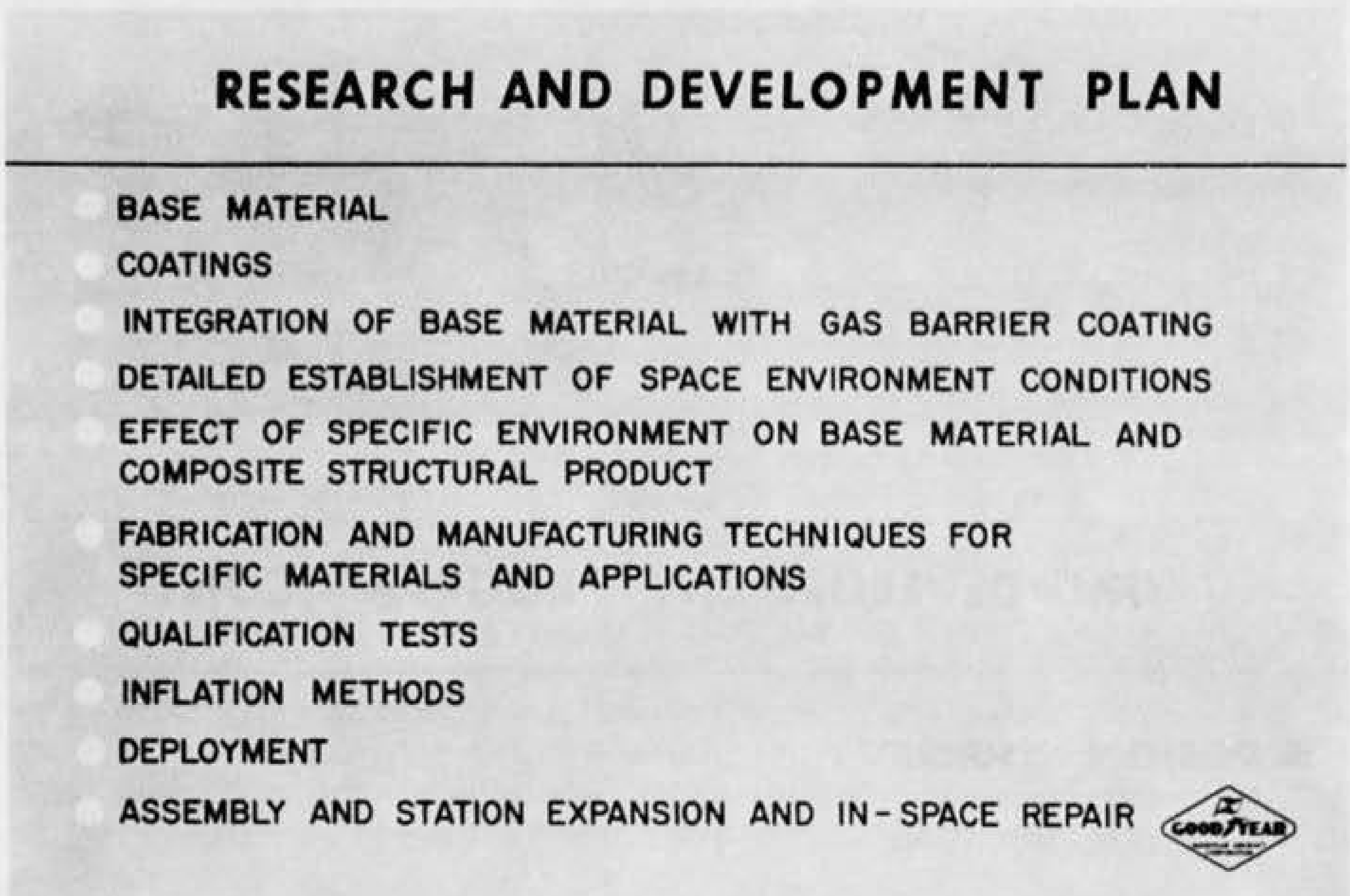

FIGURE 28

Figures 29 and 30 show that in-house we are defining three areas, those having to do with astronautics, aeronautics and the third area, which is the tough one here, getting into the theories and experiments that are necessary to prove out what you can do. The thing that is different about this and hard structures, is that we now have to develop equations and consider some things that we didn't have in conventional hard structures.

In a hard structure, once it is deflected beyond a certain point, you forgot about equations. We have to set up some new formulas and things that we can use.

GAC DEVELOPMENT PROGRAM

A. ENVIRONMENTAL MATERIAL

- ASTRONAUTICS
  - LITERATURE SURVEY - EFFECTS OF SPACE ENVIRONMENT ON MATERIAL
  - TEST PROGRAM - HIGH VACUUM, ULTRAVIOLET, AND TEMPERATURE EFFECTS ON SELECTED MATERIALS
- AERONAUTICS
  - RE-ENTRY - ADVANCE DEVELOPMENT OF PRESENT MATERIALS AND COATINGS
  - LIGHTWEIGHT MATERIALS - CLOTH-FILM FABRIC DEVELOPMENT, POLYURETHANE ELASTOMER DEVELOPMENT

FIGURE 29

GAC DEVELOPMENT PROGRAM (CONT)

B. DESIGN THEORY

- INITIAL BUCKLING
- STRESS, STRAIN, AND CREEP (CORD-TYPE FABRICS)
- POST BUCKLING
- STRUCTURAL DAMPING FACTOR
- EMPIRICAL FACTORS AND PROOF OF THEORY

FIGURE 30

A typical example, Figure 31 shows some of the formulas that you find in use in sheet metals. You see the constants that you normally have in some of them change to variables in the new formulas. They might even change from one direction to another because we can change the material that way too.

STRESS-STRAIN EQUATIONS

ISOTROPIC **(METAL SHEET, FILM, FOIL, etc.)**

$$\epsilon_x = \frac{1}{E}(\sigma_x - \mu\sigma_y)$$

$$\epsilon_y = \frac{1}{E}(\sigma_y - \mu\sigma_x)$$

$$\gamma_{xy} = \tau_{xy}/G$$

ORTHOTROPIC **(FABRICS)**

$$\epsilon_x = \frac{1}{E_x}(\sigma_x - \mu_{xy}\sigma_y)$$

$$\epsilon_y = \frac{1}{E_y}(\sigma_y - \mu_{xy}\sigma_y)$$

$$\gamma_{xy} = \tau_{xy}/G$$

FIGURE 31

Figure 32 is a typical example for a curve for a metal (left side). On the right side is a typical fabric. There is nothing wrong with having it non-linear as long as you know what it is and use it accordingly. A property we use on the airship is shown by the lowest part of the figure. We find some of these materials are—you put a load on a piece of material and let it hang for a period of time and it might eventually break. If you can predict it in advance, you can take advantage of it.

If you have these occasions once in a while where you have a very high load that you are anticipating and encounter, you can increase the pressure or increase the strength of your structure while you are flying and bring it back down to the normal pressure. You don't get it for nothing. You give up some of the life of the material.

You might cut it from 100 to 10 years. This gives you a rough idea, hurried brief background of a subject that we think has tremendous potential. It appears with this ability of folding up things in a small package and putting them on a launch pad, using the type of boosters that are planned today, we should be able to use space by opening them up into large structures that can do all types of work from the space station type, solar type. We in the R. & D. area feel this is one of the areas that offers great potential challenge and you can see we have had some great successes in our work in it.

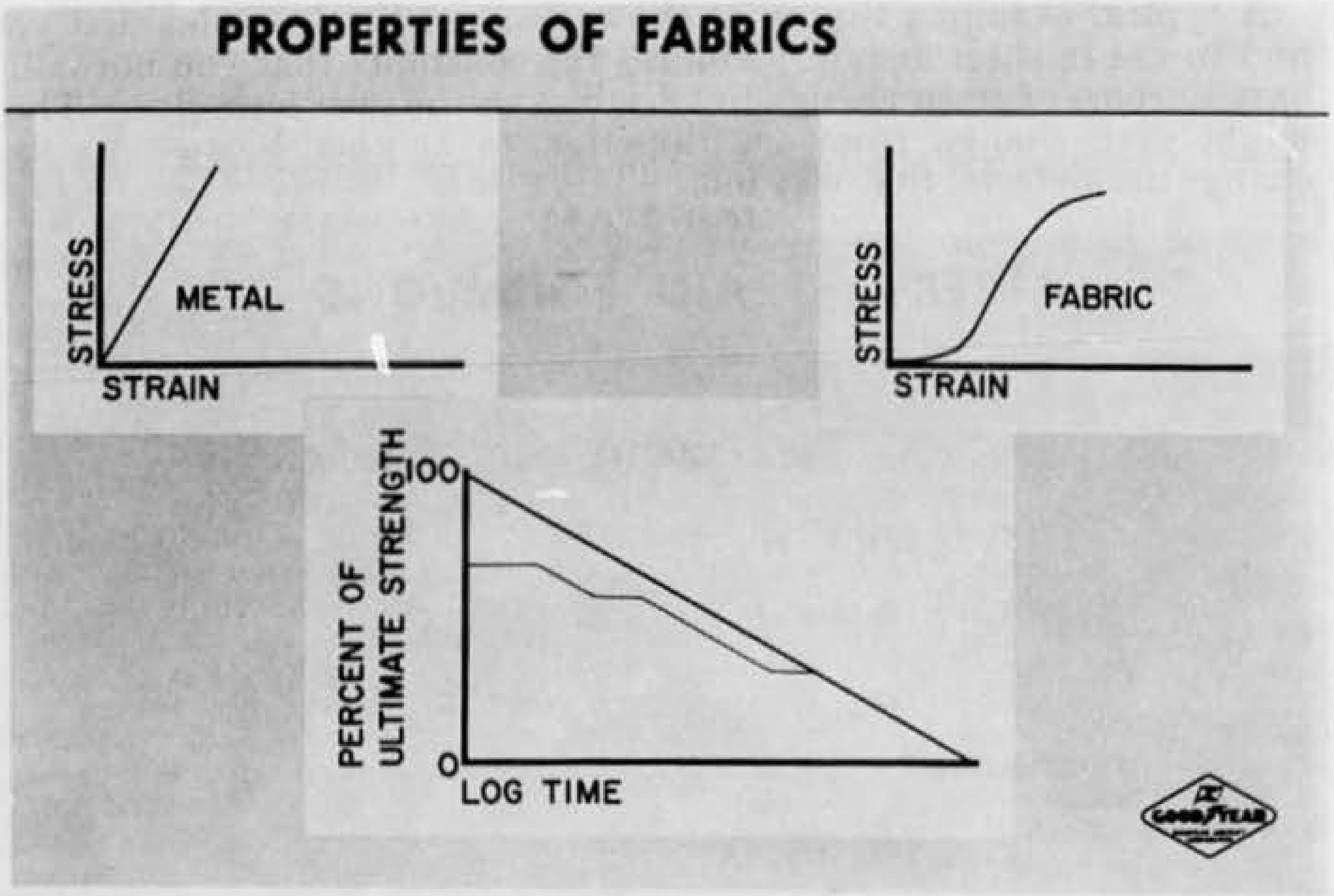

FIGURE 32

The CHAIRMAN. One question was asked about the cost. It is probably too early, isn't it, to give any definite idea about the cost?

Mr. RICHARDSON. I would like to try to answer that question, Mr. Chairman. Yes, it is pretty difficult to pin out exactly the cost of all of these things.

However, I think it is very evident that when you make a structure like this, we have it fully made on the ground, we don't have a lot of rivets and actuators and things like that and the cost element is bound to be much lower than making similar types of metal structures.

Also, there are a lot of things that we can do with structures such as this that can't be done with metal structures. I think to come out and name a dollar for such and such an item is quite a difficult thing to do at this time, because all of them involve, what is the mission, what are boosters required, what are the experiments that are to be carried out, or what is the final application of the equipments that have to go into it, and all of those get into the answer of cost.

We are very certain that the costs of vehicles like this will be much lower than comparable metal vehicles.

The CHAIRMAN. Thank you very much.

If there are no questions, I want to thank these gentlemen first from NASA, and then secondly from the Goodyear Aircraft Corp. for some very interesting and very valuable hearings that we have had this morning. Our membership has appreciated it very much and we have gotten a lot of information.

Mr. RICHARDSON. Thank you very much, Mr. Chairman. We appreciate the opportunity to come because we think it is a subject that as the weeks, months and years come on ahead of us, it is one you are going to hear more of in the space effort of our country.

The CHAIRMAN. Without objection, we will place in the record at this point the statement of the Goodyear Aircraft Corp. and the biographies of Mr. Richardson and his staff.

I am satisfied of that fact that you mentioned, Mr. Richardson.

If there is no further business, the committee will adjourn, subject to call.

(The biographies and statement referred to are as follows:)

R. W. RICHARDSON

GOODYEAR AIRCRAFT CORP., AKRON, OHIO

Robert W. Richardson, vice president for Goodyear Aircraft Corp. since November 1954, was first associated with the Goodyear organization in 1934 as a member of the production squadron of Goodyear Tire & Rubber Co.

He was transferred from the squadron the following year to take a position with Goodyear Service in Brooklyn, N.Y., and later was associated with the Goodyear store in Boston, Mass. In 1936, he returned to Akron to join the Mechanical Goods Sales Department (now Industrial Products), of Goodyear Tire & Rubber Co.

Subsequently, Richardson held sales positions with the Industrial Products division in Chicago and Buffalo and in 1941 was appointed district manager of Goodyear's Aviation Products division at Dayton, Ohio. He returned to Akron in 1944 as assistant manager of the Industrial Products manufacturers' sales organization.

He served as manager of the Aviation Products division from 1945 until 1951, when he was appointed assistant to the vice president in charge of manufacturers' sales.

In 1952, he left Akron to assume the post of assistant to the president of Kelly-Springfield Tire Co., a Goodyear subsidiary. In February 1954, he was appointed vice president of that company.

Richardson returned to Goodyear in July, 1954, when he was appointed sales manager of the company's North-central division at Chicago, Ill. He was named to his present position at Goodyear Aircraft four months later. Born in Seattle, Wash., Richardson was graduated from Culver Military Academy and attended Purdue University. He is a member of the Wings Club, New York City, and holds a private pilot's license.

He resides with his wife and three children, Thomas, Frances, and John, in Hudson, Ohio.

R. S. ROSS

GOODYEAR AIRCRAFT CORP., AKRON, OHIO

Robert S. Ross is now manager of aeromechanics research and development department at the Goodyear Aircraft Corp. He has been with Goodyear since July, 1949, and is responsible for all aeromechanics projects of a research and development nature in the undersea, surface, atmospheric and space field.

Previous to his position at Goodyear Aircraft, Dr. Ross was Technical Director of the Daniel Guggenheim Institute, Akron, Ohio. He also taught at the University of Akron as Associate Professor and at the Case Institute of Technology, as Special Lecturer.

Born May 31, 1920 in Lorain, Ohio, he earned his Bachelor of Science, Master of Science, and Doctor of Philosophy degree at Case Institute of Technology in 1942, 1943, and 1945, respectively.

Dr. Ross has been active in the field of aeronautics since 1942 and has worked on lighter-than-air, and heavier-than-air projects including airships, balloons, helicopters, convertaplanes, airplanes, and missiles. The Inflatoplane and Convoplane were two of his projects. He has also been responsible for subsystem development such as jet engine reversers and supersonic escape capsules.

He is a member of the Aircraft Research and Testing Committee of the Aerospace Industries Assoc. and was chairman of that committee in 1959. He is an Associate Fellow of the Institute of Aeronautical Sciences, and a member of Sigma Xi.

He holds a professional engineers license in Ohio, is a licensed pilot, has authored many technical articles and holds several patents in the aeronautical field.

He is married to the former Betty I. Bailey and they reside at 4270 Hickory Lane, Cleveland, Ohio.

R. T. MADDEN

GOODYEAR AIRCRAFT CORP., AKRON, OHIO

Robert T. Madden, manager of astronautics sales at Goodyear Aircraft Corp., is responsible for programs concerning space and re-entry vehicles, recovery equipment, structural components for outer space applications, as well as astronautics research and development programs.

Madden joined Goodyear Aircraft in 1952 as an Engineering Specialist in the firm's Research and Development Department. He moved into the Sales organization in 1956 and handled the sale of escape capsules for supersonic aircraft and re-entry vehicles before transferring to astronautics sales in 1959.

Prior to his association with Goodyear Aircraft, Madden spent 4½ years with the National Advisory Committee for Aeronautics conducting research on supersonic aircraft and ram jet propulsion systems. He also worked in the aircraft industry as a missile systems engineer and as an ignition applications engineer for turbine engines.

A 1943 graduate of the University of Notre Dame with a Bachelor of Science degree in Aeronautical Engineering, he also took courses in high speed aerodynamics at Stanford University in 1948.

Madden spent 3½ years with the United States Navy during World War II as an aircraft squadron engineering officer. At the time of his separation from the Navy in 1946, he was aircraft overhaul inspection officer at Naval Air Station, Alameda, Calif.

A member of the American Rocket Society, Madden resides with his wife, the former Helen Marie Gallagher, and five sons in Hudson, Ohio.

SUMMARY PRESENTATION ON EXPANDABLE STRUCTURES

By

GOODYEAR AIRCRAFT CORP., AKRON, OHIO

The utility of lightweight, packagable fabric structures in considerations of current and future engineering designs has led to a relatively new technology—broadly identified as expandable structures.

This structural approach permits the designer to select and orient filaments and elastomers to best suit a specific application in the anticipated operational environment. This ability to create lightweight structures when combined with packagability looks very promising, particularly for vehicles and components to be used in space and re-entry applications.

Although expandable structures have been considered for many types of undersea and earthbound uses, space vehicle applications can be classified in three major categories.

I. High strength expandable structures for use in orbital and space vehicles, such as manned and unmanned space stations.

II. High temperature, high strength expandable structures for use in manned and unmanned re-entry vehicles.

III. Lightweight expandable structures with possible foam rigidization for use in solar concentrators, antennae, unmanned satellites, and so forth.

In each application for expandable structures, the vehicle remains folded on the launch pad and the desired geometrical shape of the configuration is established by inflation with a suitable gas, once the vehicle arrives at its operational altitude.

As noted above, in some application, after erection, the shape may be maintained by lightweight foam or other rigidizing techniques. By "patterning" or weaving the fabric structure in the desired final configuration, it is possible to produce virtually any size or shape.

One of the big advantages of this type of structure is the ability to assembly and inspect the entire configuration in the fabrication area before the unit is deflated and packaged into a canister for efficient handling as a ground transport or booster payload.

Shapes such as spheres, ellipsoids, paraboloids, cylinders, and other bodies of revolution can be readily fabricated in single wall structures by pattern design, or "goring" to develop the desired inflated geometry. For those applications where specialized shapes are desired, dual wall structures are formed of a Goodyear product called Airmat (Goodyear Tire & Rubber TM). This development has evolved from the process of weaving simultaneously the two wall fabrics with interconnecting filaments, the length of these filaments accurately establishing the wall spacing.

Using this technique, it is possible to create almost any desired shape in the form of a pressurized expandable structure. Further developments in the basic fibers and elastomers permit the utilization of high temperature metals and glasses which result in structures capable of withstanding the heating of specific re-entry applications.

It has become apparent that the need for larger space payloads has resulted in the development of boosters which are dimensionally impossible to carry on our existing highways or railroads. New means of transporting these from the source of manufacture to the launch site must be developed.

A review of airship capabilities for handling large missile boosters indicates that this is one of the most feasible methods yet devised for effectively handling this problem.

The airship's ability to operate from extremely small areas and to travel anywhere in the world with a cargo that will encounter less than a one-half g load has been established in feasibility studies. Within the state-of-the-art, it is possible to utilize airships for performing the mobility function of all anticipated boosters. Attached is an illustration of a typical airship configured to handle a large booster.

The need for developing a lightweight structure of high structural integrity for use in a space environment has resulted in the investigation of the ability of expandable structures to be utilized in a manned space station application.

Here it is necessary to provide a large volume in the space environment while the vehicle size must be compatible with an existing nose cone on the launch pad.

The ability to fold an entire space station into existing nose cone dimensions permits the utilization of current boosters to place a manned space station and recovery vehicle in orbit at an early date.

Once in space, the station can be expanded to its full dimensions and the man move at will from his recovery vehicle into the station and back again. This arrangement eliminates the need for a rendezvous between the manned vehicle and the space station which would be required if each were sent up individually.

After performing a mission in space, the man could utilize his re-entry capsule to return to Earth leaving the space station in orbit. Feasibility studies have been made of this concept utilizing a Mercury type re-entry capsule and an expandable torus type space station which would permit the performance of a two week manned space mission while utilizing available planned boosters as launch vehicles.

Methods for constructing the expandable portions of the space station are now being evaluated by NASA and GAC and a 30-foot diameter portion of one is pictured under construction at GAC. An artist's concept of how this unit will look in space is also shown.

Expandable structures have been investigated as re-entry vehicles, both of the ballistic type, which primarily uses drag forces to decelerate it and of the lifting type which would permit flying in from space to a predetermined landing area, much as the conventional airplane.

Attached is a photo of a typical ballistic type decelerating system, generally known as Ballute which utilizes a large lightweight inflated balloon for developing drag forces required for controlled re-entry. This GAC-developed system has already been tested in supersonic wind tunnels and on the Cree missile up to speeds of Mach 3.5 and programs are now underway which will evaluate its use at ten times the speed of sound. This is an extremely simple and reliable system and has been a very successful Air Force program.

The feasibility of lifting type re-entry vehicles utilizing expandable structures is now being investigated and it appears that the utilization of this principle will permit the erection of light wing loading vehicles that could enter the earth's atmosphere at very high altitudes and maneuver to a predetermined landing site.

This type of re-entry vehicle would not encounter the high temperatures required by conventionally constructed units, thus providing decreased problem areas in all the vehicle's subsystems. Investigations are now being made of the types of materials as well as the manufacturing methods required.

The utilization of this concept should permit the development of lifiting type re-entry vehicles which can operate from existing boosters. A typical re-entry vehicle in both the launch pad configuration—completely folded and the space and re-entry configuration are shown on an attached photograph.

The requirement for power systems in space with consideration of the Sun as a source of energy. In order to collect this energy and transform it into useful electrical power, it is ordinarily necessary to provide a large solar concentrator to focus the Sun's energy into an absorber.

Expandable structures provide an ideal means for making collectors of high dimensional accuracy which can be folded up into small packages on the launch pad and expanded in space. A means has already been developed for rigidizing these structures so that they can be counted on for use as reliable orbital and space subsystems components. These are usually made of films and foams and are extremely light in weight.

This type of structure also lends itself ideally to all types of large space antennae. A typical rigidized solar concentrator made by GAC for the Air Force is shown in an attached photograph.

The use of expandable structures for space applications requires fundamental work on materials, manufacturing methods, and application analysis, some of which is planned by NASA and the Air Force. However, engineering feasibility studies and tests conducted to date indicate that these large structures can be used with existing boosters to perform missions which ordinarily would have to wait for the development of larger launch vehicles. The application of this technology now should not only provide a new immediate space capability but also a tremendous potential for future systems.

(Whereupon, at 12:10 p.m. the committee adjourned, to meet again on Tuesday, May 23, 1961, on another subject.)

○

The validity of the Mercury design concept was demonstrated in the fall of 1959, during an Atlas-boosted capsule test nicknamed "Big Joe." In that test a capsule was made to reenter the Earth's atmosphere after being accelerated to nearly orbital speed. The Big Joe capsule, which survived the scorching heat of reentry, was later recovered many hundreds of miles from Cape Canaveral.

To date more than 100 wind-tunnel tests of the Mercury capsule have been performed; and about 150 capsule models have been dropped from airplanes in the parachute development program. The escape system has been tested four times in simulated off-the-pad abort maneuvers, and seven more escape system tests were performed in connection with the Little Joe flights. Mercury escape systems were also activated on two Redstone and Atlas flights when booster performance was abnormal. The excellent condition of the capsule after these escape tests, several of which were unusually severe, increased the confidence in the Mercury escape system. Small monkeys were carried in two of the Little Joe flights and a chimpanzee was flown in a Redstone flight to exercise the life-support system and gain further information on the effects of space flight.

All of the early flight tests were made with so-called boilerplate capsules. These capsules simulate the shape and weight of the Mercury capsules but do not contain many of the systems and subsystems that will be required for manned operation. Boilerplate capsules are of simple construction, utilizing heavy welded sheet metal.

Concurrent with this research and development effort, the design and fabrication of the Mercury capsules was proceeding at McDonnell. Modifications to the design, arrangement, and structure were made during the conduct of the program, as requirements for such changes became evident as a result of the research and development tests. Nevertheless, a structural prototype capsule was delivered in January 1960, and the first production capsule was delivered during March 1960, a scant 13 months after the contract was initiated; such rapid delivery of a device as complex as the Mercury capsule is without precedence. Twelve capsules were delivered by the end of April 1961.

Requirements for the Redstone and Atlas launch vehicles, used in the Mercury program, were also firmed up early in 1959. Continuing cooperation between NASA and the military services has been required to assure compatibility between the Mercury capsules and the launch vehicles.

Four Atlas flights have been launched. Two of these flights provided verification that capsule heat protection was sufficient for the most severe reentry heating conditions. Although the remaining two flights did not achieve the planned objectives, capsule pressure integrity during an inflight booster explosion was demonstrated on one flight, and the spacecraft escape system was successfully demonstrated on the other.

Four Mercury-Redstone boosters were successfully launched. Three of the flights involved production spacecraft and one was a booster development test with a dummy spacecraft.

A highly successful qualification of the man-Mercury spacecraft-booster combination occurred on May 5, 1961, when Astronaut Alan Shepard flew the first manned Mercury-Redstone mission.

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THE COMMITTEE ON SCIENCE AND ASTRONAUTICS, House of Representatives, is for the advanced research projects in the Defense Department. The committee is to see that this Nation has a defense research and engineering program superior to that of any other nation. The research and engineering programs of the Army, Navy, Air Force and the Advanced Research Projects Agency are supervised by the Department of Defense. The job of the Office of the Secretary of Defense is to see that the competition between the military services is kept within reasonable bounds and that only the most promising development programs are permitted to go into the costly production phase.

To conduct the review of the research, development, test and engineering program there is a staff of professional personnel who have engineering and scientific background. In addition to reviewing the program data thus submitted the Department of Defense staff carries on almost constant communication with their opposite numbers in the military departments who know the most about specific programs and projects; they make visits to military installations such as test ranges, proving grounds and laboratories to observe the work going on at firsthand and also visit the plants of defense contractors who are perfoming research and engineeing work for the DOD.

The Air Force is the largest and includes such additional items as systems planning studies; considerable effort on flight medicine and related environmental studies; the operations and logistics studies conducted by Rand; and the technical information exchange represented by ASTIA. The advanced research work of ARPA in the field of propellants and other work related to space programs and the research and testing programs of DASA are also included under this activity. DASA means Defense Atomic Support Agency and this group runs the nuclear weapons tests and the weapons effects experiments.

DOD research and engineering effort is closely coordinated with the other research programs of the Federal Government wherever appropriate. The work is carried on closely with that of the Atomic Energy Commission on all research, engineering, and testing concerned with application of atomic energy to military uses.

There is a constant liaison and coordination with the Department of State in the mutual weapons development program and applicable NATO activities. There is a close working relationship with the Federal Aviation Agency on research and development pertaining to communication systems related to air navigation. There is a close coordination between the medical research programs of the Department of Health, Education and Welfare and the Department of Defense.

The Department of Defense is interested in the Maritime Administration programs of transportation and logistics, including cargo-handling research. Almost all areas of basic research conducted by the National Science Foundation are of interest to the Department of Defense, and the DOD has participated in many studies and programs conducted by the National Science Foundation, including of course, the Internation Geophysical Year program.

There are other Government agencies doing or sponsoring work which relates in varying degrees to the defense effort. Private industry is also spending increased sums for research and engineering in many fields where the results can be used for military as well as for civilian purposes.

U. S. Congress - Committees of the House

Standing Committee of the House

Government Operations

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L. H. Fountain, of North Carolina
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Christine Ray Davis, Staff Director

The work of preparing and considering legislation is done largely by committees of both Houses of Congress. The personnel of the standing committees of each house is chosen by a vote of the entire body. All bills and resolutions are referred to the appropriate committees, which may report a bill out in its original form, vote against it in committee, make changes, or allow the proposed legislation to die in committee . - U. S. Government Organization Manual, 1960-1961.

OVERTON BROOKS - Democrat, Shreveport, Louisiana. Born in East Baton Rouge Parish, Louisiana, 21 December 1897; son of Claude M. Brooks, deceased, and Mrs Penelope (Overton) Brooks, living; has four sisters and one brother. Married Miss Mollie Meriwether on 1 June 1933 and they have one daughter, Laura Ann.

Education - Attended public schools of East Baton Rouge Parish, completing the 4-year high school course in 3-1/2 years. Entered Louisiana State University, taking the Arts and Sciences course. Left the University to enlist in the 1st Division United States Army, July 1918. Returned to Louisiana State University and graduated from the Law School 10 April 1923 with honors, 3 months before the end of the regular term. Has LL.B degree and lacks one hour credit for masters degree.

Law Practice - Admitted to practice law before State Supreme Court and began practice at Shreveport, Louisiana 1923. Became United States Commissioner on 1 September 1925 and as such served for 10 years. Delegate to National Demogratic Convention in Chicago, Illinois in 1952 and at Los Angeles, California in 1960. Elected to the 75th and to the twelve succeeding Congresses.

Military Service - Enlisted in the 1st Division, United States Army in July 1918 and was honorably discharged on 1 September 1919. Served in France, Belgium and Germany.

Organization Membership - Member Episcopal Church; is a 32d degree Mason, Shriner; member of Elks, American Legion, Veterans of Foreign Wars, Louisiana Farm Bureau Federation, Shreveport Bar Association, Louisiana Bar Association, Kiwania Club, and Forty and Eight Organization.

Committees - President of National Rivers and Harbors Congress for 5 years and now chairman of the board of this organization. Member of Government Operations Committee. In January 1959 was made chairman of Major House Committee on Science and Astronautics and and reappointed to this chairmanship in 1961

Adresses - Home - 614 Linden Street

Office - Federal Building, Shreveport La.

Karth, Joseph Edward,

Born: August 26, 1922 in New Brighton, Minnesota.

Educated in Ramsey County elementary schools and North St. Paul High School. Attended the University of Nebraska - School of Engineering for 2 years of college courses in engineering - education was interrupted by a call to Combat Duty. Served in E. T. O. - received a recommendation for a Battlefield Commission.
Employed by Minnesota Mining and Manufacturing Co.; International Representative of the OCAW-AFL-CIO for 10 years. Member of the Minnesota House of Representatives from 1950 to 1958. and during the special session of 1958 was voted "Outstanding Legislator". Elected to 86th Congress on Nov. 4, 1958.
Military Experience: Listed Above.

Organizations
V. F. W.
American Legion
Indianhead Council of the Boy Scouts
First Presbyterian Church - White Bear Lake, Minnesota
Married the former Charlotte Nordgen and they have two sons.
Party;: Democrat in Congress and Democrat-Farmer-Labor in Minnesota.

Congressional Committees:

Committee of the House: Science and Astronautics: Member

Home Address: 2334 East County Road, St. Paul 9, Minnesota

Office: House Office Building; Washington 25, D. C.

McCormack, John W.

Born: December 21, 1891 in Boston, Mass. the son of Joseph H and Mary E. (O'Brien) McCormack. Married M. Harriet Joyce in 1920.

Educated in the Public Schools. Admitted to Mass. Bar in 1913 and is a member of the law firm of McCormack and Hardy.

Mass. Constitutional Convention: 1917-1918
Mass. State House of Representatives: 1920-1922.
Mass. State Senate: 1923-1926 (Democratic Leader)

U. S. Congress: House of Representatives: 70th Congress - from the 12th Mass. District. (Majority Leader)

Military experience: None

Organizations:
South Boston Citizens Association
American Legion
Knights of Columbus
Elk
Moose
Catholic Order of Foresters
Ancient Order of Hiberians
Democratic Party
Hon. Degrees: LL.B. conferred by Boston University and Holy Cross College and Villanova College, Tufts College, Catholic University of America and many others.

Honors: Knight of Malta, First Class; Peace Metal of the 3rd order of St. Francis; Knight Commander, Order of St. Gregory the Great with Star; Legion of Honor, Republic of the Philippines.

Congressional Committees:

Franklin Delano Roosevelt Memorial Commission (Created by Public Law 372, 84th Congress)
Committee of the House on Government Operations: Member

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The implementation of the orbital phase of Project Mercury will require the use of a global network of tracking and data acquisition stations. A total of 18 such stations will be required at the following locations: Cape Canaveral; Grand Bahama; Grand Turk; Bermuda, a ship in the Atlantic Ocean; Canary Islands; Kano, Nigeria; Zanzibar, a ship in the Indian Ocean; western Australia; Woomera, Australia; Canton Island; Hawaii; southern California; west Mexico; White Sands, N. Mex.; south Texas; and at Eglin Air Force Base. In July 1959, the Western Electric Co. was selected as the contractor to construct and install the equipment at the Mercury network stations. To date, agreements with foreign countries have been finalized, the sites have been prepared, and construction at all sites is complete. The installation of equipment at these sites has also been completed. Nine of the network stations and the two network ships will be maintained and operated by the Department of Defense and its contractors.

Capsule recovery will be effected by the U.S. Navy. Recovery plans were formulated jointly by NASA and the Navy and numerous exercises have been conducted in order to establish the best search and recovery patterns. Realistic tests of these methods were achieved during the successful recoveries following Little Joe, Redstone, and Atlas tests.

Early in 1959, the seven Mercury astronauts were selected. Since that time they have participated in an intensive training program which has now progressed to the point where the men are ready for the first manned ballistic flights. This training program employed NASA simulators, in addition to facilities of the military services. A team of aeromedical monitors has been detailed to NASA from the military services and from the Public Health Service. During future flight operations, these monitors will determine the condition of the astronaut as he passes over each of the network stations and will participate in the recovery and postrecovery activities.

Future goals

Project Mercury is a continuing program of concurrent efforts in research, development, engineering, manufacturing, test, and training, all aimed at the focal point of successful manned orbital flight at the earliest possible time.

Project Mercury is being pursued with the greatest sense of urgency. This urgency stems from the fact that the project will supply answers to many questions that must be answered before one can proceed with the next step in the manned space flight program. Before future programs can go very far downstream, much must be learned about man's capability in space and about the general technology of manned space flight. This, basically, is why it is most important to do Project Mercury, and to do it soon.

Project Mercury has been endorsed by the National Aeronautics and Space Council, and approved by the President, as a program of top national priority. Consequently, it carries a DX priority rating. But a DX priority rating alone does not assure that a project will move forward at a great rate of speed. The implementation of a project such as Project Mercury demands, on a continuing basis, great energy, great enthusiasm, and great determination. Work on Project Mercury, both at the McDonnell plant and at Cape Canaveral, is pro-

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ceeding on a three-shift, 7-day-a-week basis. All members of the Mercury team, be they in NASA, in DOD, or in private industry, are making every effort to meet the goals established for them.

It must be recognized, however, that Project Mercury is a research and development program, and, therefore, does not lend itself to the firm type of scheduling that can be maintained on a typical production job. Instead, it is only possible to establish target dates with the full recognition that such target dates must be changed as new knowledge is gained.

In Project Mercury, target dates have been established for every facet of the operation. These include target dates for deliveries of parts, components, subassemblies, systems, and complete capsules; they also include target dates for capsule preparation sequences and launch periods for all flight tests. As is always the case in a complex research and development program, some of these target dates have been met ahead of schedule, others on schedule, some behind schedule. Yet, there is always sufficient flexibility in this type of program to allow for some adjustment of schedules. For example, if a certain subassembly is not received from a vendor on time, work can proceed on the installation of another subassembly; and if the target date for a given flight test is missed, other tests might proceed ahead of schedule.

Perhaps the most important target date in the overall Mercury schedule is that for the achievement of manned orbital flight. As was mentioned earlier, Dr. Dryden in congressional testimony in 1958, implied that this mission could be accomplished sometime during 1961. If no setbacks are encountered during the flight qualification program, it is likely that this target date will be met.

General Description

The Mercury program consists of a number of phases, the culminating phase being manned orbital flight for a period of 4½ hours, or three times around the Earth. Prior to the manned orbital flights, detailed design, research and development, and qualification programs must be pursued. The design phase of the program was largely completed during 1959; however, as a result of the continuing research and development program, many design refinements and design changes have been made in the basic configuration. The largest part of the research and development phase will be completed and the qualification phase of the program was started during 1960. The culminating phase of manned orbital flight should, if all goes well, occur before the end of 1961; this event will be preceded by additional manned ballistic flights in Redstone-launched capsules and unmanned orbital flights, using the Atlas launch vehicle.

Let us now examine the manned orbital mission. The capsule will rest atop an essentially unmodified Atlas launch vehicle as shown in figure 1. The launch will take place at Cape Canaveral, Fla., and will be in a northeasterly direction toward the island of Bermuda. Initial ascent will be almost verticle; as the velocity increases, however, the flight path inclines and, long before the vehicle is over Bermuda, it will be traveling parallel to the surface of the Earth at orbital velocity. The point at which orbital velocity is achieved is called injection.

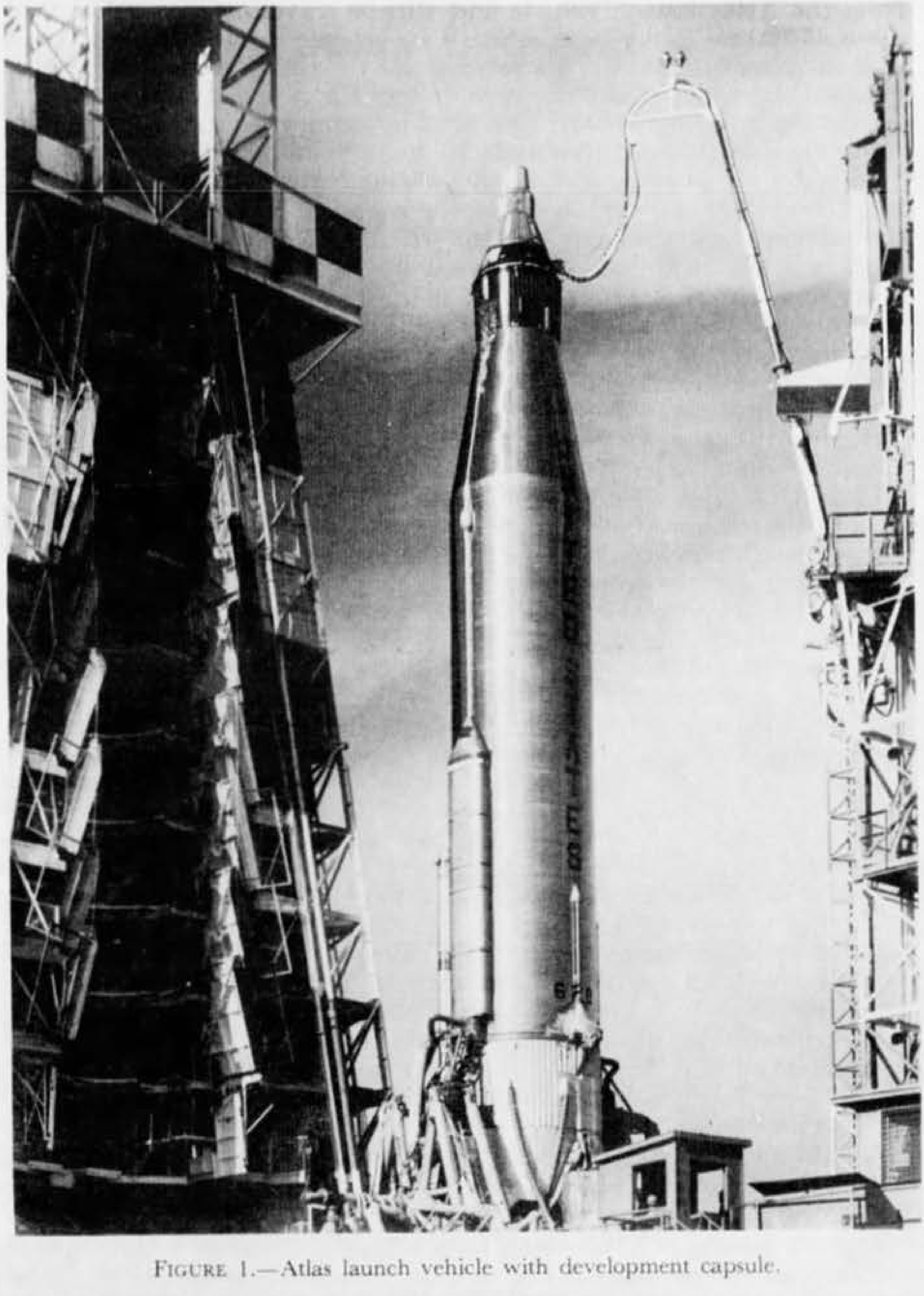

FIGURE 1.—Atlas launch vehicle with development capsule.

[COMMITTEE PRINT]

PROJECT MERCURY

SECOND INTERIM REPORT

STAFF STUDY

OF THE

COMMITTEE ON SCIENCE AND ASTRONAUTICS
U.S. HOUSE OF REPRESENTATIVES
EIGHTY-SEVENTH CONGRESS
FIRST SESSION

[Serial h]

MAY 26, 1961

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At this point the manned capsule, or spacecraft, will be separated from the Atlas launch vehicle and will be traveling at a velocity of about 17,500 miles per hour. Small rocket jets carried on the capsule will then rotate the capsule to orient it in the desired direction in space—that is, with the blunt capsule face forward and with the astronaut's feet pointing toward Earth. The manned spacecraft will then circle the earth three times at latitudes varying from approximately 32° north to 32° south. As the capsule nears the end of its third orbit and is traveling overhead between the islands of Hawaii and the California coast, a retrorocket system will be fired to slow the capsule slightly below orbital velocity. This deceleration from an orbital velocity of about 17,500 miles per hour to the suborbital velocity of approximately 17,150 miles per hour, will cause the capsule to descend earthward; as the capsule descends from its nominal orbital altitude of about 100 miles, it will encounter the denser atmosphere. The aerodynamic drag forces in the atmosphere will rapidly slow the capsule further until it is at a subsonic velocity of approximately 350 miles per hour over the Atlantic Ocean not far from the island of Puerto Rico. At this point, a small stabilizing parachute will be deployed; later, at an altitude of 10,000 feet, deployment of a large 63-foot diameter cargo parachute will take place and the capsule will be gently lowered to the surface of the ocean.

While the capsule is circling the Earth, near-continuous radio contact will be maintained with the astronaut. As the capsule is lowered to the surface of the ocean, location aids such as Sofar bombs will be ejected and direction-finding radio signals will be sent out to aid in rapid location of the capsule. Ships and aircraft in the planned recovery area will then home on the direction-finding signals. Aircraft will guide the recovery surface vessels to the scene of capsule impact.

To this point, a normal mission has been considered, with the assumption that everything goes as planned. As in the case of a manned aircraft with ejection seats and pilot parachutes, provision must be made for unplanned emergencies. Next, some of these provisions that have been made to handle such emergencies as might occur will be considered. First of all, as shown in figure 2, a separate rocket propulsion system, called an escape or abort system, is provided. This will carry the capsule to safety, should the Atlas malfunction while on the launch pad or during the early phases of ascent. The abort system may be energized automatically or by ground control, or by the astronaut himself.

Should an abort or emergency landing be necessary, it is apparent that the capsule will land in other than the planned recovery area. Therefore, provisions must be made for retrieval of the capsule from emergency areas. If the emergency should occur while the capsule and launch vehicle are on the launch pad, the capsule, after firing the escape rocket system, would land within a short distance of the launch pad, and emergency recovery provisions can readily be implemented. Should an emergency condition occur fairly early in the flight while the vehicle is well below orbital velocity, the capsule would land in the area between Florida and Bermuda. This area will be covered with aircraft and surface vessels for possible emergency recovery purposes. If an abort should be required at near-

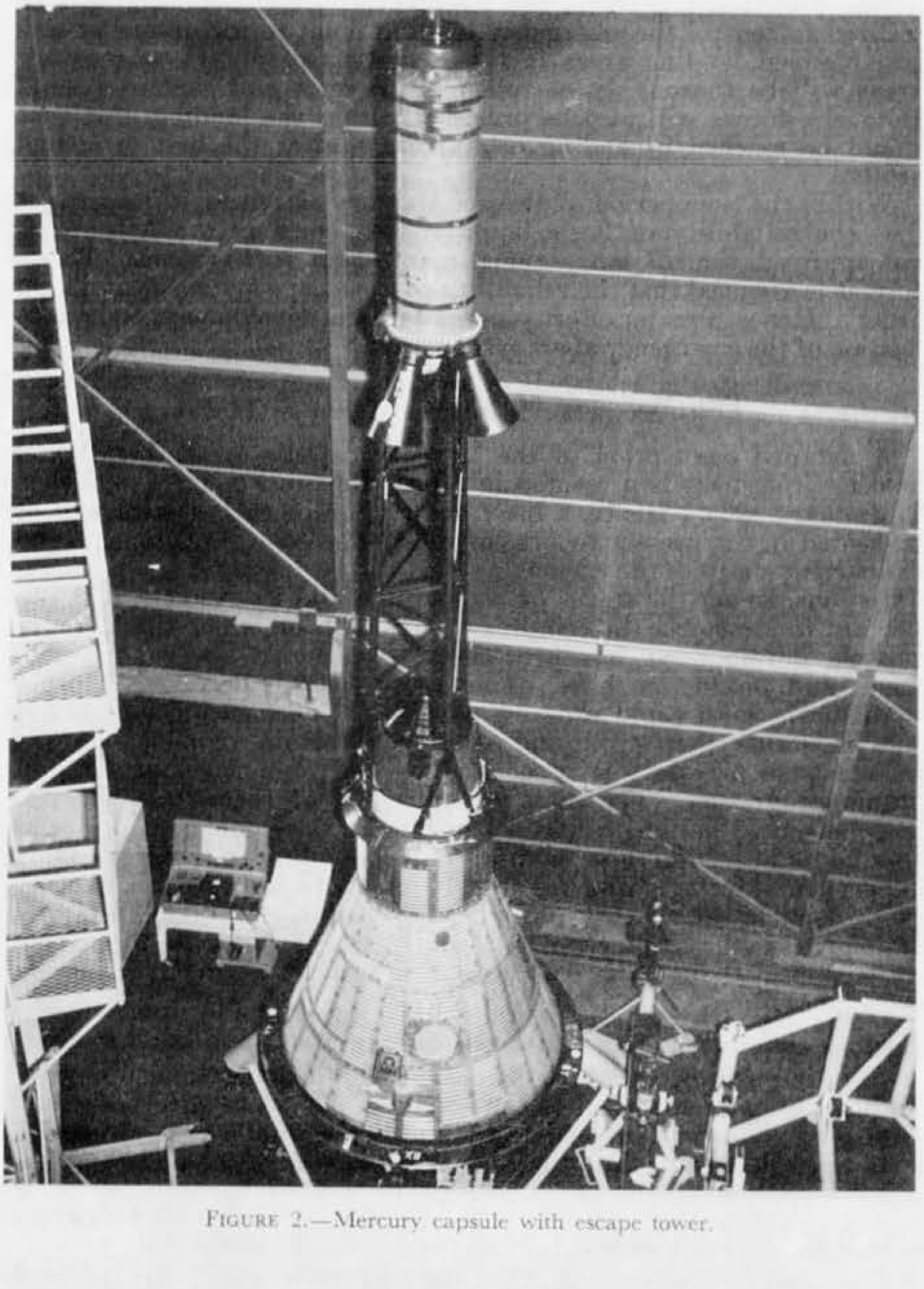

FIGURE 2.—Mercury capsule with escape tower.

orbital velocity, the capsule could land anywhere over a substantial portion of the Earth's surface unless some corrective action is taken. Under such circumstances, the retrorockets of the capsule will be utilized to control the emergency landing point to within one of several planned landing areas in the Atlantic Ocean. These recovery areas will be thoroughly patrolled by aircraft and surface vessels. Recovery forces will also be provided within the landing area that would be reached by ending orbital flight after the first or second orbits.

Within the time period of Project Mercury activities, it is apparent that the reliability of large liquid rockets, such as the Atlas, cannot approach that of conventional manned aircraft systems. Therefore, it is essential that the reliability of the escape system be of a high order. Hence, a major effort is going into the development and qualification of the emergency abort system.

The Mercury Manned Capsule System

A detailed description of the Mercury capsule or spacecraft and associated systems is presented in House Report No. 1228, published in January 1960. Hence, a brief description of each system will be presented in the present report; in addition, recent developments and the current status of the various systems will be discussed.

In considering the status of the capsule and its systems, it is important to remember the compressed timetable on which the Mercury capsule development has proceeded. Concurrent design, development, and production have, of necessity, been undertaken in order to make the most rapid progress possible. Under such conditions, it was inevitable that retrofit and redesign of certain components of the system were necessary as associated research and development programs progressed. The most sophisticated of theoretical analyses and analytical designs cannot anticipate all developmental problems that might arise, and those modifications that might be required. Only experimental investigations of actual prototype hardware can, in many cases, confirm satisfactory equipment operation. In many instances, system deficiencies show up only under actual full-scale flight conditions, even though the most extensive ground testing possible has been carried out.

Basic capsule structure and heat shielding

The Mercury spacecraft, figure 3, has a 74.5-inch maximum diameter with an 80-inch spherical radium heat shield. The afterbody consists of a cone frustum which surrounds the pilot's pressure vessel, a 32-inch-diameter cylinder which contains the parachutes and onboard recovery systems, and a cone frustum which forms a communication antenna and contains the drogue parachute and horizon scanners.

The heat of reentry will be dissipated by a large rounded heat shield. Early Redstone-launched Mercury flights will utilize a beryllium heat sink for this heat shield, whereas later orbital flights will use an ablation heat shield material.

At the time the original Mercury specification was written, the heat sink approach was within the state of the art, while there was no experience with ablation materials for the case of reentry from satellite orbit.

The decision was made, therefore, to design the Mercury capsule so that it could safely reenter the atmosphere with a beryllium heat sink. It was recognized that a vehicle of a shape designed specifically for a heat sink could be fitted, at a later date, with an ablation heat shield.

The approach used, therefore, was a conservative one. If ablation techniques were found to be applicable to satellite reentry, the Mercury capsule could use such materials. On the other hand, if ablation did not prove to be adequate, the Mercury capsule could, without change, accept a beryllium heat sink. As a result of the Big Joe development flight tests made in September 1959, and subsequent analysis of results, a firm decision to go ahead with the use of an ablation heat shield for all the orbital flights was reached. The recovered Big Joe capsule is shown in figure 4. The previously ordered beryllium heat sinks were designated for use in Redstone ballistic flights.

The Big Joe flight test also showed unexpectedly high afterbody heating under the most critical reentry conditions. Although hundreds of wind tunnel tests had been made on the afterbody heating problem, none had been able to duplicate fully the actual full-scale reentry conditions and thus, it took the actual full-scale flight to uncover this problem. In order to withstand this higher heating, the thickness of the external skin on the conic afterbody has been increased, and the construction of the cylindrical part of the afterbody has been changed to beryllium plate in place of the formerly used light-gage metal.

During the Mercury capsule research and development program, it was found that the impact load sustained during a landing on the ground, such as would occur in an off-the-pad abort, could exceed human tolerance limits under certain wind conditions. Therefore, the impact-alleviating or cushioning device, shown on the MR-3 capsule in figure 5, was developed. The cushioning effect is obtained by use of a collapsible skirt which is located between the heat shield and the capsule structure. At the time of parachute deployment, the heat shield is disconnected from the capsule and suspended about 4 feet below the capsule with the collapsible skirt extended. With the heat shield so suspended, the volume between the heat shield and the capsule structure fills with air. Upon impact, the entrapped air escapes through holes in the sidewall of the skirt, thereby acting as a pneumatic shock absorber. Some strengthening of the capsule lower bulkhead structure was found necessary to withstand the loads transmitted by the skirt upon landing impact.

Extensive tests have been made to confirm that the installation will attenuate land impact loadings to levels acceptable to human occupants.

The installation of the impact attenuation skirt allowed removal of four inflatable flotation bags which were located in the upper section of the capsule. These bags were to be inflated on impact and were to serve the purpose of keeping the top end of the capsule out of the water during astronaut egress through the top emergency hatch. With the skirt installed, the space between the heat shield and the capsule structure will fill, after impact, with some 8,000 pounds of water. In this manner the impact bag assembly acts as a sea anchor, thus preventing the capsule from capsizing during astronaut egress.

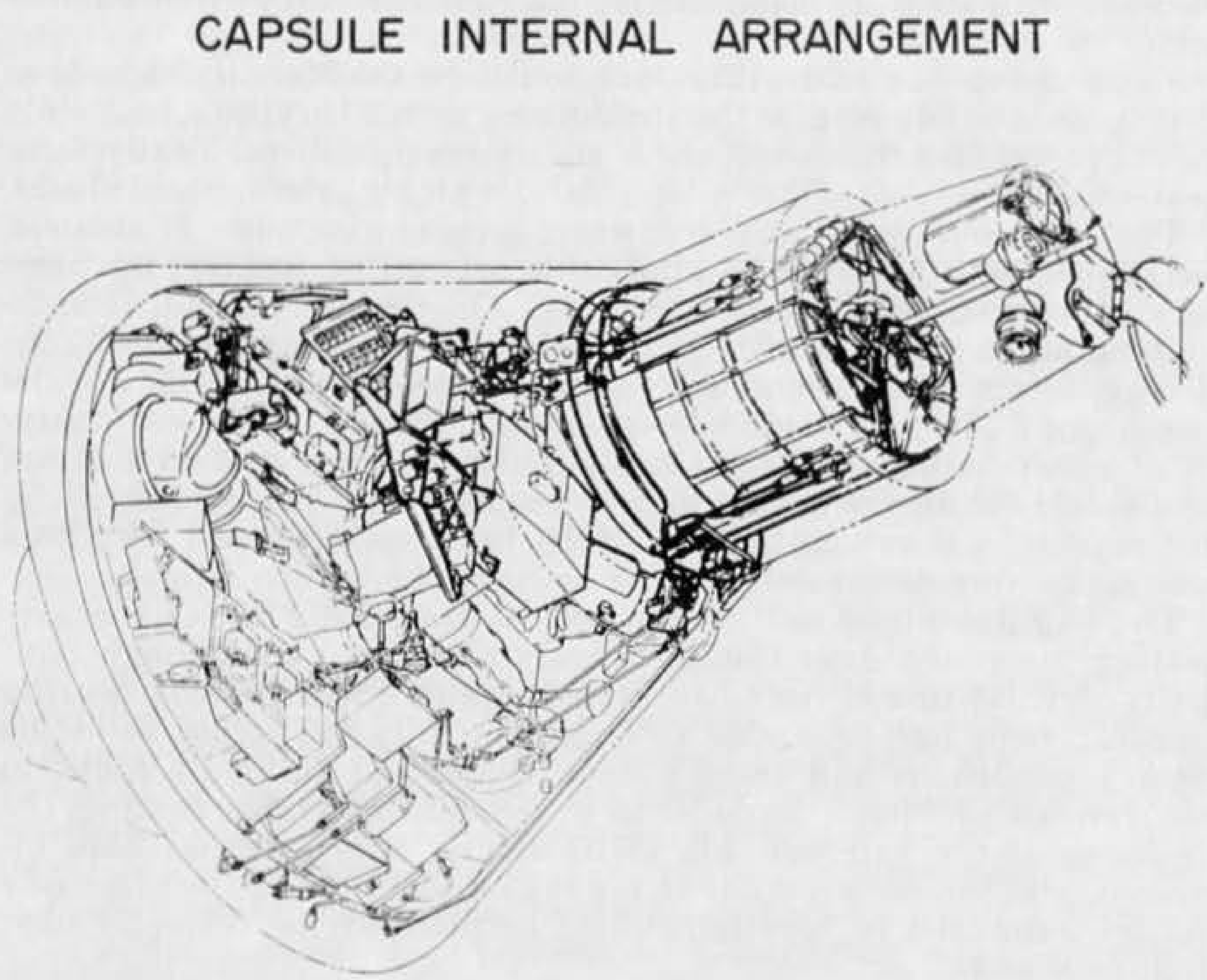

FIGURE 3.—Mercury capsule internal arrangement.

FIGURE 4.—Detailed photographs of recovered Big Joe capsule.

FIGURE 5.—MR-3 capsule with extended impact bag.

Retrograde rockets

The return of the capsule from orbit is initiated by the firing of a retrorocket system which slows the capsule from orbital velocity to approximately 350 miles per hour below orbital velocity. Three separate rockets are used, and each of the three has its own prime and reserve ignition system, so that utmost reliability can be assured. In an emergency any two of the three retrorockets would bring about reentry, although for expeditious recovery, all three are used.

Development of the retrorockets has been completed. During development, 40 motors were fired at the Thiokol factory and additional motors were fired under simulated space conditions at the U.S. Air Force Tullahoma facility and the NASA Lewis Research Center Altitude Facility. Qualification tests of the retrorocket motors have also been completed.

Escape system

As has been mentioned previously, provision is made within the Mercury capsule system to terminate the mission and escape from the vicinity of the launch vehicle in case of malfunction. The escape maneuver is carried out by use of the escape rocket up to the time of booster cutoff. In order to provide rapid separation of the capsule from the launch vehicle, the escape rocket has a high level of thrust over a short period of time. Because of its location on the tower extending ahead of the capsule, the escape rocket motor utilizes a triple nozzle with the three nozzles canted outward so that the exit flow does not impinge upon the capsule structure.

It is important that the magnitude and direction of the resultant thrust vector of the three nozzles be controlled to close limits and that the direction of action be known precisely. In this way, the capsule can be forced away forward and to one side of the booster during an escape maneuver, without setting up a tumbling motion.

Development and qualification tests of the escape motor have been completed. A total of 59 motor firings was performed during the development and qualification tests. In addition to tests performed by the manufacturer, one escape motor was vacuum-test fired at the U.S. Air Force Tullahoma facility, four escape motors were vacuum-tested at the NASA Lewis Research Center, and three Little Joe and two beach abort tests at Wallops Island were made, all successfully.

Landing and recovery system

The Mercury capsule utilizes parachutes to achieve a safe descent and landing. Altogether, four parachutes are installed in the capsule. The drogue parachute has a 6-foot diameter, conic, ribbon-type canopy with approximately 6-foot-long ribbon suspension lines, and a 30-foot-long riser made of dacron to minimize the elasticity effects during deployment. The drogue parachute is packed in a protective bag and is ejected by a mortar. This parachute provides a backup stabilization capability for the capsule in the event of failure of the reaction control and stabilization system and also serves to slow the capsule to approximately 200 miles per hour before main parachute opening shock.

The main parachute is a 63-foot diameter ring-sail cargo-type parachute. Throughout the test program, this parachute has shown extremely favorable opening characteristics, as well as good stability after opening. The reserve parachute is identical to the main parachute. It is deployed by a flat circular-type pilot parachute. The main parachute is deployed automatically by means of sequencing and altitude sensing devices; however, should the automatic system malfunction, the pilot can manually deploy either parachute.

The flight test program of the landing system was completed August 11, 1960. The final qualification program consisted of 56 drops of a boilerplate capsule, equipped with the landing system components. These drops were made from Air Force C–130 aircraft up to 30,000-foot altitudes, or from a Marine HR2S helicopter at low altitude in order to simulate off-the-pad abort conditions.

Environmental control system

The environmental control system shown schematically in figure 6 must provide an acceptable atmosphere for the astronaut throughout the period of capsule occupancy. The system is designed to provide a sufficient supply of oxygen to sustain life for 40 hours and to maintain cabin pressurization under emergency conditions. Carbon dioxide content, gas temperature, and humidity are maintained within acceptable limits. Oxygen is stored in two spherical containers at very high pressures. A water cooling system, designed to operate in weightless flight, is used to dissipate the heat generated by electronic equipment and by the astronaut. Activated charcoal and lithium hydroxide are used for odor and carbon dioxide removal.

A qualification program for the environmental control system has been completed. Manned tests of the system were begun on June 20, 1960. The test program included a number of 4-hour tests which demonstrated the system operation in all modes including simulation of system failures. A 28-hour mission simulation and a 12-hour duration postlanding test have also been made. Many components of the environmental control system were installed during centrifuge tests at the U.S. Navy Johnsville human centrifuge (AMAL) in October 1960. These components operated very satisfactorily under the simulated flight conditions of the Redstone launched flights.

Attitude control system

The attitude control system must provide for automatic or manual attitude sensing and control of the capsule throughout the flight. Attitude sensing is accomplished through a combination of horizon scanner and gyroscopic equipment. The location of the capsule in the pitch, roll, and yaw planes is controlled by a reaction jet system which uses hydrogen peroxide as a monopropellant. While in orbit, the control forces required are very small and a low thrust mode of operation of the reaction jets is sufficient. During retrorocket firing and during atmospheric reentry, a high-level thrust is required. In order to produce this dual level of thrust, two sets of reaction thrust chambers are provided in the automatic system. In order to increase overall mission reliability, provision is also made for the pilot to sense and control the capsule's attitude. A periscope and window are used for visual attitude reference by the astronaut. A third set of reaction jets, activated by the pilot's control stick, is provided.

Qualification and reliability testing programs have been completed on the horizon scanner, periscope, automatic stabilization and control system, and rate stabilization and control system.

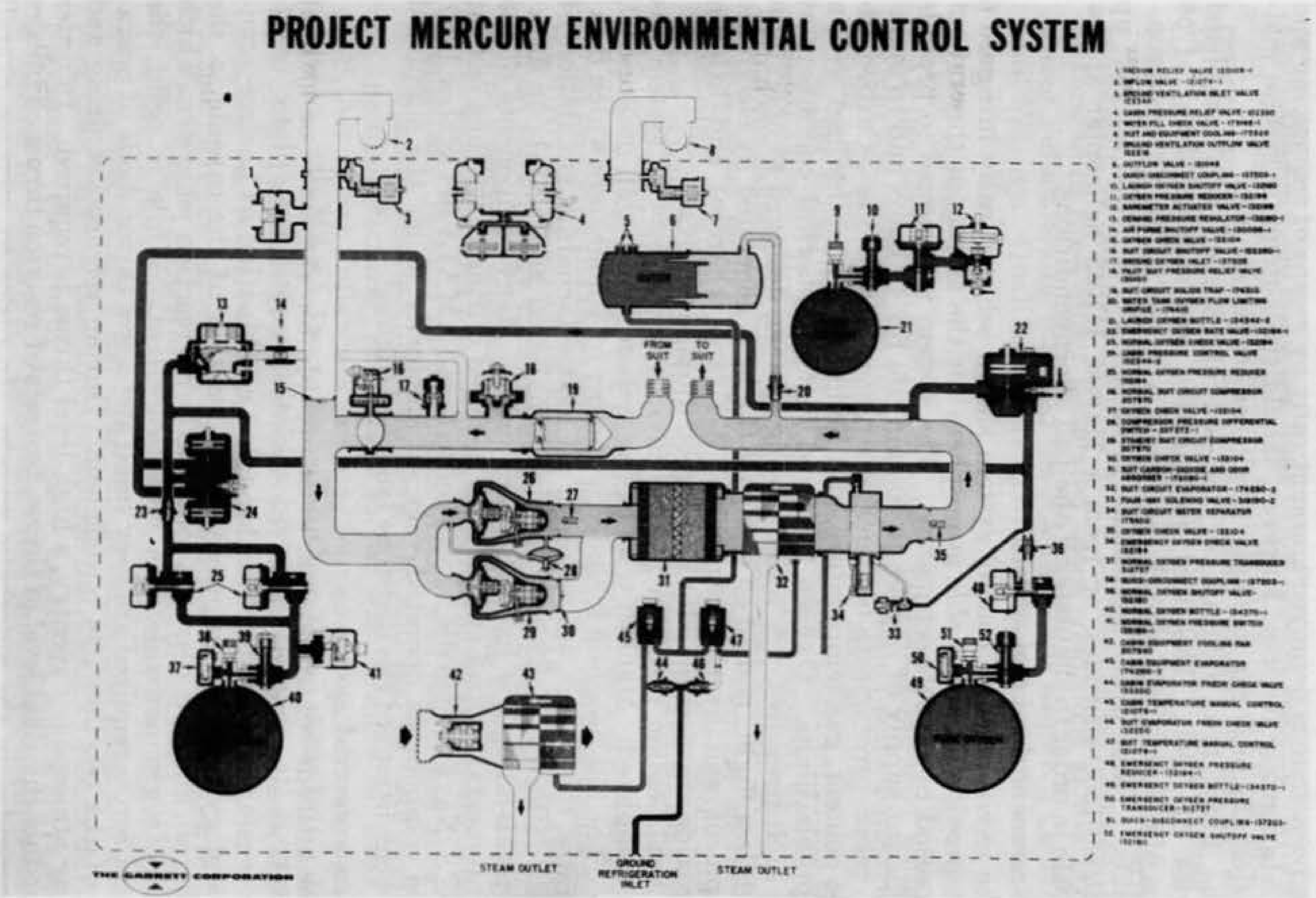
PROJECT MERCURY ENVIRONMENTAL CONTROL SYSTEM
FROM SUIT
TO SUIT
STEAM OUTLET
GROUND REFRIGERATION INLET
STEAM OUTLET
THE GARRETT CORPORATION

FIGURE 6.

The automatic reaction control system uses solenoid valves for on-off control. The manual reaction control system utilizes either mechanical actuated valves with direct mechanical linkages to the pilot controller or solenoid valves.

A thrust chamber evaluation program at the NASA Lewis Research Center was completed early in 1960. Since that time, the qualification tests of the reaction thrust chambers and the associated equipment have been completed.

Pilot support and restraint

Production of individually fitted couches for the astronauts has now been completed (fig. 7). These couches were used during simulated Redstone flights run on the centrifuge in October 1960. Although experience with the body restraint harness indicated it was acceptable for the flight mission, experience with the egress trainer has indicated that the pilots should be able to release the harness positively and rapidly. It had been necessary to unthread the knee and chest buckle on the original harness; however, a revised harness, currently in use, carries quick release fittings. The original head restraint system has been removed. It was felt that this locked the head so firmly that any shoulder or body movement might injure the neck. Consequently, the current configuration provides lateral restraint only and permits the head to move upward and forward. Tests which were conducted on the Air Force deceleration sled at Holloman Air Force Base demonstrated the adequacy of the modified system.

Communications (onboard)

The Mercury capsule communication system is designed to provide two-way voice communication, position tracking capability, air-to-ground physical and biological data transmission, ground control of vital capsule events and postlanding search and recovery assistance.

The communication system is made up of the following equipment:

(1) A 2-watt UHF voice transmitter-receiver. This unit is designed to provide two-way voice communication for the entire mission including continuous radio carrier for direction finding after main parachute deployment.

(2) A ½-watt UHF voice transmitter-receiver which provides backup for the 2-watt system and serves identical functions, once selected by the astronaut.

(3) A 5-watt HF voice transmitter-receiver. This unit is designed to provide extended range for two-way voice communications, backup for UHF voice circuits for emergency use, or for normal use when orbital path is beyond line of sight range.

(4) A 1-watt HF rescue voice transmitter-receiver. This unit is designed to provide two-way voice communications with beyond line-of-sight range capability. It will be energized only after impact, as a backup for UHF voice communication during the recovery phase.

(5) A 3.3-watt telemetry receiver (high frequency). This unit is designed to provide for biological and physical data transmission to ground-range stations; a backup for onboard instrumentation data tape recorder; verification of events transmitted to or programed within the capsule; and emergency telegraph transmission in the event of complete voice-communication failure.

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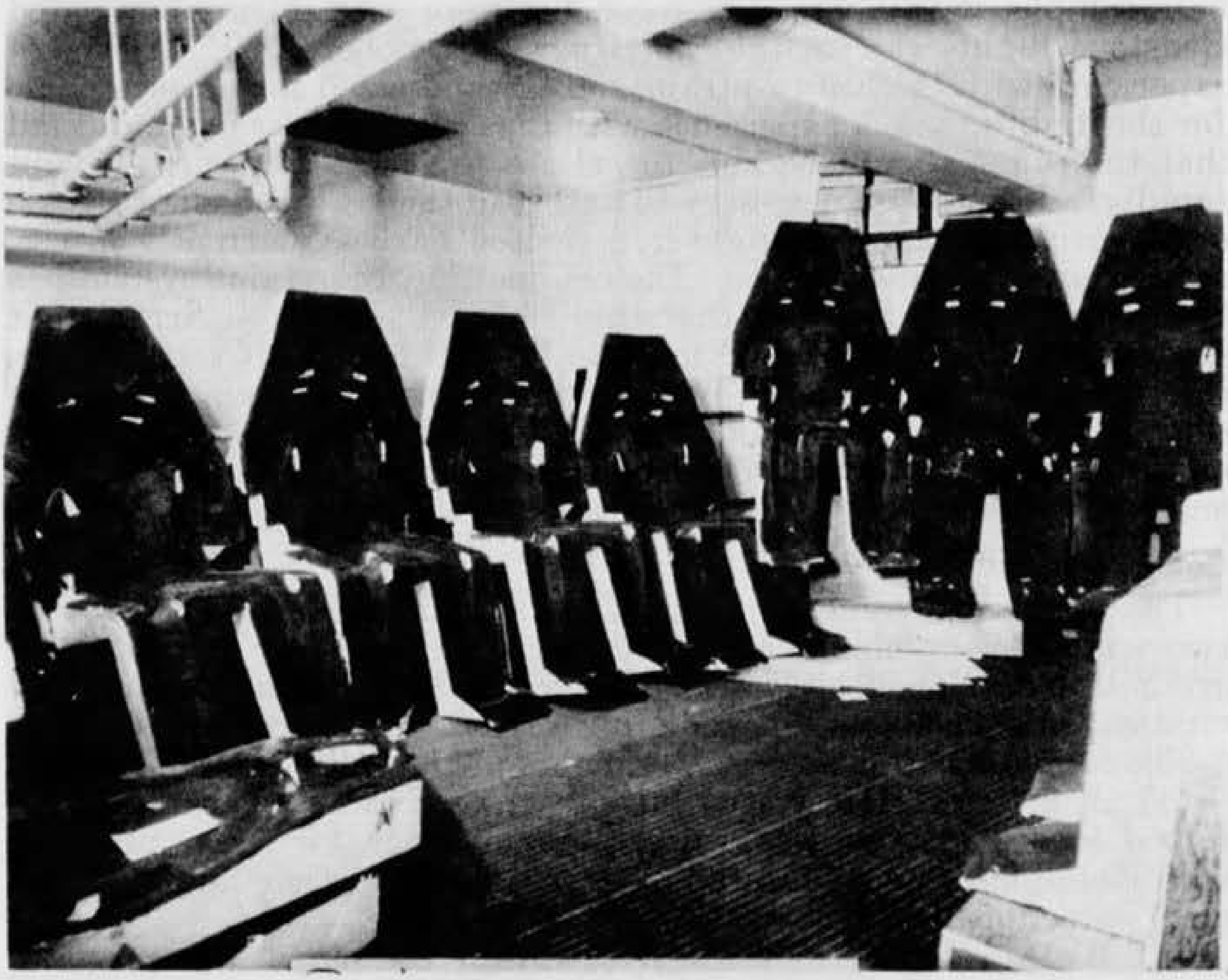

FIGURE 7.—Project Mercury molded couches.

(6) A 3.3-watt telemetry transmitter (low frequency). This unit is designed to perform the same function as the high frequency telemetry transmitter and provides redundancy of flight safety data transmission.

(7) Command receivers. Two identical 20-channel receivers with parallel outputs are provided to enable ground control of (*a*) capsule abort, (*b*) retrotimer reset, and (*c*) retrofire.

(8) C-band and S-band radar beacons for tracking by ground radars.

(9) UHF/HF rescue beacons (SARAH) for search and recovery aid after capsule impact.

(10) Auxiliary UHF rescue beacon (super-SARAH) for redudant search and recovery aid.

System development tests have been performed to determine mutual compatibility of communications systems components with each other and with other capsule systems equipment. As a result of these tests, a number of equipment alterations were made to alleviate problems uncovered. Among these corrective actions were internal filtering and repackaging of the rescue beacon, internal powerline filtering in the command receiver, addition of powerline filters to the telemetry transmitter, and redesign of the telemeter transmitter power supply. These were problems that did not appear until all equipment was working together within the actual capsule structure.

Instrumentation system

The instrumentation system monitors the physical condition and environment of the astronaut, capsule characteristic and condition and operation of capsule controls. This information is supplied to telemetry transmitters and to a tape recorder to provide data for analysis and evaluation. Cameras are installed to observe and record the astronaut's facial expressions and the capsule's instrument panel. The instrumentation system also provides program control power to operate instrumentation and other system components.

Electrical power supplies

The basic electrical power supply system for orbital capsules consists of three 3,000-watt-hour and three 1,500-watt-hour silver-cell 28-volt batteries connected so as to provide three independent systems called main, standby and isolated d.c. supplies. Although the supplies are normally independent, circuitry is provided for automatic combination of the standby and main batteries in the event of depletion of the main supply. In addition, manual switching will interconnect all three supplies into one common system at astronaut option. This arrangement permits utilization of all installed batteries if found necessary, in flight. The normal mission requires less power than that supplied by the main battery complement. The reserve power in the standby and isolated sources, therefore, is completely available for unforeseen emergencies or unanticipated power utilization.

The d.c. battery power is converted to a.c. by means of static inverters. As in the case of the batteries, independent inverters are provided.

All batteries, inverters, and other electrical system components to be used aboard the Mercury capsule have successfully completed their qualification test program. Qualification tests have included the general requirements for performance, humidity, salt spray, fungus, immersion, sand and dust sealing, contact drop, radio noise, overload capacity, electrical rupture, endurance, operating force mechanism operation, short-circuit characteristics, and actuation forces as applicable to the specific device. Special testing such as air leakage through bulkhead connectors, temperature cycling, low and high temperature, vibration, shock, acoustic noise, pressure altitude, power input requirements, electrical efficiency, oxygen environment, etc., are also conducted in accordance with the specific Mercury conditions.

Capsule deliveries

The first McDonnell capsule was delivered to NASA on January 27, 1960, less than a year after the contract with McDonnell was signed. This capsule was essentially only a structural shell, however, and did not contain most of the internal systems that would be required for a manned flight.

The second MAC capsule (fig. 1), was delivered to NASA on March 14, 1960, and the third and fourth were delivered in the last week of July. The third delivered capsule, scheduled for the first Redstone flight, is the first capsule that contains most of the systems and subsystems that will be needed for manned orbital flight. Twelve capsules had been delivered by the end of April 1961.

On August 16, 17, and 18, 1960, a McDonnell capsule, completely equipped for manned flight, was subjected to a development engineering inspection at the McDonnell factory. The purpose of this inspection was to insure that the capsule, as engineered and manufactured, was safe for manned flight. Representatives of NASA, MAC, USAF, Space Technology Laboratories, and Convair participated. This inspection was typical of those which are required during aircraft development programs. It focused the attention of a large group of engineers, of various backgrounds and interests, on capsule system details and operational procedures. Following this inspection, the capsule entered a period of capsule system functional checks at the McDonnell factory, before being shipped to Cape Canaveral, Fla., for preflight activity.

The delivery schedule for capsules subsequent to April 1961, will depend largely on results from orbital flight tests. Should major difficulties be encountered during these tests, production of subsequent capsules will, of course, need to be interrupted for design changes and retrofit. As has been described before, such actions are inherent in high-priority advanced development programs which must undertake simultaneous development and production in order to compress the overall program timetable.

Flight Program

The rocket-boosted Mercury flight program consists of a research and development phase and a qualification phase, as well as the manned orbital phase. Most of the research and development flights have been accomplished. The qualification phase began late in 1960.

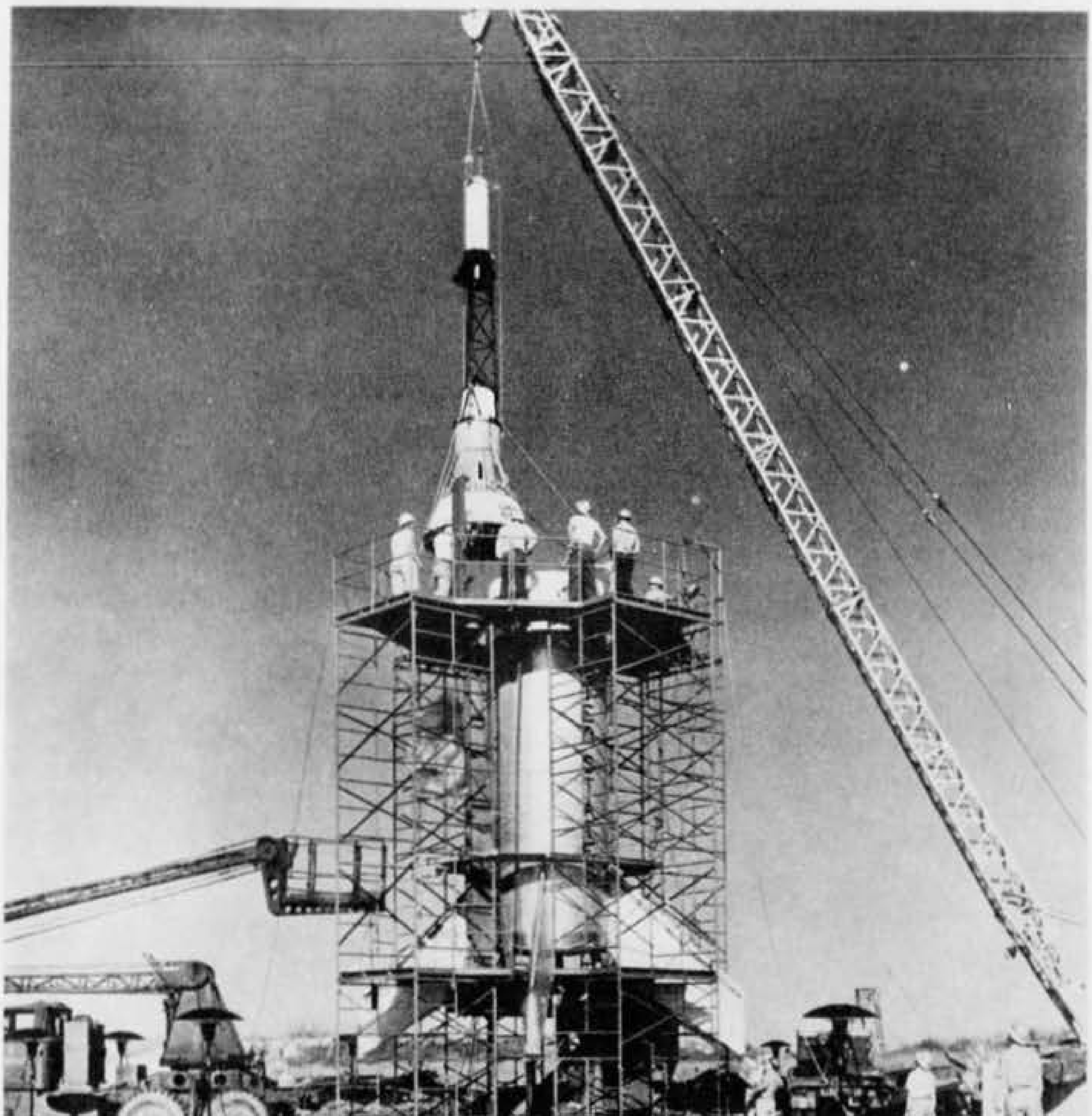

FIGURE 8.—Little Joe launch vehicle during capsule mating operations.

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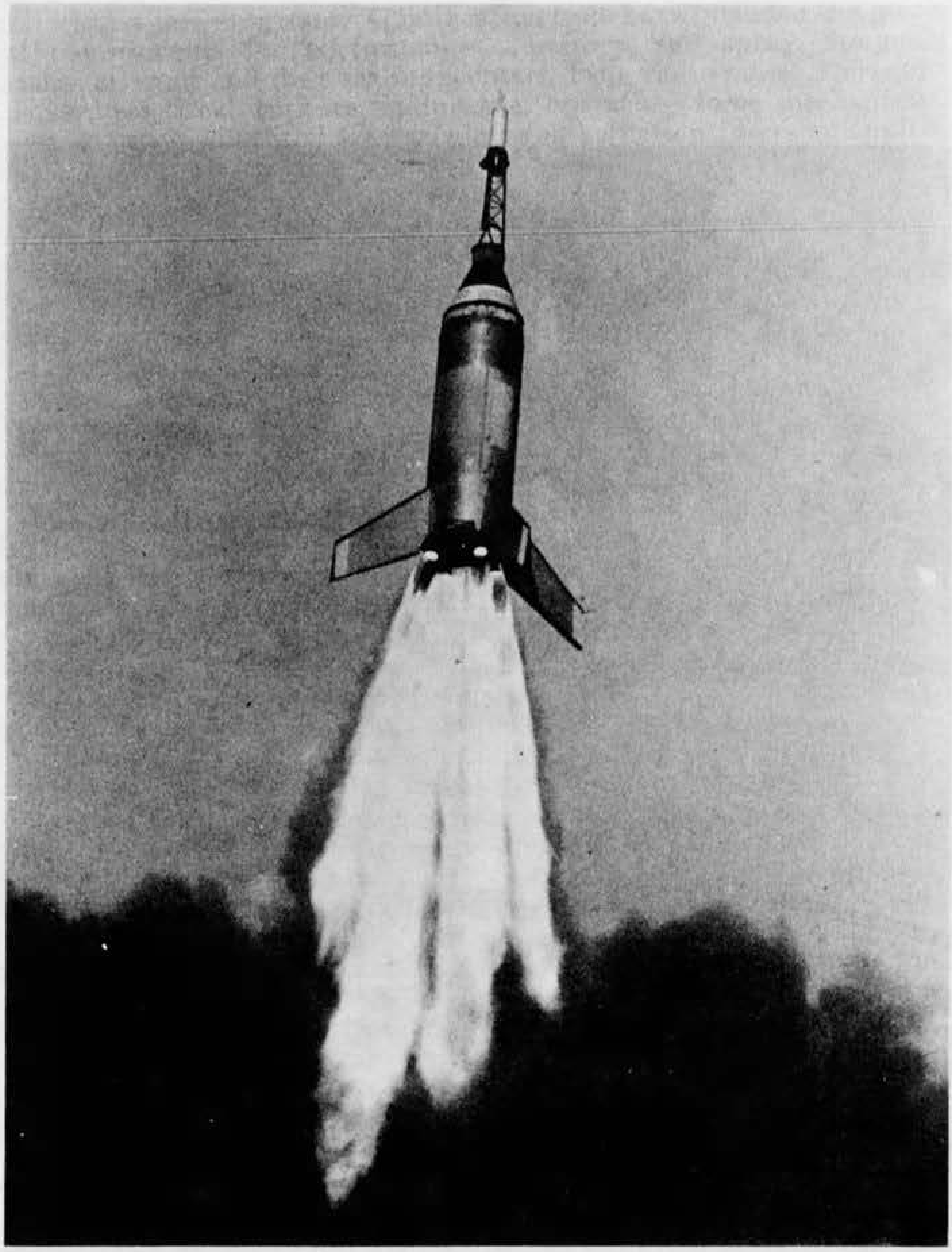

FIGURE 9.—Little Joe launch from Wallops Island, Va.

Little Joe

The Little Joe launch vehicle was used primarily during the research and development phase of project Mercury. Little Joe, which was developed especially for project Mercury, is a fin-stabilized launch vehicle which is propelled by four solid-fueled Castor rockets and four Recruit rockets. Launch weight is approximately 20 tons, and launch thrust is ¼-million pounds. Prelaunch preparations at Wallops Island are shown in figure 8. A photograph of a Little Joe launch is shown in figure 9. To date, the following Little Joe tests have been performed:

(*a*) *Little Joe I, October 4, 1959.*—A first Little Joe vehicle was flown with a dummy capsule which was not separated from the launch vehicle. The flight was for the purpose of testing the launch vehicle rather than the capsule. This flight proved the stability and integrity of the launch vehicle and provided a successful test of the destruct system at maximum range.

(*b*) *Little Joe II, November 4, 1959.*—The primary objective of this flight was to check the operation of the escape system for the combination of mach number and altitude which causes the maximum dynamic pressure during launch. The escape rocket igniter fired at maximum dynamic pressure; however the major portion of the propellant did not ignite until 10 seconds later. Because of this delayed burning, the capsule did not separate from the booster until the dynamic pressure had decayed to one-fifth of the design value. All the other capsule functions occurred as programed and the capsule landed in the Atlantic Ocean about 6 miles offshore at Wallops Island.

(*c*) *Little Joe III, December 4, 1959.*—The objectives of this flight were to determine the motions of the capsule after a high-altitude abort for a capsule with no active control system. The escape rocket fired as planned at 96,000 feet and accelerated the capsule to a mach number of 6. The capsule was boosted to an apogee of 280,000 feet and impacted, as programed, 200 statute miles from the launch site. A monkey was included on the flight and suffered no adverse physiological effects. All the flight instrumentation functioned properly and showed that the capsule was sufficiently stable to permit safe deployment of the parachute.

(*d*) *Little Joe IV, January 21, 1960.*—This was a repeat of the Little Joe II in an attempt to achieve a valid abort test at maximum dynamic pressure. All test objectives were successfully achieved; the escape maneuver was initiated at 36,000 feet and at a predetermined maximum dynamic pressure. The capsule demonstrated sufficient aerodynamic stability at this severe flight condition.

(*e*) *Little Joe V, November 8, 1960.*—All the previous Little Joe flights were accomplished with research and development boilerplate-type capsules. On November 8, 1960, Little Joe V carried a production capsule manufactured by McDonnell Aircraft Corp. Due to a malfunctioning switch assembly, the escape rocket fired prematurely during the launch phase. As a result of the premature firing, the capsule clamp ring did not release and the capsule failed to separate from the booster.

This flight was to have checked the operation of the capsule escape system during an abort at maximum aerodynamic loading. The capsule for this flight was previously subjected to an acoustical vibration test program at the NASA Langley Research Center. It successfully withstood acoustical vibration levels in excess of 145 decibels. A pilot occupied the capsule during these tests in which the noise levels were typical of levels which will be encountered during an Atlas launch. It was encouraging to find that the capsule structure attenuated the noise sufficiently to enable the pilot to communicate, using his standard radio equipment.

(*f*) *Little Joe V–A, March 18, 1961.*—This was the second attempt to qualify a production capsule at the maximum dynamic pressure condition. The flight was only partially successful because the sequence system malfunctioned and caused an abort at the improper time. The test did show, however, that the capsule would withstand parachute opening shock loads in excess of the design loads.

(*g*) *Little Joe V–B, April 28, 1961.*—The capsule flown in the previous test was recovered in good condition and reflown in another attempt to attain the flight objectives of Little Joe V. The Little Joe V–B flight provided an unexpected severe test of the capsule escape system. Due to the fact that one of the booster motors fired 5 seconds late, the booster pitched over more rapidly than planned and flew a low-altitude trajectory. The peak altitude was only 14,000 feet and the dynamic pressure at the time of abort was 1,800 pounds per square feet; approximately twice as high as planned. All capsule events and recovery were normal. Capsule postflight condition was good.

Big Joe

Big Joe was the name given to the research and development Mercury capsule which was flown on an Atlas launch vehicle and is shown in figure 10. The flight was conducted on September 9, 1959, with the following primary objectives:

(*a*) Validation of the adequacy of the ablation heat shield.

(*b*) Determination of capsule dynamic stability during hypersonic reentry.

The Atlas guidance was preprogramed to provide a duplication of a normal entry from orbit; however, the Atlas booster engines failed to separate from the launch vehicle and the added weight caused the Atlas to burn out at a lower speed and a higher flight-path angle than scheduled. These burnout conditions resulted in a steep reentry with the same maximum reentry heating rates as expected during orbital reentry; however, the total heat input was lower than expected. The excellent postflight condition of the heat shield verified that the design would be satisfactory for the Mercury capsule. The reentry was accomplished without the aid of a reaction control system. Although the capsule entered the atmosphere at an angle of attack greater than 90°, the amplitude of the angle of attack oscillations decreased to nearly 10° at maximum reentry dynamic pressure. Because of the steep reentry angle, reentry deceleration was 12g, 50 percent greater than expected during reentry from orbit.

An unexpected but important result of the flight was the high degree of heating on the conic and cylindrical afterbody portions of the capsule. The high heating rates resulted from unpredictable shock wave interaction and shock wave impingement on the capsule afterbody. As a result of the high afterbody temperatures, the external shingle material on the McDonnell production capsules was

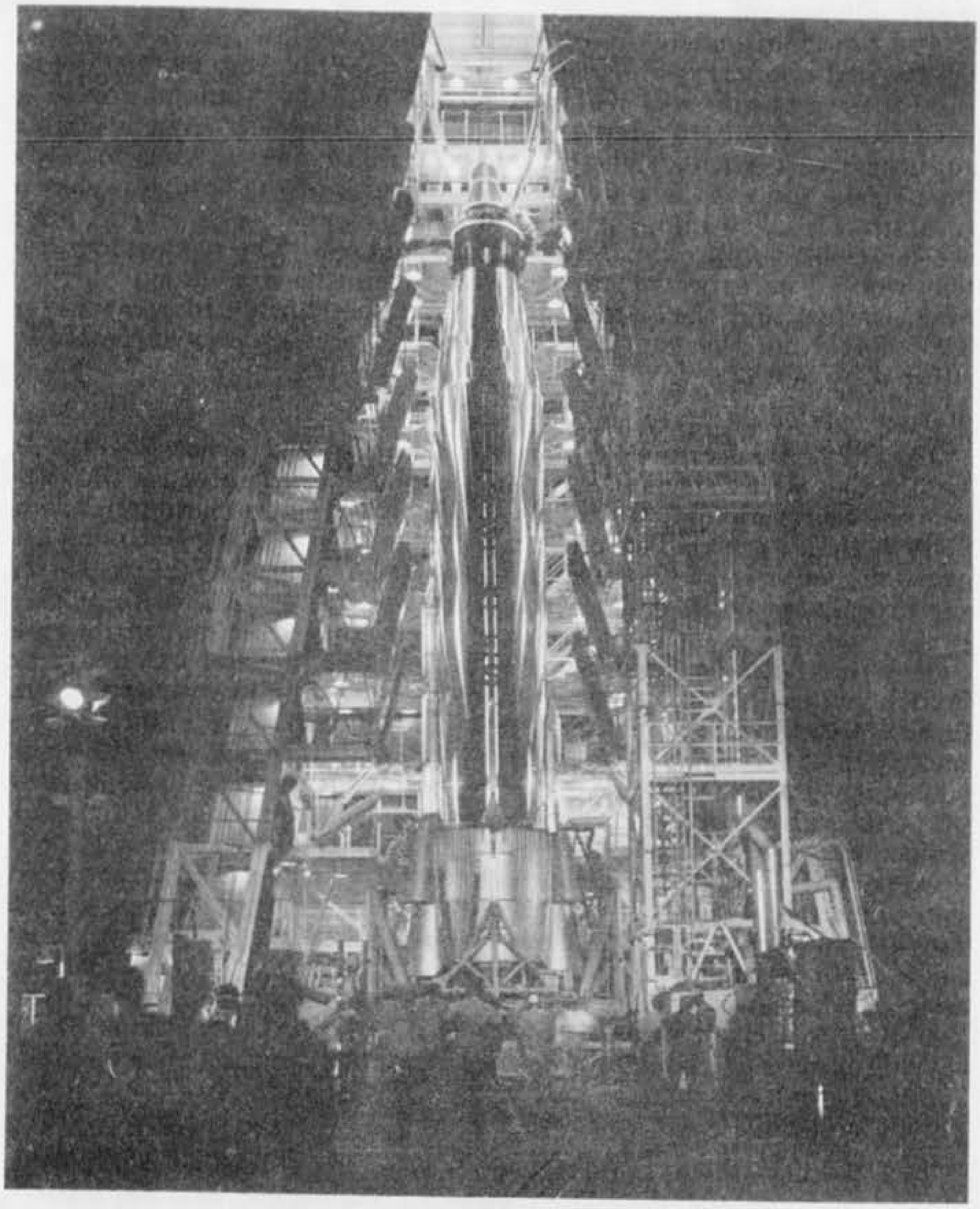

FIGURE 10.—Big Joe and gantry.

changed from a cobalt alloy to a nickel alloy. The material on the cylindrical parachute canister was changed from a cobalt alloy to beryllium.

Beach abort flight

The first McDonnell production capsule was flown on a simulated off-the-pad abort trajectory at Wallops Island on May 9, 1960. The production capsule was mounted on an Atlas-type adapter with a production capsule-to-adapter clamp ring. Launch, from a simple support, was vertical. The thrust eccentricity was set so as to carry the capsule toward the water. A photograph of the launch is shown in figure 11. The high thrust level of the escape rocket caused peak acceleration of approximately 15g, as planned. The sequencing system worked as expected; the capsule attained a maximum altitude of 2,500 feet and the parachute lowered the capsule into the water 3,000 feet from the launch site. Capsule recovery was successfully effected by helicopter.

Mercury Atlas–1

The first Atlas-launched McDonnell capsule was flown July 29, 1960. The Atlas guidance system was programed to cause the capsule to reenter along a trajectory which would cause maximum afterbody temperatures. The reentry would also result in maximum reentry deceleration. The primary objective of this test was to qualify the capsule structure and afterbody heat protection. The flight progressed normally until approximately 1 minute after launch; at that time a malfunction occurred which resulted in destruction of the launch vehicle. The capsule, which was internally pressurized, maintained pressurization and transmitted telemetry records until it impacted in the ocean. The capsule did not carry an escape tower; consequently, the sequencing system was not programed to deploy the parachute after a malfunction which occurred early in the launch trajectory. The capsule sank after the high velocity impact; however, nearly all of the components were recovered from the ocean floor approximately 5 miles from the launch pad. Fluctuating pressures caused by the Mercury spacecraft resulted in a structural failure at the booster-capsule interface. Modifications to the booster and the adapter were made prior to subsequent flights.

The previously mentioned pressure fluctuations are unique to the capsule payload and do not exist for the normal Atlas ICBM configuration.

Mercury-Atlas–2

The second Mercury-Atlas, which was flown February 21, 1961, closely matched the desired trajectory. The flight was programed to produce maximum capsule afterbody temperatures and maximum reentry loads. All test objectives were satisfied. The capsule landed 1,425 statute miles downrange, 13 miles short of the precomputed impact point.

The postflight condition of the capsule shingles and ablation heat shield was excellent. Maximum temperatures measured on the shingles and the antenna canister were lower than expected.

The Mercury-Atlas–2 booster was modified by the addition of an 8-inch-wide band at the top of the liquid oxygen tank. This band

FIGURE 11.—Beach abort test of the Mercury escape system.

LETTER OF TRANSMITTAL

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
Washington, D.C., May 26, 1961.

Hon. OVERTON BROOKS,
Chairman, Committee on Science and Astronautics.

DEAR MR. CHAIRMAN: There is forwarded herewith for committee consideration a report entitled "Project Mercury—Second Interim Report."

This report on this country's only man-in-space program has been prepared as an aid to the Congress and the public. The report summarizes the current status of Project Mercury and assesses the accomplishments to date which have culminated on May 5, 1961, with the successful ballistic flight of Comdr. Alan B. Shepard, USN, the first U.S. astronaut to experience the environment of outer space.

This report was prepared under the supervision of Mr. Howard J. Silberstein, who wrote the introductory summary, the conclusions, and edited the report. The bulk of the information was provided by the Office of Space Flight Programs, National Aeronautics and Space Administration. Information on military support of the project was provided by the Department of Defense.

The report has been given proper staff review prior to its submittal to you for consideration.

CHARLES F. DUCANDER,
Executive Director and Chief Counsel.

was installed to reduce the stress concentrations in the weld joint immediately below the adapter attachment flange. The adapter was also strengthened by the addition of reinforcing rings. Figure 12 shows the static test firing of the booster at Cape Canaveral.

Mercury-Atlas–3

Mercury-Atlas–3, which had been scheduled as an orbital flight, was launched April 25, 1961; however, because of a failure in the Atlas autopilot programer, the booster roll and pitch program was not activated and 40 seconds after lift-off the range safety officer sent a booster destruct command which cut off the fuel to the engines and concurrently initiated the capsule abort sequence. An automatic delay system destructed the booster 3 seconds after capsule abort. The capsule abort occurred at 14,000-feet altitude. The capsule was carried to an altitude of 24,000 feet and landed 600 feet offshore. All capsule systems appeared to work satisfactorily. The capsule was recovered in good condition and will be reflown.

Mercury-Redstone–1

The Redstone launch vehicle shown in figure 13 is used as an intermediate range test vehicle in the Mercury program. The first Mercury-Redstone flight occurred December 19, 1960. It attained a maximum speed of 4,300 miles per hour and a maximum acceleration of 6g. The MR–1 capsule reached a peak altitude of 135 miles, a range of 225 miles, and encountered 5½ minutes of zero-gravity flight. The flight was successful in every respect. The capsule control system, retrorockets, separation rockets, communications equipment and recovery equipment functioned properly. The capsule was recovered soon after landing by a helicopter, which was dispatched from the aircraft carrier *Valley Forge*.

The purpose of the Redstone flights is to qualify the capsules during short-range ballistic flights prior to the orbital flights. Manned Redstone flights will be accomplished after a series of unmanned flights when the capsule systems have proven sufficiently reliable. The Redstone flights will provide an excellent opportunity to fully qualify the capsule control system and retrorocket system in flights which will not require these systems for the completion of a successful and safe mission. These flights will also serve to develop pilot procedures and ground control procedures which can be used in the orbital flights.

Mercury-Redstone–2

The second Mercury-Redstone was successfully flown January 31, 1961. Because the booster engine operated at higher than normal thrust, the Redstone burned out at approximately 400 miles per hour higher velocity than planned. Engine fuel depletion, which occurred sooner than expected, triggered the booster automatic abort sensing system and aborted the capsule with the escape rocket.

The resultant high capsule velocity produced an apogee of 156 statute miles and a range of 421 miles; 116 miles farther than expected. The capsule experienced 6.6-minutes duration at zero-gravity and encountered accelerations during escape rocket firing and reentry of 17g and 14.6g, respectively.

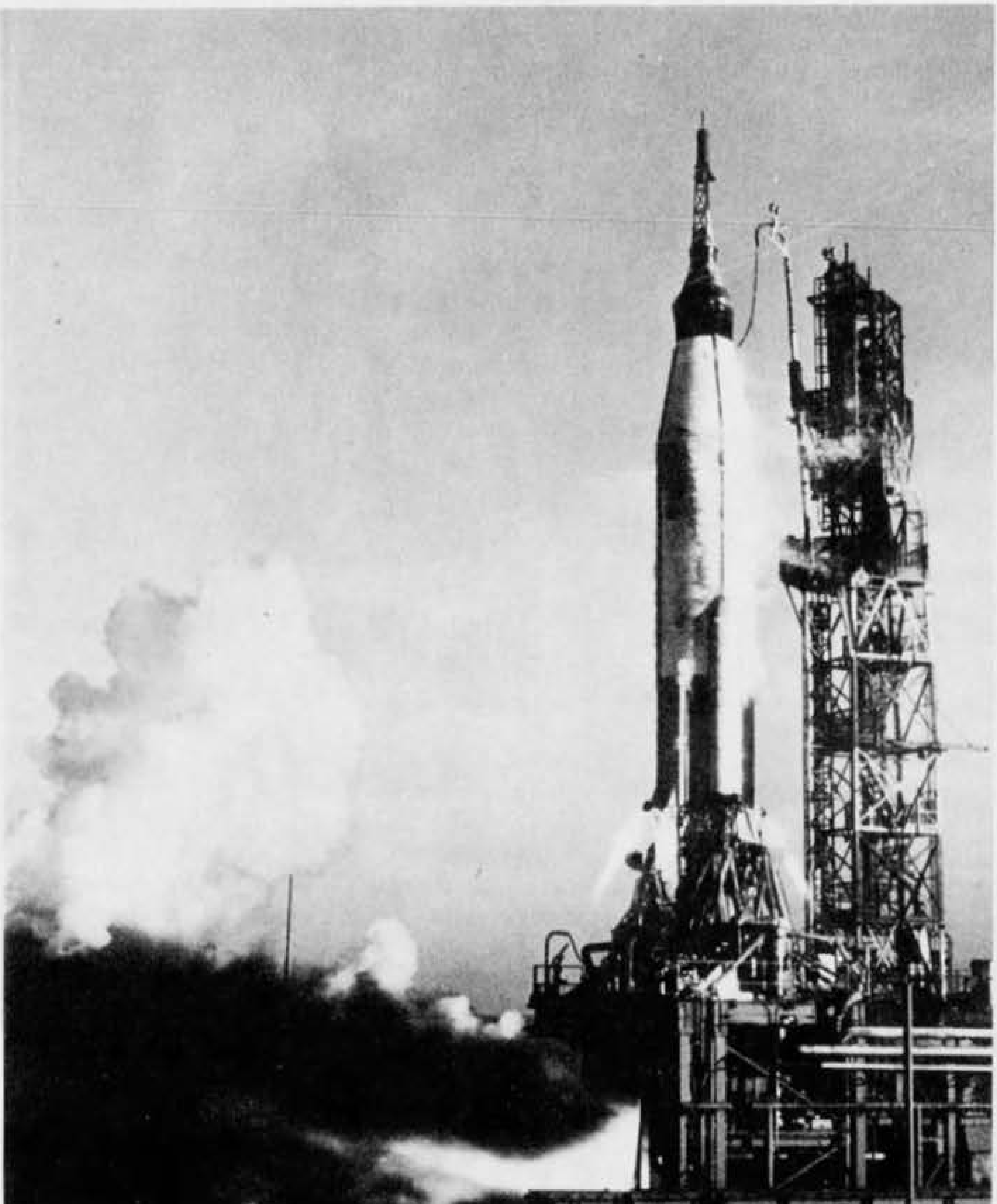

FIGURE 12.—Mercury-Atlas static test firing.

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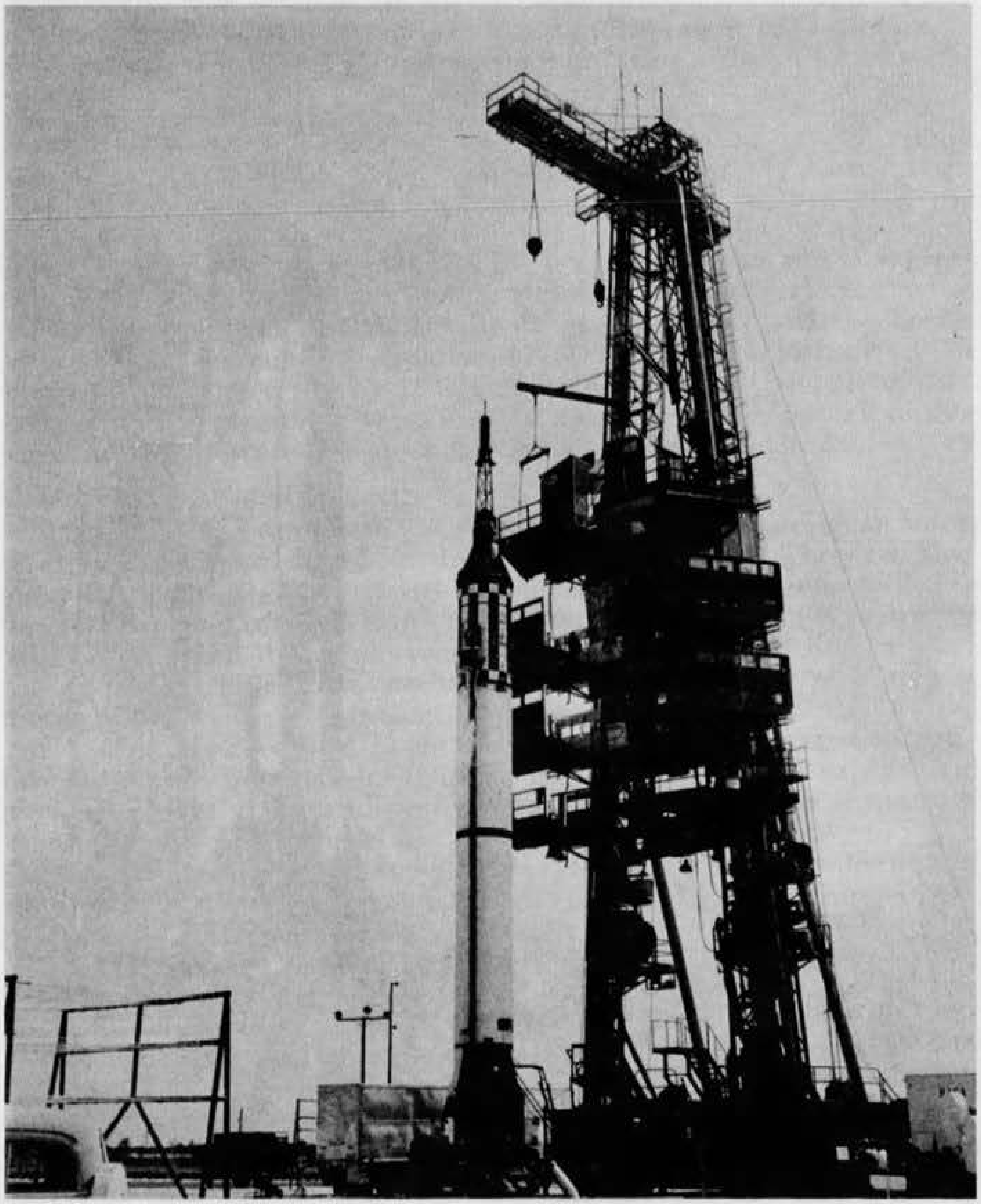

FIGURE 13.—Mercury-Redstone.

Visual observations from recovery aircraft revealed that the capsule floated upright for approximately 2½ hours, then heeled over when the heat shield dropped away. Postflight examination showed that the impact bag had fatigued due to severe wave action. Future capsules will utilize anchor chains which will prevent loss of the heat shield after landing.

The chimpanzee, which was aboard this flight, successfully performed his psychomotor tasks and was recovered in good health.

Mercury-Redstone booster development test

Because of the malfunction on the previous flight and because of a change in the control system, another booster was launched to qualify modified components prior to manned flight. This test was flown on March 24, 1961, with a boilerplate nonseparating capsule mounted on the booster. The launch was successful in every respect.

Mercury-Redstone–3

On May 5, 1961, Astronaut Alan B. Shepard flew a Mercury-Redstone mission. The flight attained an apogee of 117 statute miles and a range of 302 miles; duration at zero-gravity was 5 minutes. No unforeseen problems were encountered during the flight. Shepard reported that the angular motions of the capsule in response to the manual control system were identical to those of the flight simulators in which he trained. Manual control during retrofiring was unexpectedly easy, indicating that retrorocket thrust misalinement was small. He felt that the launch and reentry accelerations were identical to those which he had experienced many times on the human centrifuge. No difficulty was encountered with respect to zero-gravity.

Shepard also felt that because more visual, acceleration, and audio cues were present during flight than in the simulators, he had postive assurance of events such as capsule separation, escape tower jettison, retrofire, retropack jettison, and parachute deployment.

After a mild landing, Shepard opened the side hatch and was raised into a hovering helicopter (fig. 14). The helicopter then flew to the waiting aircraft carrier *Lake Champlain*. Figure 15 shows Shepard and the capsule aboard the carrier.

Future flight program

Manned Mercury-Redstone flights will continue in 1961. The purpose of additional Redstone flights is to qualify a modified capsule configuration and determine the reaction of various pilots to a space environment.

Additional unmanned Atlas-orbital flights will be attempted prior to manned orbital flight. The ability of the Atlas guidance system to vector the Mercury-Atlas to the correct altitude, velocity, and flight path angle must be demonstrated; the capsule systems must be qualified in a prolonged vacuum and zero-g environment; and the network must demonstrate its ability to track the capsule and monitor the capsule systems.

FIGURE 14.—Helicopter recovery after Mercury Redstone-3.

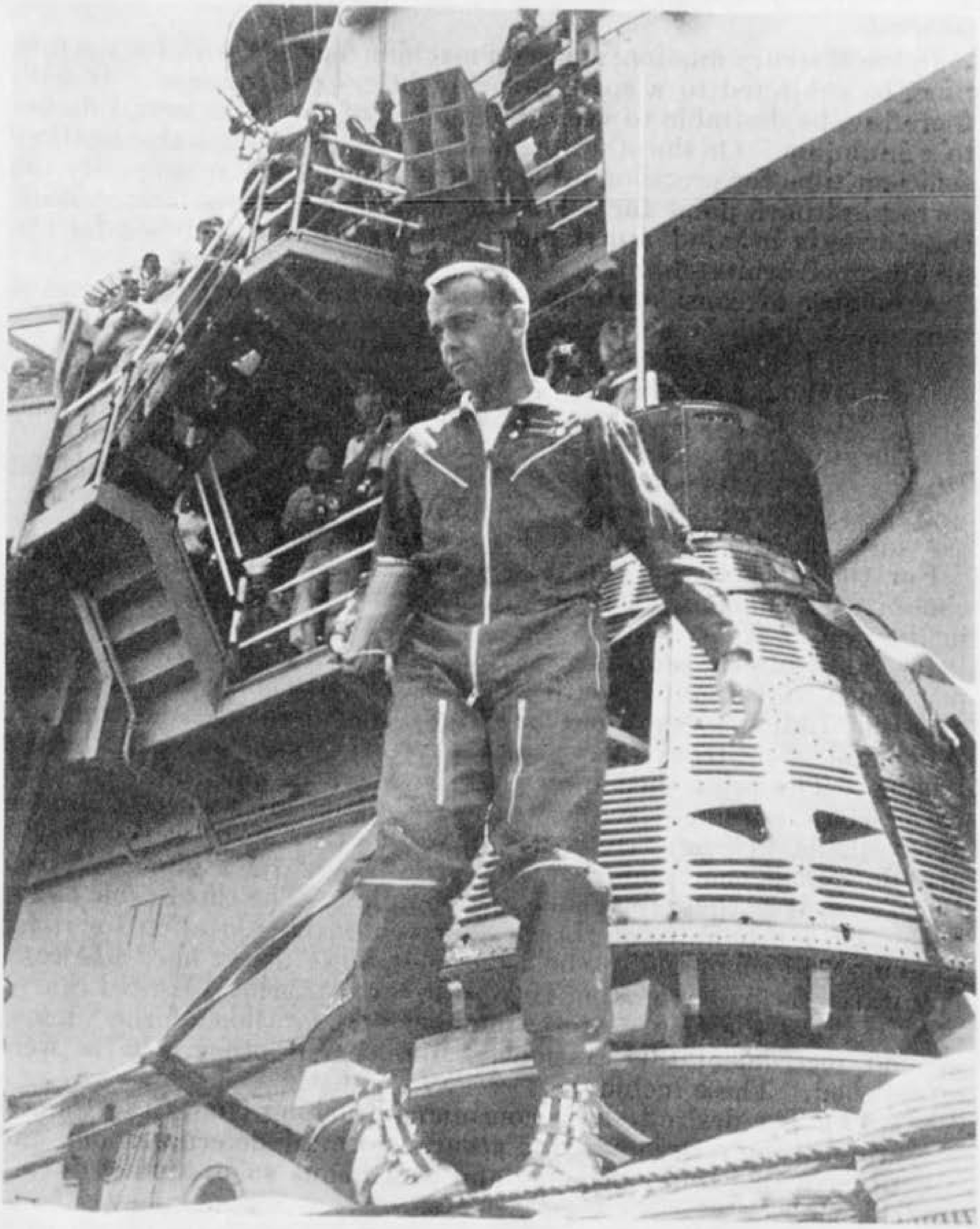

FIGURE 15.—Shepard and recovered Mercury Redstone capsule.

Tracking and Communications Network

General

In the Mercury mission, man and machine together will, for the first time, be subjected to a space and weightless environment. It will, therefore, be desirable to keep the number of orbits on initial flights to a minimum. On the other hand, it will be highly desirable to allow sufficient time for precision orbit determination in order to specify the correct retrofire point for a landing within the desired area. With these criteria in mind, a maximum of three orbits was chosen for the first manned orbital flight.

A number of considerations were taken into account to determine the most desirable launching azimuth. These were:

(1) Use of existing ground support instrumentation stations throughout the world.

(2) Use of the Atlantic Missile Range as the launch area and the impact area after the third orbit.

(3) An orbit which remained over the continental United States for a considerable portion of its flight, allowing continuous tracking, both during the orbital flight and during reentry.

For these reasons, a northeast launch from Cape Canaveral was chosen. The northeast launch which was selected results in an orbital inclination of $32\frac{1}{2}°$.

By following the map (fig. 16), it is seen that the first orbit passes just south of Bermuda, south of the Canary Islands, across Africa, over the Indian Ocean, and over the Australian Missile Range at Woomera. The track then passes across the Solomon and Phoenix Islands. The orbit then intersects the Mexican and southern California coast, passing over the southern United States where a number of available instrumention sites already exist, such as the Pacific Missile Range, the White Sands Missile Range, the Eglin Air Force Base, as well as the Cape Canaveral complex. The third orbit passes within close proximity of Hawaii, a very desirable location for radar tracking and command of the retrotimer, since direct hard-line communication is available from Hawaii to the continental United States.

In making the choice of the number and location of the various ground instrumentation stations, a number of other criteria were established. These include:

(1) The desire to have continuous tracking from Cape Canaveral through Bermuda for accurate orbital determinations and to have real-time telemetry and continuous voice contact during this time.

(2) The ability to reset the retrotimer conveniently on each orbit, as well as having direct ground command of the retrofiring during each orbit.

(3) The need for continuous contact with the capsule during launch and a reasonable length of time following orbital insertion.

(4) A desire to maintain frequent voice and telemetry contact with the capsule.

(5) The need for continuous impact prediction in case of an early abort requiring impact in the Atlantic Ocean, or during an early reentry if an emergency should occur after orbit injection.

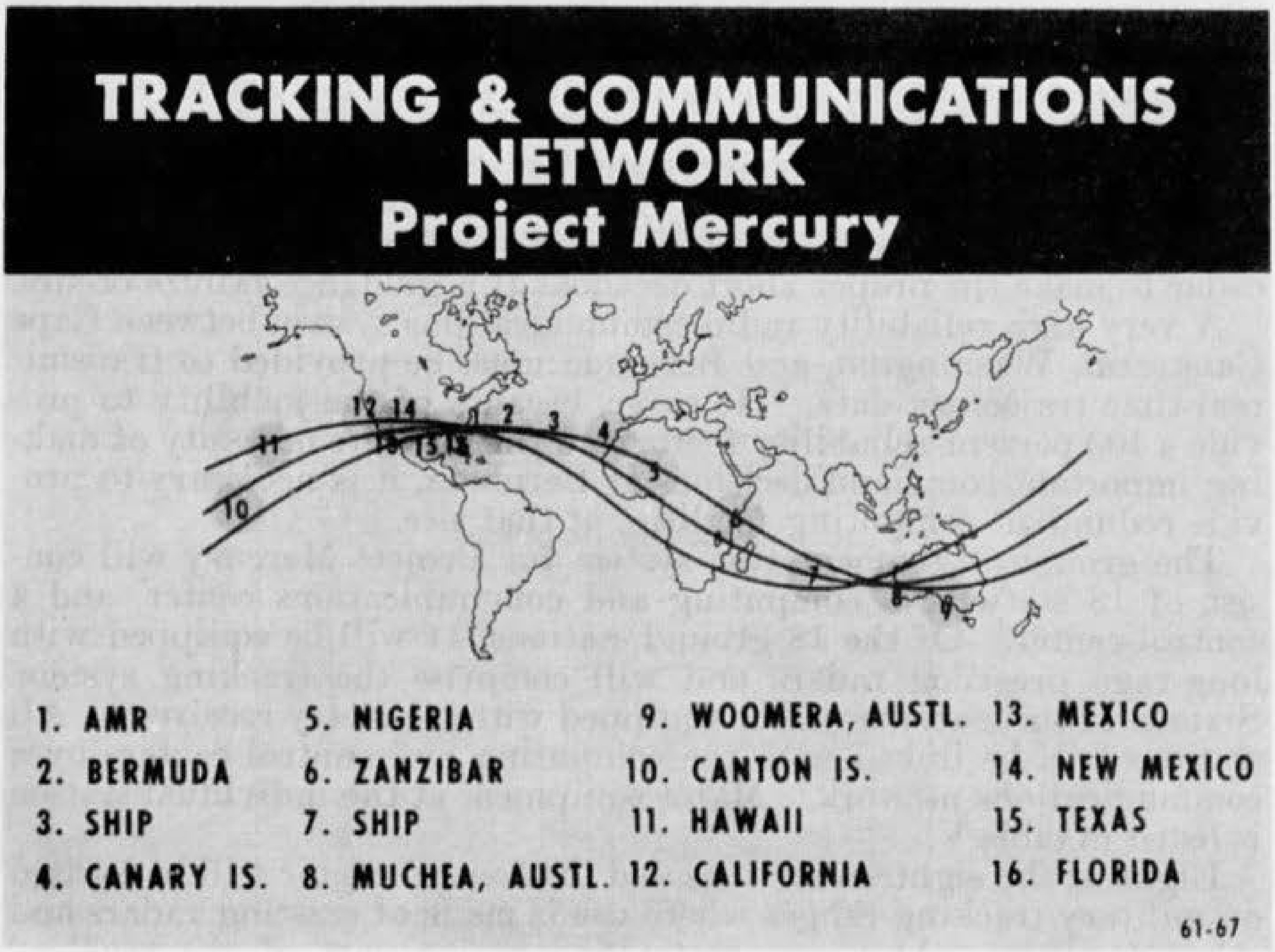
TRACKING & COMMUNICATIONS NETWORK
Project Mercury
1. AMR
2. BERMUDA
3. SHIP
4. CANARY IS.
5. NIGERIA
6. ZANZIBAR
7. SHIP
8. MUCHEA, AUSTL.
9. WOOMERA, AUSTL.
10. CANTON IS.
11. HAWAII
12. CALIFORNIA
13. MEXICO
14. NEW MEXICO
15. TEXAS
16. FLORIDA
61-67

FIGURE 16.

All of these and many other requirements, based on practical and economic limitations, resulted in a network of stations as indicated in table V. The stations transmit tracking data to a central computing facility located near Washington, D.C. The operation control center is located at Cape Canaveral.

Because of the critical period during launch and orbital insertion, additional computing facilities, other than those at Washington, are required at Cape Canaveral and at Bermuda. The General Electric Co. guidance and the Burroughs computing systems will be the primary source of information for the Cape Canaveral control center, since it is this system which performs the guidance function of the Atlas missile. These data will be used to calculate the launch trajectory and orbital insertion parameters which are to be displayed. Also, since this is the critical phase of the mission, the Azusa and FPS–16 radar systems at Cape Canaveral will provide backup information for the same displays in the control center should a malfunction of the Atlas ground guidance system occur. This redundancy is necessary since information on the capsule position and velocity will be required in order to make the proper abort decisions if a guidance failure occurs.

A very high reliability radio communications system between Cape Canaveral, Washington, and Bermuda must be provided to transmit real-time trajectory data. However, because of the inability to provide a 100 percent reliability factor and the absolute necessity of making important command decisions at Bermuda, it is necessary to provide redundant computing facilities at that site.

The ground instrumentation system for Project Mercury will consist of 18 stations, a computing and communications center, and a control center. Of the 18 ground stations, 11 will be equipped with long-rage precision radars and will comprise the tracking system. Sixteen of the stations will be equipped with telemetry receivers. All stations will be linked with the computing and control centers by a communications network. Major equipment at the individual station is listed in table V.

Eight of the eighteen stations and the control center will be located on military tracking ranges where use is made of existing radars and other facilities. At these locations, a major part of the required equipment, including most of the tracking radars, is now in existence and will be made available for this project. (These locations involve the Department of Defense test facilities and the Commonwealth of Australia.) NASA will arrange for the use of this equipment. The scope of Department of Defense participation in the support of Project Mercury operations is given in the "Overall Plan, DOD Support for Project Mercury Operations," dated January 15, 1960.

TABLE V.—*Station capability*

Station name	Coverage, passes	Radar		Telemetry reception	Communication (capsule)	Command control	Acquisition			Ground communications			Timing
		S	C				FA	SA	M	Voice	TTY	SSB radio	
Canaveral	1, 2, and 3	(X)	X	X	X	X	X	(X)		X	X		X
Grand Bahama	1, 2, and 3		(X)	X	X				X	X	X		AMR
Grand Turk	1, 2, and 3			X	X				X	X	X		AMR
Bermuda	1, 2, and 3	X	X	X	X	X	X			X	X		X
Atlantic ship	1, 2, and 3			X	X		X				X	X	X
Grand Canary Island	1 and 2	X		X	X		X				X	X	X
Kano, Nigeria	1 and 2			X	X			X			X	X	X
Zanzibar	1 and 2			X	X			X			X	X	X
Indian Ocean ship	1, 2, and 3			X	X		X				X	X	X
Muchea, Australia	1, 2, and 3	X		X	X	X	X				X	X	X
Woomera, Australia	1 and 2		X	X	X		X			X	X		X
Canton Island	1 and 2			X	X			X			X		X
Kauai Island, Hawaii	2 and 3	X	X	X	X	X	X			X	X		X
Point Arguello, Calif	2 and 3	X	X	X	X	X	X			X	X		X
Guaymas, Mexico	1, 2, and 3	X		X	X	X	X			X	X		X
White Sands, N. Mex	1, 2, and 3		X				X			X	X		X
Corpus Christi, Tex	1, 2, and 3	X		X	X		X			X	X		X
Eglin, Fla	1, 2, and 3	*	X				X			X	X		X
Goddard Space Flight Center [1]													

[1] Ground communications.

Site functions: FA, fully automatic; SA, Semiautomatic; M, manual; SSB, single side band; *, MPQ-31.

CONTENTS

Major functions of each station

1. *Functions of tracking and ground instrumentation system.*—The tracking and ground instrumentation systems will provide all the functions necessary for ground control and monitoring of all phases of the flight. Thus, it will provide continuous prediction of the location of the capsule; will monitor the status of the vehicle and occupant; and will permit the exercise of the command functions necessary for the mission. An artist's sketch of a typical command station is shown in figure 17.

The functions of tracking and ground instrumentation systems are completed when the capsule has landed and the best possible information on the location of landing point has been supplied to a recovery team.

2. *Major functions of stations.*—

(*a*) Cape Canaveral, Grand Bahama Island, and Grand Turk Island: The functions to be performed at these stations, as discussed herein, involve several locations in the AFMTC complex for tracking, telemetry, and vehicle communications. It is necessary to utilize equipment at Cape Canaveral, Grand Bahama Island, and Grand Turk Island. The use of Cape Canaveral and Grand Bahama is required during launch because of look angle problems and the associated capsule antenna patterns. Grand Turk is needed to provide coverage during the final phase of reentry where altitude limits the range of the stations.

From prelaunch through insertion, continuous telemetry, voice communications, and command capability will be provided to the control center and tracking data will be transmitted to the computing center.

(During this same period other data will be made available to the Mercury control center and will provide tracking data from the Atlas guidance system and FPS–16 to the computing center. These data are separate from the function of the station as discussed herein.)

During successive passages, the station will provide tracking, telemetry, and voice communication coverage. Command capability is also necessary in order to permit resetting the retrofiring programer and to furnish command backup of certain internally programed events during reentry and landing.

(*b*) Bermuda: The Bermuda station will determine if the capsule has been placed into an acceptable orbit and effect an emergency landing in one of the major recovery areas if the trajectory is not acceptable. Tracking, computing, telemetry, and command equipment will be provided with the capability to perform this function essentially independent of data from the launch site.

Other functions may be as follows:

(1) To command an abort at the direction of the control center in the event of serious capsule equipment failure or pilot difficulty late in the launch phase.

(2) To command an abort as directed by the control center for impact in a major recovery area in the event of certain propulsion or guidance system malfunctions.

(3) If the flight is normal, tracking and data transmission to the computing center will be required.

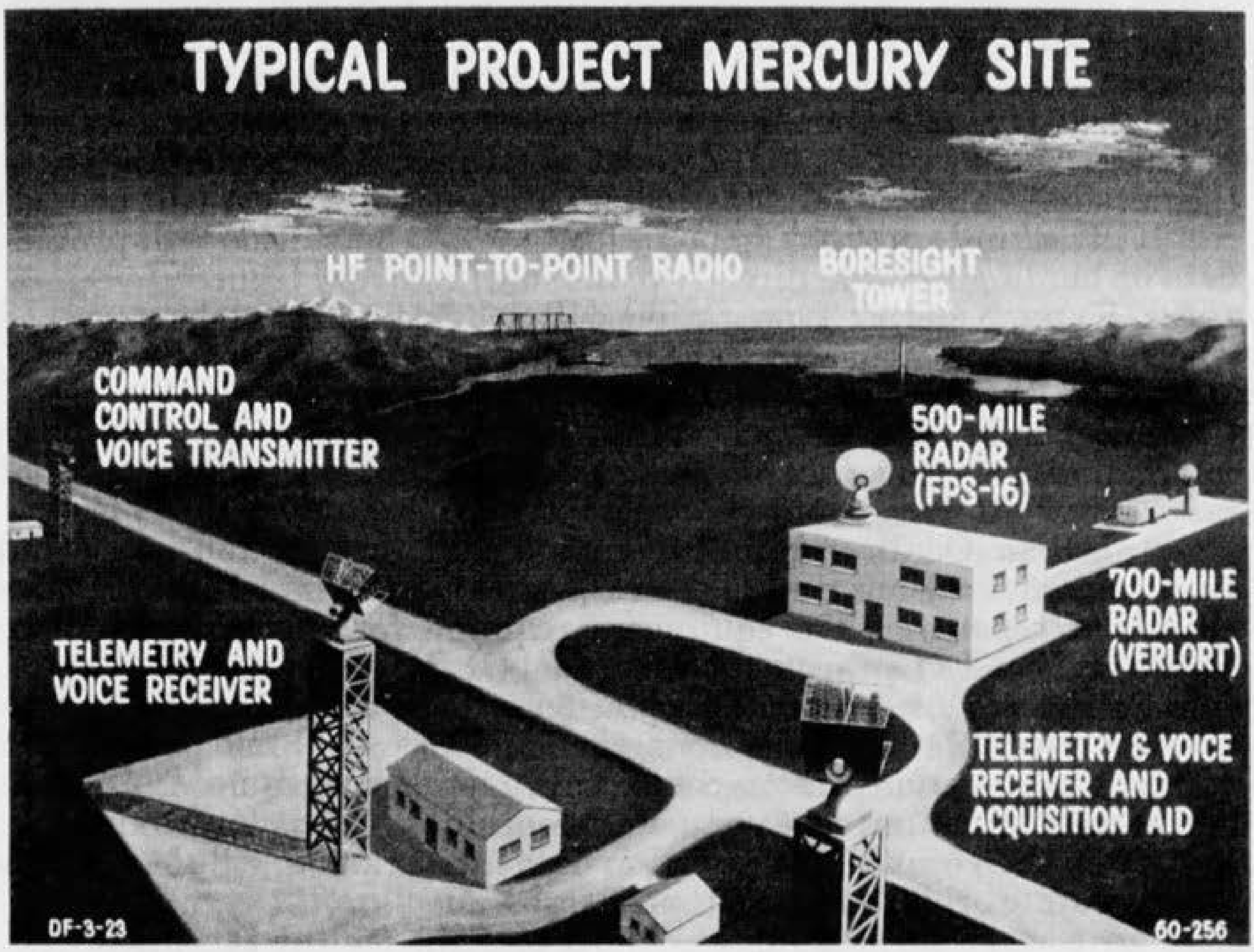

FIGURE 17.—Typical Project Mercury network station.

(4) If the flight is not normal, the impact point will be computed for use by the search and recovery group.

After a successful insertion, the Bermuda station must provide normal tracking and vehicle communications on successive passes. The station must also transmit commands to reset the retrofiring timer as directed by the control center. In the event of an emergency landing at the end of the first or second passage, tracking and computation of the landing point are required.

(*c*) Atlantic ship: This station will provide telemetry and voice communication coverage in the area of the mid-Atlantic on all three passes.

The equipment required for this station will be placed aboard a Government-furnished C1–M–AV1 ship.

(*d*) Grand Canary Island: This station will provide normal tracking, telemetry, and voice communications coverage for the first and second passes in the general area of northwest Africa. In the event the mission is aborted near the insertion point, the station will provide reentry tracking and landing point location. This station will provide data on landing location directly to the local recovery team.

(*e*) Kano, Nigeria: This station will provide normal telemetry and voice communications coverage on passes 1 and 2 in the general area of central Africa.

(*f*) Zanzibar: This station will provide normal telemetry and voice communications coverage on passes 1 and 2 in the general area of east-central Africa.

(*g*) Indian Ocean ship: This station will provide telemetry and voice communications coverage in the area of the mid-Indian Ocean on all three passes. The equipment required for this station will be placed on board a Government-furnished C1–M–AV1 ship.

(*h*) Muchea, Australia: This station will provide tracking, telemetry, and voice communications coverage on all three passes of a normal mission and transmit command functions as required. Tracking data obtained at this point in the orbit, which is approximately 180° from the point where insertion data are obtained, will lead to the most accurate orbit determination.

If an emergency landing is required at the end of the first orbit, the Australian station will be instructed from the control center to reset the capsule timer for firing of retrorockets at the proper time to initiate reentry and landing into a prepared recovery area off the east coast of the United States.

(*i*) Woomera, Australia: The Woomera location will provide C-band tracking, telemetry, and voice communication coverage on orbits one and two. The NASA will make arrangements with the Weapons Research Establishment of Australia for operation and use of an FPS–16 radar located at Woomera.

(*j*) Canton Island: This station will provide normal telemetry and voice communications coverage on passes one and two.

(*k*) Kauai Island, Hawaii: The function of this station is to provide tracking, telemetry, and voice communications on passes two and three and to transmit command functions as required. This station also maintains voice communications with the control center.

(*l*) Point Arguello, Calif.: The function of this station is to provide tracking, telemetry, and voice communication coverage for passes two and three, and to transmit command functions as required. The station also maintains voice communications with the control center. This station provides the first tracking data after reentry initiation on passes two and three. Telemetry data received will indicate whether the retrorockets have been fired at the programed time. If not, this station will command retrofiring to initiate reentry.

(*m*) Guaymas, Mexico: The function of this station is to provide tracking, telemetry, and voice communications coverage for passes one and two and to transmit command functions as required. The station also maintains voice communications with the control center. This station provides the first tracking data after reentry on pass one should this be required. Telemetry data received will indicate whether the retrorockets have been fired at the programed time. If not, this station will command retrofiring to initiate reentry.

(*n*) White Sands Missile Range, N. Mex.: This station contributes to the continuous tracking coverage in the United States on all three orbital passes, using an existing FPS–16 radar at White Sands.

(*o*) Corpus Christi, Tex.: The station in southern Texas provides tracking, telemetry, and voice communication for all three passes and contributes to continuous coverage of the reentry trajectory.

(*p*) Eglin Air Force Base, Fla.: The function of this station is to contribute to continuous tracking coverage in the United States on all orbital passes. Data transmission is required from Eglin to AFMTC to extend the reentry trajectory plot at the Mercury Control Center. Teletype tracking data will be sent to the computing center. NASA will use an existing FPS–16 C-band radar and MPQ–31 S-band radar at this station.

(*q*) Computing and Communications Center, Goddard Space Flight Center: The computing and communications center is located at the Goddard Space Flight Center, Greenbelt, Md. The primary functions of the computing and communications center will include:

(1) During orbital flight, the center will compute and transmit to the required stations the following information:

(*a*) Parameters describing the trajectory.

(*b*) The predicted location of the capsule.

(*c*) The predicted location of impact for emergency reentry.

(*d*) Time to fire retrorockets to land in next recovery area.

(*e*) Time to fire retrorockets to accomplish a normal landing.

(2) During reentry, the center will provide and transmit to the control center continuous prediction of the landing point on essentially a real-time basis.

(3) Throughout the entire operation, the center will provide acquisition information to all field sites.

(4) The center will serve as the main communications terminal for the Mercury operations. Communications to all field sites will pass through the center's communication area, and the appropriate switching and monitoring facilities will be provided.

(5) During launch and insertion the computing center will receive tracking data from the Cape Canaveral tracking systems including the GE Burroughs Guidance System. Using these tracking data in combination with selected telemetry data, the center

will compute and send data for displays at the control center suitable for the following functions:

(*a*) Monitor the launch to determine if the orbit achieved is satisfactory.

(*b*) If the orbit is not acceptable, determine times of retrofire to land in several designated recovery areas.

(*c*) Determine capsule landing point and present position.

(*r*) Control Center, Cape Canaveral: An existing building at AFMTC is used for the NASA Mercury Control Center.

The function of the control center will be to provide control and coordination of all activities associated with the Project Mercury operation. The necessary communications, displays, and control equipment will be provided to perform the following basic functions:

(1) Coordination with the blockhouse and central control during launch, including monitoring of vehicle propulsion and guidance, and assistance on range safety.

(2) Control of all stations outside Cape Canaveral.

(3) Monitoring of pilot and capsule systems.

(4) Instructions to pilot.

(5) Inflight trajectory monitoring.

(6) Commands to capsule equipment.

(7) Initiate emergency aborts during launch and insertion.

(8) Initiate emergency landing at completion of first or second passage.

(9) Initiate normal reentry and landing.

(10) Supply landing location information for search and recovery team.

3. *Function of the demonstration site.*—Existing NASA buildings and land at the NASA Wallops Station, Va., are being used to establish a temporary station consisting of selected items of equipment identical to that used at remote sites. This equipment has been installed and tested to determine performance characteristics and suitability for the Mercury mission. Field modifications and test procedures are being developed at this site. The technical information developed at this site will be applied to the remote Mercury sites to bring all sites up to the performance required for the Mercury mission.

Ground communication system

The purpose of the Mercury ground communication system is to provide a communications network connecting 18 range stations around the world with the Goddard Space Flight Center at Greenbelt, Md., and the Mercury Control Center at Cape Canaveral, Fla., as shown by the accompanying world map and circuit layout (figs. 18 and 19). The system will carry telephone, teletypewriter, and high-speed data information. Electronic computers at Goddard will process incoming data and provide as its output, acquisition messages and other related information to all range stations. Teletypewriter information, into and out of Goddard, will be handled by an automatic teletypewriter switching system. A significant portion of the traffic over the system will be information generated automatically by the radars or computers and transmitted at teletypewriter speeds. Generally, 60 words per minute transmission will be employed. For high

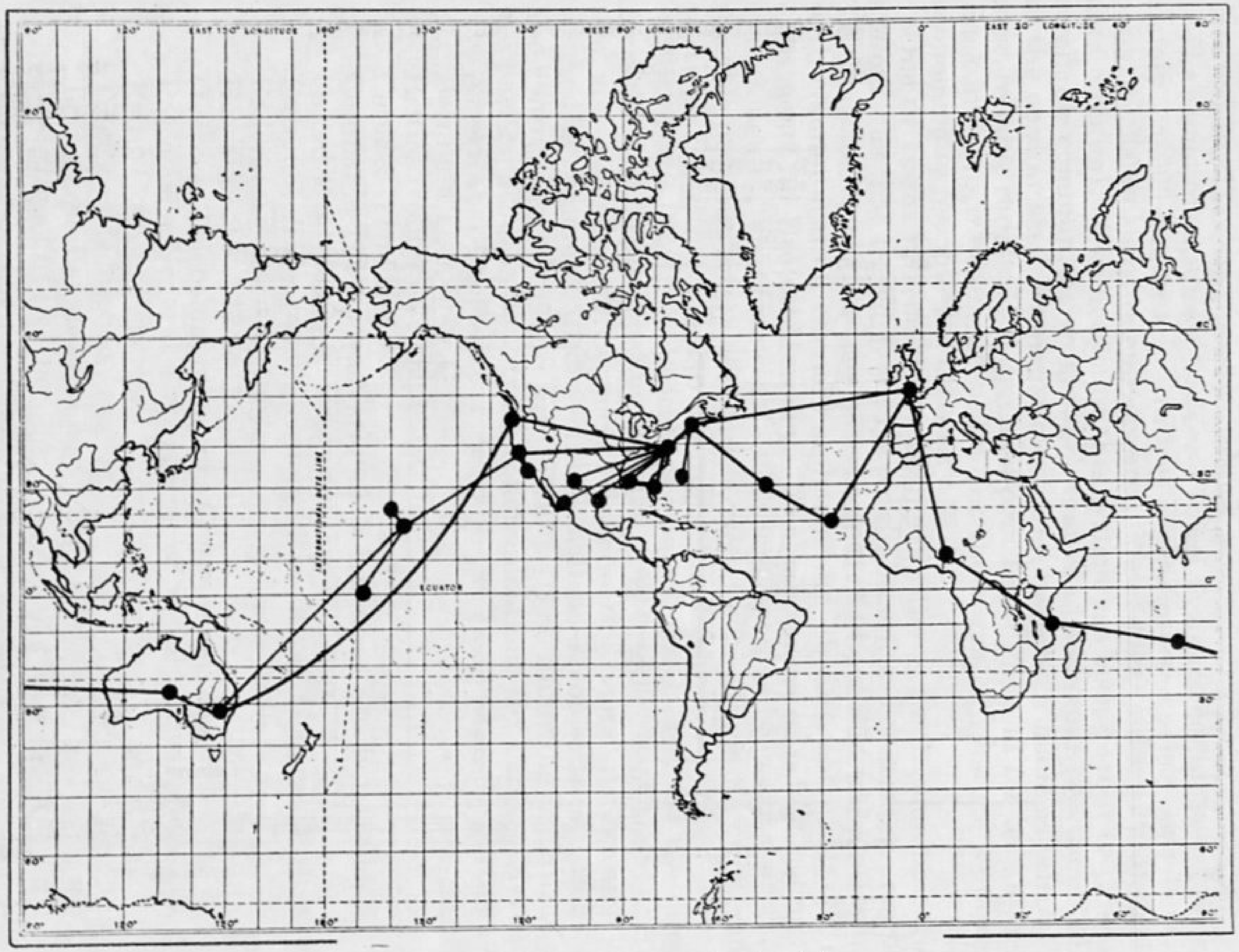

FIGURE 18.—Map of communication links.

GROUND COMMUNICATIONS CIRCUIT LAYOUT

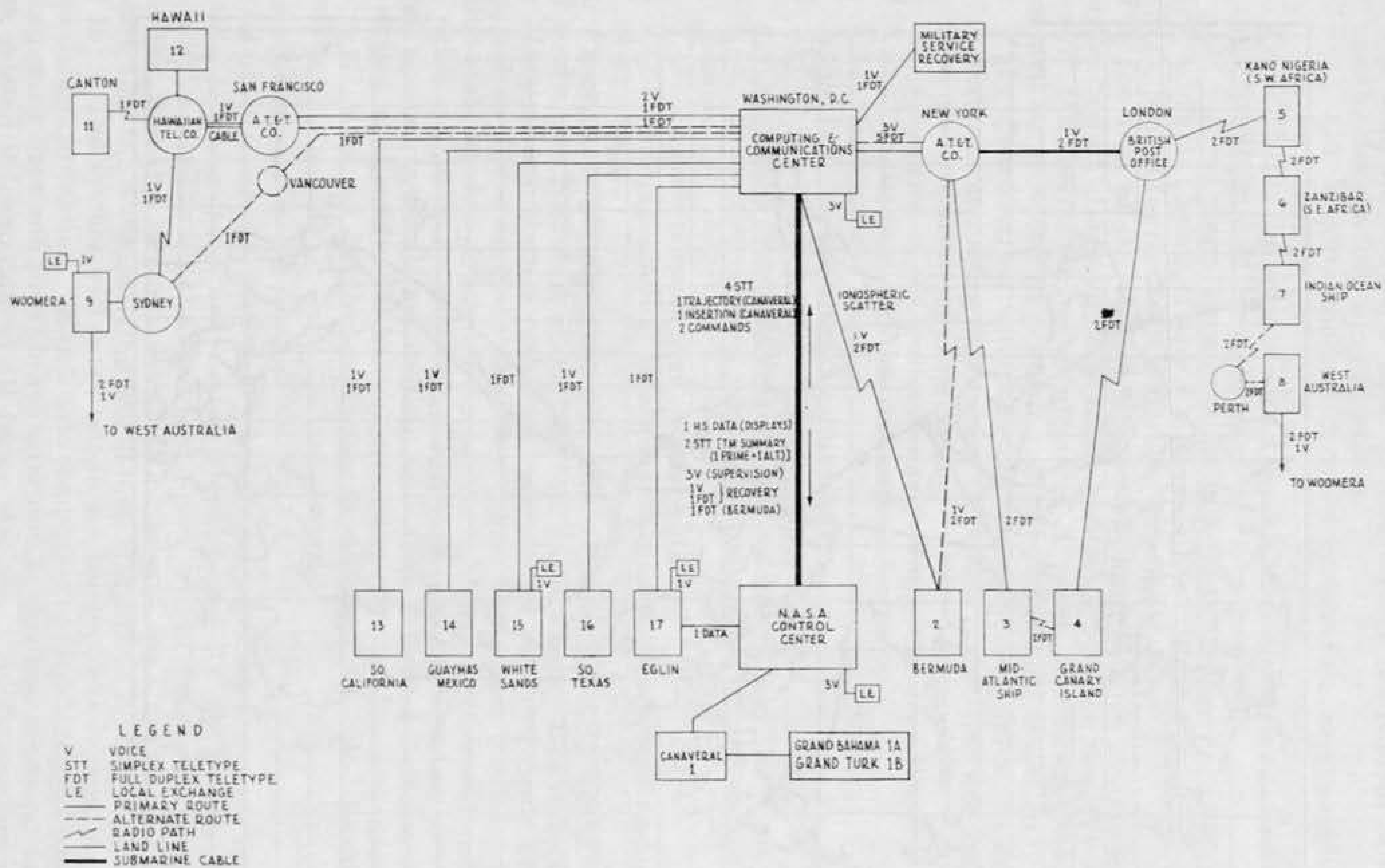

FIGURE 19.—Ground communications circuit layout.

priority traffic between Goddard and Cape Canaveral, teletypewriter circuits capable of transmitting 100 words per minute will be provided. High-speed data circuits between the computers at Goddard and Cape Canaveral will be provided to handle the large volume of data flowing between these two points.

The communication system for Project Mercury comprises approximately 125,000 circuit miles (about 88,000 miles of teletypewriter circuits; 32,200 miles of telephone circuits and 4,800 miles of high-speed data circuits). The design of this system has been geared to provide a reliable communication network that can be expanded economically as the need arises. Propagation studies have been made to select the most reliable radio routes for both primary traffic and for backup use. Backup facilities were provided for those routes where it appeared economically feasible and necessary.

One of the requirements in setting up the ground communication system was that leased facilities would be utilized wherever possible. To this extent, negotiations have been carried out and are continuing, with communication carriers at home and abroad, outlining the requirements for Project Mercury. The importance of safeguarding the system against any foreseeable interruptions has been stressed and a suitable program set up with the carriers for handling Mercury traffic, particularly with respect to the oversea radio links.

Within the North American Continent, practically all the circuit facilities will be provided by the operating companies of the Bell System and independent carriers. Outside the North American Continent the communication facilities will be a combination of leased and constructed radio and wire circuits. The following organizations are participating in supplying communications for Project Mercury:

American Telephone & Telegraph Co. Long Lines Department.
Bermuda Telephone Co.
British Columbia Telephone Co.
Cable & Wireless, Ltd.
Compania Telefonica National de Espana, Canary Islands.
Canadian Overseas Telecommunication Corp.
External Telecommunications Executive, General Post Office.
Federal Aviation Agency.
Hawaiian Telephone Co.
Overseas Telecommunications Commission, Australia.
Postmaster General, Department of Supply, Australia.
Radio Corp. of America.
Telefonas de Mexico.
Transradio Espanola, S.A., Canary Islands.
Department of Defense.

Station phasing and implementation progress

The network as described in the foregoing material is being implemented through a prime contract with the Western Electric Co., Inc.

Western Electric heads a team of subcontractors consisting of the following:

1. Burns and Roe, Inc., responsible for architectural and engineering design of the stations as well as construction phases of station development.

2. The Bendix Corp., responsible for the design, fabrication and installation of most of the electronic subsystems such as the telemetry equipment.

3. International Business Machines Corp., responsible for computation equipment, programing and operation.

4. Bell Telephone Laboratories, Inc., responsible for such items as simulation equipment and operational sequence procedures including system checkout routines, communication traffic studies, etc.

Western Electric not only serves as system manager and in the function of system integration, but also is responsible for network communications.

As an example of specific progress and to provide a report on how the implementation of the network has proceeded, milestones will be given for the Kauai Island, Hawaii, station:

Event	Completion date
1. Site survey	Dec. 10, 1959
2. Site design	May 15, 1960
3. Instrumentation equipment on site	Nov. 5, 1960
4. Site construction	Nov. 5, 1960
5. S-band tracking system installed	Jan. 20, 1961
6. C-band tracking system installed	Jan. 17, 1961
7. Telemetry equipment installed and tested	Feb. 1, 1961
8. Vehicle-ground communication equipment installed and tested	Feb. 8, 1961
9. Ground-ground communication equipment installed and tested	Jan. 25, 1961
10. Station support equipment on site	Nov. 7. 1960
11. Station dynamic tests	Mar. 20, 1961
12. Ground-ground communications integrated with communications center	Dec. 3, 1960
13. Station operational	Mar. 4, 1961

Computations for Project Mercury flights

There are three major computer installations associated with the Project Mercury flight computations; they are located at:

1. Cape Canaveral, Fla.
2. Bermuda.
3. Greenbelt, Md. (Goddard Space Flight Center).

At Cape Canaveral and Goddard, computations are made which concern the launch and injection into orbit phase of flight. The GE Burroughs computing system, in addition to performing its usual Atlas guidance function, will feed data by telephone line to Goddard. At Goddard, two IBM 7090 computers will determine, in real time, whether or not the launch trajectory and the predicted orbit are acceptable. This information will then be sent back to the Mercury Control Center, where it will be displayed. A backup display is provided through the Cape Canaveral Azuza or FPS-16 radar system, together with an IBM 709 computer installation.

If the real time orbit predictions indicate an acceptable orbit [Go decision], the capsule will be permitted to go into orbit. If the orbit is definitely unacceptable [No-Go decision], the mission will be terminated. If the decision is questionable at Cape Canaveral, the final decision to abort will be turned over to Bermuda.

At Bermuda, an IBM 709 computer installation is utilized to accomplish the following computations:

1. Monitors launch to ascertain a "Go" or "No-Go" decision depending on whether or not an acceptable orbit is achieved. This decision is to be accomplished within 30 seconds after the sustainer engine cuts off. This is a backup function to Cape Canaveral.

2. Computes the time to retrofire to permit the capsule to land in a preselected landing area in case the orbit is unacceptable.

3. Performs the reentry computation and predicts the impact point in case of an early abort.

4. Performs necessary computation and preparation for transmission of radar data to Goddard during second and third passes of capsule over the Bermuda area.

At Goddard, computations are accomplished on the two IBM 7090 installations, one acting as a backup for the other. The following functions are performed:

1. Determination of orbit, in conjunction with Cape computers.
2. Processing of all radar inputs from remote sites.
3. Defining and refining orbit.
4. Sending acquisition data to remote sites.
5. Providing data to the Mercury Control Center at Cape Canaveral, including information on time to fire retros.
6. Calculates and updates final impact point during reentry.

Network checkout procedures

The Mercury network is the most complex and extensive set of ground-support instrumentation implemented thus far in space programs. To properly test each subsystem and then the integrated system, both statically and dynamically, various checkout procedures will be employed.

Static component and subsystem tests are first accomplished. This includes the individual units and subsystems, such as the telemetering receiving equipment, the ground-to-capsule communications equipment, command control, C–band tracker, S–band tracker, acquisition aid equipment, to mention only a few. This type of testing is accomplished as installation proceeds and largely employs standard electronic test equipment as well as some specially designed apparatus.

As the subsystems are installed and successfully pass their static tests, there begins mutual radio frequency interference testing to detect and guard against troublesome stray energy that manifests itself as malfunctioning equipment. This is actually the beginning of full-station testing.

All subsystems are operated together in static-station testing. Dynamic testing begins against actual targets. The test targets are aircraft that execute "fly by" tests, or dynamic tests at each station throughout the entire network. These aircraft are outfitted with equipment identical to the electronic gear in the Mercury capsule, thereby allowing the station to determine electrical and mechanical difficulties in a near-operational situation. This type of testing also represents excellent training for the station operators.

Network tests represent the final step prior to an actual mission. Magnetic tapes are prepared in advance for each station. These tapes contain signals for the operators, the tracking radars are given simulated target information, simulated telemetry data is "received," simulated "conversations" are held with the simulated astronaut.

Commands can be issued from the station since emergency situations can be contained on the tapes. Each station has its own tape. The station's part is timed to happen in the exact same sequence from launch that an actual capsule pass would occur at the station. In short, an entire three-orbit mission can be simulated on the network as often as necessary to check out the net and to train operators without ever actually launching a mission. It is to be further noted that the capsule trainer discussed elsewhere can be part of the station dynamic tests and, thus, have capsule, astronaut, and network tested together in the final way the missions will actually progress.

Such dynamic network tests are currently being programed on tape. Subsystem and station static tests are now being accomplished.

Operations

Hangar checkout of capsules

The Mercury capsules are airlifted from the McDonnell plant at St. Louis, Mo., to Cape Canaveral, Fla. After the capsule arrives at the Cape Canaveral airstrip, it is trucked to the NASA capsule checkout area in hangar "S". Although a completed capsule receives a preliminary systems checkout at the factory, the final detailed systems check is made at the Cape. After an initial inspection check, the capsule is placed in a specially constructed building in which the hydrogen peroxide reaction control system is activated and functional checks are accomplished. Because of the fire hazards accompanying a hydrogen peroxide spill, this building is fully equipped with a water sprinkler system and a remote console for the test conductors. All persons handling the plumbing connections for the concentrated hydrogen peroxide must wear goggles, plastic caps, coveralls, boots, and gloves. Initially, both the peroxide and helium storage tanks within the capsule are filled, and differentially pressurized, with helium. They are then capped off and the pressure decay is monitored. This procedure is used to check the hydrogen peroxide and the helium plumbing systems for leaks and, in particular, the flexible bladder which will separate the peroxide from the helium. The system is then filled with the hydrogen peroxide and a 24-hour decomposition test is performed. If the system is compatible with the peroxide, there will be only a low rate of pressure increase. After this check, the peroxide valves are remotely actuated and thrust reaction time is monitored by measuring the temperature rise in the nozzles.

Following the reaction control system tests, the capsule is returned to a clean air-conditioned enclosure in the hangar and detailed checks are made on: (1) the d.c. and a.c. electrical systems; (2) the sequencing system which automatically controls all the capsule events from launch through capsule separation, tower jettison, capsule attitude, retrofiring control system modes, parachute deployments, and recovery beacon activation; (3) the communications system which includes the high frequency and ultrahigh frequency radios, command receivers, telemeter transmitters, FPS–16 and Verlort Radio beacons, and recovery beacons; and (4) the automatic stabilization and control system which involves attitude sensing limits for the horizon scanners, gyro-erection and precession, relays and logic circuits. The capsule then undergoes a simulated flight test where all capsule systems are programed as "in flight" and their performance is monitored. Upon completion of this test, all onboard capsule data recording equipment—film and tapes—are processed and evaluated. A critical portion of the Cape checkout is performed in an altitude chamber which creates a near-vacuum environment for subsystem functional checks and establishes the pressure integrity of the capsule. As the simulated altitude is lowered, the barostatically actuated capsule landing system will be functionally checked out.

One of the final hangar operations is an elaborate weight and balance check. Because the capsule aerodynamics are critically dependent upon the capsule center-of-gravity location, extreme care must be taken to maintain the center-of-gravity at a prescribed point. The thrust axes of the escape and retrorockets are also accurately alined at this time.

Capsule checkout operations require a large quantity of complex ground checkout equipment. This gear must support capsule preflight operations in the hangar and at each of the launch pads. Most of the monitoring and calibration equipment is contained in full-size trailers. Connecting cables are strung to the various checkout sites. To check the automatic control system, for instance, the capsule is installed in a two-axis test fixture and a heating element is used to simulate the Earth's horizon. The capsule is sequentially rotated in all three axes at various rates and attitudes. Signals from the gyro signal amplifiers are monitored and recorded on strip charts in the trailer. Calibrations of the telemetry system are also made while the capsule is installed in the test fixture.

The last operations in the hangar involve installation of the various rockets, explosive bolts, SOFAR bombs, and other pyrotechnics. The environmental control system is charged with high-pressure oxygen and the flight batteries are installed at this time.

Launch vehicle checkout

Concurrent with the capsule hangar checkout, the appropriate Redstone or Atlas launch vehicle is erected at the launch site and the numerous plumbing and electrical connections are accomplished. Functional checks are performed on the vehicle monitoring instrumentation, the automatic abort sensing equipment, the guidance and control equipment, the emergency destruct package, and the pressure integrity of the fuel and liquid oxygen tanks.

Checks during mate of booster and capsule

In addition to determination of mechanical compatibility, the installation of the capsule on the booster provides an opportunity to check the capsule ground support equipment within the blockhouse and launch gantry. Figures 10 and 13 show the gantry arrangements and the capsule systems checkout trailers which are used during capsule and booster checks at the launch pad. Figure 20 shows several of the capsule monitoring consoles in the blockhouse. This support equipment will enable personnel in the blockhouse and in the Mercury control center to monitor the pilot and capsule systems when the capsule is on the launch pad. During this period, the capsule radios, telemetry, and beacons are energized simultaneously with booster telemetry and beacons. Radio frequency interference checks are accomplished at this time.

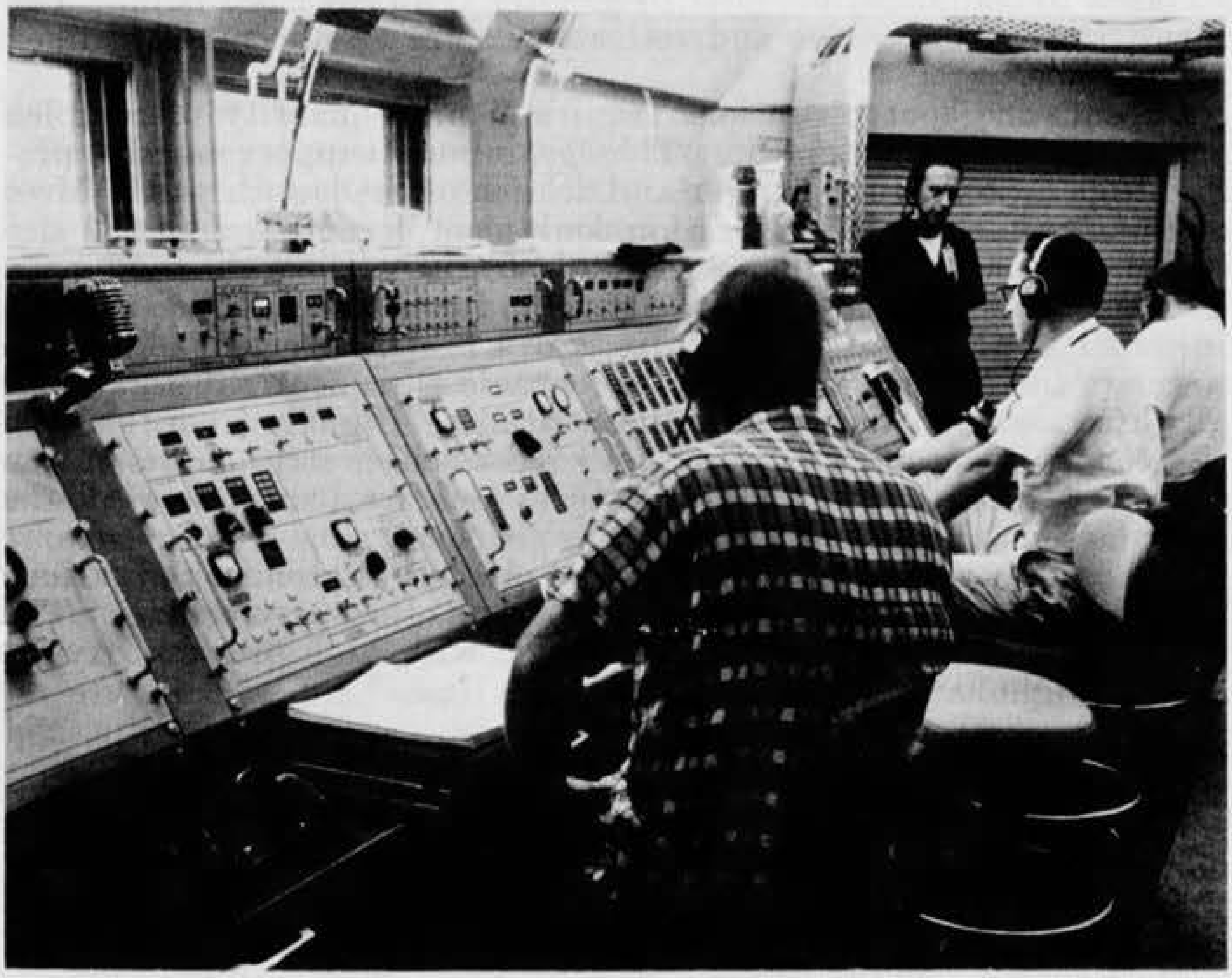

FIGURE 20.—Typical console installation in the blockhouse.

Flight safety review board

A flight safety review board will convene and evaluate the records of the launch vehicle and capsule tests. At this time, any difficulties which occurred during booster and capsule checkout will be discussed, and must be resolved to the satisfaction of everyone on the board. The board members will include representation from the launch vehicle contractors, the capsule contractor, the astronauts and other NASA operations personnel.

Prelaunch countdown

The prelaunch countdown is divided into two parts; the first portion starting 30 hours prior to launch and continuing for 4 hours. The final portion begins the following midnight and continues until the scheduled launch time of 7 a.m. This split count arrangement allows the launch crews a rest period in the midst of a long countdown. During the first 2-hour period, detailed capsule systems checks will be accomplished from the remote monitoring consoles in the blockhouse. During this initial 2-hour countdown period, the worldwide network of communications and tracking stations is alerted and routine tests are made on the telemetry, radar, the voice radio communications, and the command radio. Concurrently, the Mercury control center communications, telemetry, abort commands, and trajectory displays are activated and checked out. Seven hours prior to launch, the second half of the countdown is begun. A carefully designed sequence of launch vehicle fueling and LOXing, capsule, rocket and pyrotechnic arming, and radio frequency interference checks are accomplished. Extreme care must be taken to be certain that no stray voltages are applied when the pyrotechnics and rockets are being armed. Care must also be taken to maintain radio silence on certain critical frequencies. Approximately 4 hours before launch, the Navy recovery ships arrive on station in the impact area and approximately 2 hours prior to launch, local launch site surface vessels are called on station. The launch site helicopters and the search aircraft are phased-in just prior to launch. During manned shots, the pilot will enter the capsule approximately 2 hours prior to launch and will play an active part in the capsule check and countdown.

Mercury control center

Overall control of the Mercury missions is conducted from the Mercury control center at Cape Canaveral. A photograph of the control center building is shown in figure 21. This complex also serves as a telemetry receiving station; the large dish-shaped antenna will receive telemetered information from the capsule subsystems. The primary function of the center is to actively control the flight phase of the Mercury missions. Figure 22 is a block diagram of the flight control organization. The operations director is in charge of the mission and also serves as chairman of the Flight Safety Review Board. Immediately subordinate to the operations director is the flight director who actively participates in the countdown, coordinates the input from the systems controllers, and is responsible for making the decision to abort the mission if a malfunction should

FIGURE 21.—Mercury control center at Cape Canaveral.

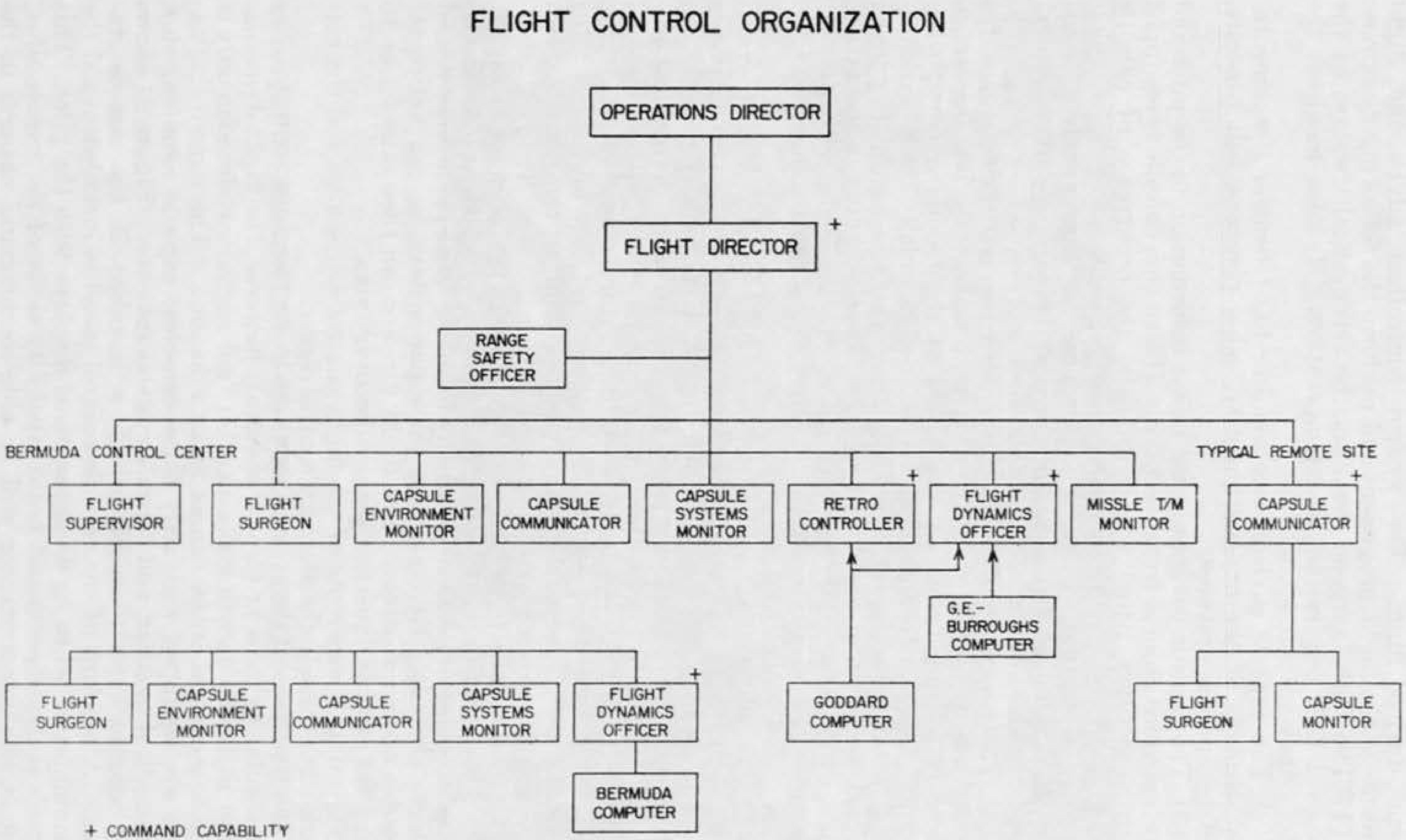

FIGURE 22.—Flight control organization.

occur during flight. The system controllers advise the flight director as the flight progresses and perform the following functions:

(1) The flight surgeon monitors the aeromedical displays of the pilot's EKG, respiration, and temperature. He also monitors the pilot's voice transmissions.

(2) The capsule environment monitor has telemeter instrumentation displays of the oxygen quantity, cabin pressure, suit pressure, and system temperatures.

(3) The capsule communicator relays information to the pilot and receives voice reports from the pilot. His station console is equipped with a sequence panel which indicates the occurrence of capsule events such as escape tower separation and retrofiring.

(4) The capsule systems monitor observes the capsule attitude and the amount of fuel remaining in the hydrogen peroxide control systems, and the status of the capsule electrical system.

(5) The retrocontroller panel displays the retrofiring times for normal reentry, end of each orbit, and emergency landing areas. These retrofiring times are calculated at the Goddard Computing Center. The retrocontroller keeps the capsule's clock synchronized with the optimum retrofiring time which is continually being refined by calculations based on the latest tracking information. Changes in the capsule retrofire clock setting can be accomplished through voice instruction to the astronaut or by radio commands from the retrofire controller's panel.

(6) The flight dynamics officer has the responsibility of evaluating the capsule orbital parameters at the end of the launch phase. He will use four plot boards which display flight path angle, velocity, capsule position, and impact prediction. Based on predetermined limits for these parameters, the flight dynamics officer will recommend that the capsule be permitted to continue orbital flight (go decision) or, if the capsule has not attained orbital velocity and flight path angle, he will request immediate retrofire to bring the capsule down in a planned recovery area (no go decision).

(7) The missile telemeter monitor will observe telemeter displays of critical launch vehicle parameters such as acceleration, engine chamber pressure, electrical and hydraulic system performance, and vehicle attitude. By observing these parameters, he can anticipate possible abort situations. The flight director can then take action to bring the capsule down in a planned recovery area.

Figure 23 shows some of the flight controller consoles and the network status map in the Mercury control center.

The functions of the systems monitors in the Bermuda control center are similar to those at Cape Canaveral; however, the flight dynamics officer at Bermuda will make an orbit "go" or "no go" decision only if the Cape control center cannot make a decision. The remote site stations are equipped with only three consoles: capsule communicator, aeromedical monitor, and capsule systems monitor. Figure 24 shows the communicator's console which is installed at the remote stations. A mockup of the capsule control panel is included to aid the communicator when he discusses panel displays with the pilot. This console includes command radio capability at six of the remote sites; that is, the communicator will be able to command changes in the retrotimer and command retrofire. Some of these communicators will be astronauts.

FIGURE 23.—Flight controller consoles at control center.

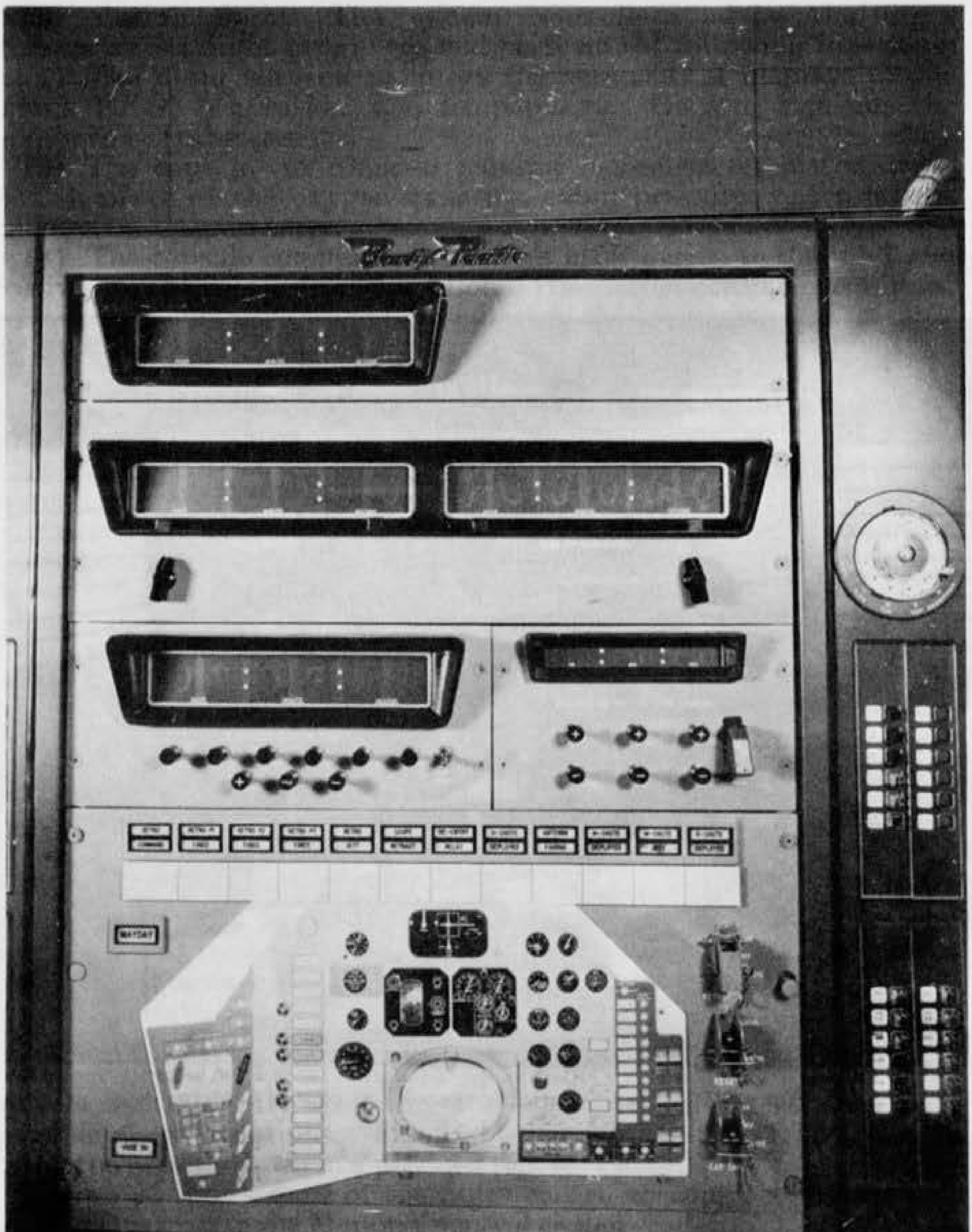

FIGURE 24.—Flight controller console at remote station.

Flight simulation

An important phase in the checkout of the equipment and in the familiarization for the flight controllers is the simulation training which precedes a flight. Because of the need to coordinate the network, recovery forces, capsule and launch procedures, and the Goddard and Cape computers, it was found necessary to provide advance operational experience. Figure 25 is a photograph of simulation consoles and shows the capsule procedures trainer used in the simulation room at the control center. By using this simulation equipment in conjunction with the Goddard computer, the Mercury missions are simulated and procedures are developed which will be utilized during the various phases of the operation.

Operational procedures during mission

During the prelaunch phase, flight control is delegated to the launch blockhouse. At lift-off, control passes back to the Mercury operations director at the control center. The pilot determines that his elapsed time clock starts at lift-off, thereby synchronizing capsule time with ground elapsed time. During the launch, the pilot reports pitch angle and acceleration to the ground. As the capsule rises through an altitude of 11,000 feet, the capsule internal pressure will start to vent overboard. A differential pressure regulator will maintain the capsule pressure 5 pounds per square inch above surrounding atmospheric pressure. The pilot notes that the cabin pressure does not decrease below 5 pounds per square inch. When a guidance command shuts the engine down, the pilot manually actuates an override switch and separates the capsule if automatic capsule separation does not occur. He also checks that the capsule attitude indicators display predetermined values. If the capsule gyros have drifted excessively during launch, the automatic control system will be inaccurate and he will manually control the capsule using his periscope and window for attitude reference. The capsule should be either automatically or manually turned to the retrofire position so that retrorockets can be fired in the correct direction if a rapid reentry is found desirable.

Operational procedures near orbit insertion

One of the most critical points in the Mercury orbital mission is at orbital insertion when the Mercury capsule is separated from the Atlas launch vehicle. At this point, it is necessary to determine whether the mission should be allowed to continue, or an abort should be executed so that the capsule will land near a previously established recovery area. An acceptable orbit is considered to be one which will insure the capability of a safe recovery at the end of the first orbit; that is, the lifetime must be sufficient so that the retrorockets can be fired within range of a command station near the end of the first orbit in order to land in the planned recovery area. In addition, the heating conditions must fall within acceptable limits in the region of perigee, and the reentry loads must be within given tolerances. It has been assumed that if the conditions existing at orbit insertion are such that the capsule completes one and one-half orbits, an adequate margin of safety will have been attained. Therefore, any acceptable combination of insertion conditions should guarantee the opportunity

PROJECT MERCURY—SECOND INTERIM REPORT

Introduction

The Honorable Overton Brooks, Chairman of the Committee on Science and Astronautics, during the second session of the 86th Congress, submitted to the U.S. House of Representatives the First Interim Report on Project Mercury, dated January 27, 1960. Almost 1½ years have passed since the issuance of that report. This committee report described the goals, the research and development program underway to achieve the program goals and the training program for the Astronauts. The purpose of this report is to summarize the current status of the Mercury project, to assess accomplishments to date and acquaint the Congress and the public with a feel for the tremendous complexity of the problem of putting a man into Earth orbit, sustaining his life in a space environment and recovering him safely.

Project Mercury is currently this Nation's effort to place a man in space at the earliest possible time. Since its inception, both the National Aeronautics and Space Administration and the Department of Defense have mapped out more comprehensive manned space flight programs. However, these later projects, named Apollo and Dyna-Soar, must depend upon the successful development of larger space boosters such as Saturn, Titan II, Atlas G, or perhaps a newly conceived large solid rocket arrangement. Because Apollo and Dyna-Soar depend upon as yet unflown, larger boosters and are designed to project more than one man into Earth orbit, it is not expected that either of these projects will be capable of placing manned payloads in orbit for 6 to 8 years. Project Mercury is expected to provide many answers for these future manned space programs—answers which must be obtained concerning manned space flight environment, and man's ability to perform a useful function in space as soon as possible. Consequently, Project Mercury is being prosecuted by NASA, assisted by the DOD, with the utmost sense of urgency. Mercury enjoys top national priority as approved by the President of the United States. It carries DX priority rating.

Project Mercury represents the Wright Brothers phase of space flight. It is sure to appear as crude and daring-do to future generations as the clumsy wood and cloth "kits" of aviation's bygone era. Both represent major phases in man's technological development. Both have experienced controversial criticism on the one hand and admiration for the courage, dedication and vision of the men who strive for achievement on the other hand.

FIGURE 25.—Procedures trainer console installation.

to command retrofiring, thus controlling the landing point, at any time during at least the first complete orbit.

The problem is then reduced to finding as accurately as possible the orbital conditions that will permit the capsule to complete one and one-half orbits. When these conditions are defined completely in the ranges of velocity, flight path angle, and altitude, the actual orbital conditions obtained may be compared to the established limiting conditions in order to decide whether the mission should be allowed to proceed.

After a successful orbit has been achieved, the pilot will report to the remote stations as he passes overhead, telemetry signals will be received, and tracking data will be recorded. The remote site information will be sent back to the Mercury control center, by way of the Goddard Communications Center. Tracking acquisition information is calculated at the Goddard Computing Center and is sent out to the remote sites. It will be an objective of the control center to keep the remote sites as fully informed on the current situation as possible. Thus, in the event of a breakdown in communications, they may be better able to make decisions independently if a critical situation develops. The various times of retrofire will be continuously computed on the basis of new information as it becomes available, and it is imperative that remote sites be kept up to date on these items.

As the time of reentry is approached, the control center will be supplied with tracking data from the computers at Goddard and the presentation of impact prediction will be given in real time. The main function of the control center at this time is to keep the recovery forces up to date on impact prediction.

Recovery

The probability of capsule landing locale varies throughout the different phases of a flight and is a major factor in establishing the recovery requirements. The basic philosophy of recovery in the Mercury program is to provide a rapid recovery capability (1) in the normal landing area; (2) in those areas where landings would occur in case of an abort during the early phase of flight; and (3) once each orbit. "Rapid recovery" implies that location and retrieval vehicles are on station in these areas during orbital flight to assure recovery within a specified time that is in the order of from 3 to 6 hours. All of the recovery areas resulting from this recovery philosophy are located in the North Atlantic Ocean. The probability of containing all landing points within these areas is very high.

The planned recovery areas are shown in figure 26. In addition to the nine areas depicted, a launch site recovery area exists at Cape Canaveral in the event an abort occurs during the final countdown or early in the boost phase of flight. The launch site recovery forces will have the capability to effect recovery for a capsule on land or in shallow water.

Should an unsatisfactory condition develop during launch, a mission will be aborted so that landings from such conditions will be contained in areas one through six. If the orbital parameters at insertion are satisfactory and if the capsule systems are functioning properly, the capsule will be permitted to continue in orbital flight. In case of "no-go" decision at orbital insertion, the abort procedures will be such that all landings will be contained in areas five or six.

FIGURE 25.—Procedures trainer console installation.

to command retrofiring, thus controlling the landing point, at any time during at least the first complete orbit.

The problem is then reduced to finding as accurately as possible the orbital conditions that will permit the capsule to complete one and one-half orbits. When these conditions are defined completely in the ranges of velocity, flight path angle, and altitude, the actual orbital conditions obtained may be compared to the established limiting conditions in order to decide whether the mission should be allowed to proceed.

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FIGURE 26.—Planned recovery areas.

If a "go" decision at insertion is made, the capsule is committed to the completion of at least one orbit before a landing in a planned area is possible. Planned recovery areas seven through nine afford the capability to abort or terminate the mission once each orbit. Retrorocket firing points for landing in these three areas are located approximately 300 miles off the west coast of the United States. After passing the retrofiring points for area six, approximately 70 minutes of orbital flight time are required to reach the retrofiring point for area seven. Approximately 90 minutes of flight time elapsed in progressing from retrofiring point seven to eight and eight to nine. Thus, once the "go" decision is made at insertion, the capsule is committed to a comparatively long flight time before landing in an area where short-term recovery capability exists.

Backup and redundant systems have been provided for all basic capsule systems such that the probability of a malfunction occurring in orbit is considered remote and the standard operating procedure will be to terminate the mission by landing in a planned area if at all possible. However, a planned course of action for effecting the recovery in a low-probability contingency area is also required. In addition to the recovery forces in the Atlantic Ocean several standby ships and aircraft stationed under the orbital flight paths will be alerted for possible contingency recovery operations.

Astronaut Program

The seven Mercury pilots participated in numerous training activities during the past year. They also helped to establish many of the Mercury operating procedures and subsystems design details. Each is an engineer and has been assigned to work in a specialty area. Each man is intensely interested in the program and has a sincere desire to be chosen for manned flight. The astronaut biographies were presented in House Report No. 1228.

Flight simulators

To familiarize the pilots with the capsule and the various normal and emergency operational aspects of the Mercury flight, the following simulators and facilities were among those utilized during the past year:

1. *Procedure trainer.*—McDonnell has provided two procedures trainers for Project Mercury. The interior arrangement of these trainers is identical to that of the capsule. The displays within the trainer are operated by high-speed computers. One of the trainers is located at the space task group and is used to familiarize the astronaut with operation of the capsule system. It is also used in conjunction with a remote network station console to provide training for the capsule systems and aeromedical monitors. The second trainer is located at Cape Canaveral and is used to provide mission simulation training for the astronauts and the flight controllers. It also aids in the checkout of the computer circuits in the Goddard Computing Center and the trajectory display equipment at the Mercury control center. Figure 27 shows the instructor's console for the procedures trainer and the astronauts' capsule simulator in the background.

FIGURE 27.—Procedures trainer, instructor station.

2. *Johnsville centrifuge.*—The Navy centrifuge at Johnsville, Pa., has also been a valuable training simulator. The Mercury pilots have undergone three training sessions at this facility; the last session was a realistic simulation of the Redstone prelaunch activities and inflight control procedures. These tests also provided an opportunity for some of the range stations aeromedical monitors to observe the displays of biomedical instrumentation during acceleration. The centrifuge gondola arrangement is shown in figure 28 and the closeup of an astronaut within the gondola is shown in figure 29.

3. *Zero-gravity flights.*—The pilots have had three opportunities to participate in weightless flying research programs. Air Force C–31, C–135, and F–100F aircraft were used. By flying zero-gravity parabolas, these aircraft achieved periods of weightlessness of 10 seconds, 30 seconds, and 60 seconds, respectively. Astronaut Shepard experienced 5 minutes of weightlessness during the MR–3 flight. No adverse effects were realized.

4. *Multiaxis simulator.*—The multigimballed simulator at the NASA Lewis Research Center was used for pilot indoctrination at high values of angular acceleration and rotation. This facility was operated at 30 revolutions per minute about all three angular axes. The pilot used a manual reaction control system (compressed nitrogen) to stop the rotations. The pilots successfully maintained orientation at angular accelerations far in excess of any which will be encountered in Project Mercury. A picture of this facility is shown in figure 30.

5. *Egress training.*—Although the pilot would normally stay within the capsule until it had been placed aboard ship, there is a possibility that he might desire to climb out after a water landing. Egress might be desirable to facilitate rapid rescue, in the event of high temperatures within the capsule, or if the ventilation system were not functioning properly. To accomplish egress training under realistic sea conditions, an egress capsule was taken to Pensacola, Fla. The egress capsule is a boilerplate model manufactured by McDonnell Aircraft Corp. Weight and hydrodynamic characteristics are identical to that of the flight version. The interior mockup is identical to the flight version and affords the same degree of egress restriction. To leave through the top of the capsule, the pilot must first release his restraint harness, communications, oxygen hoses, and bioinstrumentation connectors. He then raises partially out of the couch and removes the 3-foot-diameter bulkhead from the top of the pressurized compartment. Next he must push the empty parachute container out of the cylindrical neck of the capsule and work himself out the top. He then inflates his liferaft and ties it to the capsule to maintain the capsule adjacent to the liferaft and take advantage of the capsule recovery beacons. A photograph of one of the pilots emerging from the egress trainer capsule is shown in figure 31.

For normal helicopter recovery a procedure has been developed whereby a hovering helicopter lowers two lines; one attaches to the capsule and holds it erect while the second line lowers a sling near the side hatch. The pilot then crawls through the side hatch into the sling and is lifted into the helicopter. This is the procedure that was used after Alan Shepard's Redstone flight.

Under emergency conditions, much more rapid egress is possible through the capsule's side hatch.

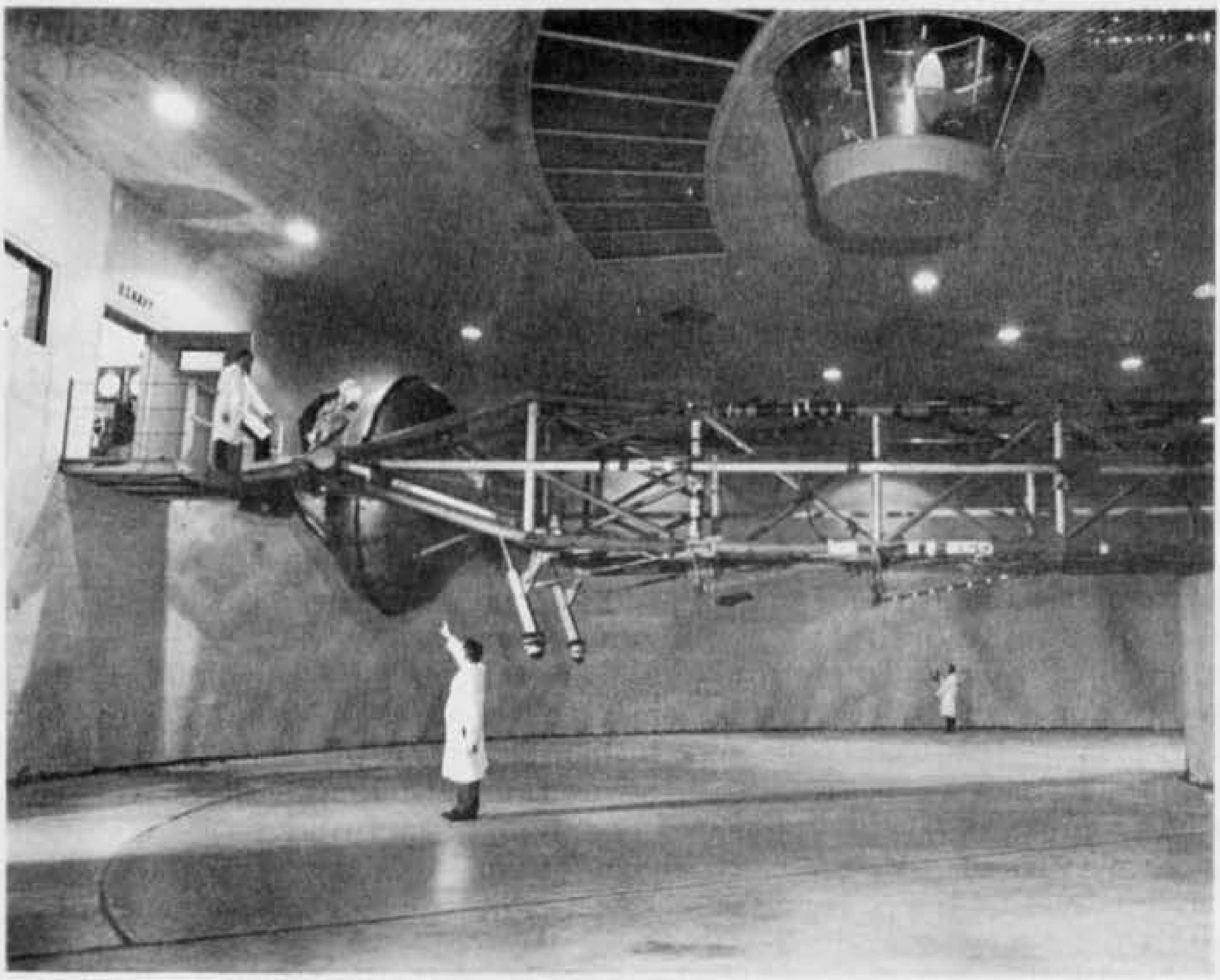

FIGURE 28.—Human centrifuge at U.S. Navy, AMAL, Johnsville, Pa.

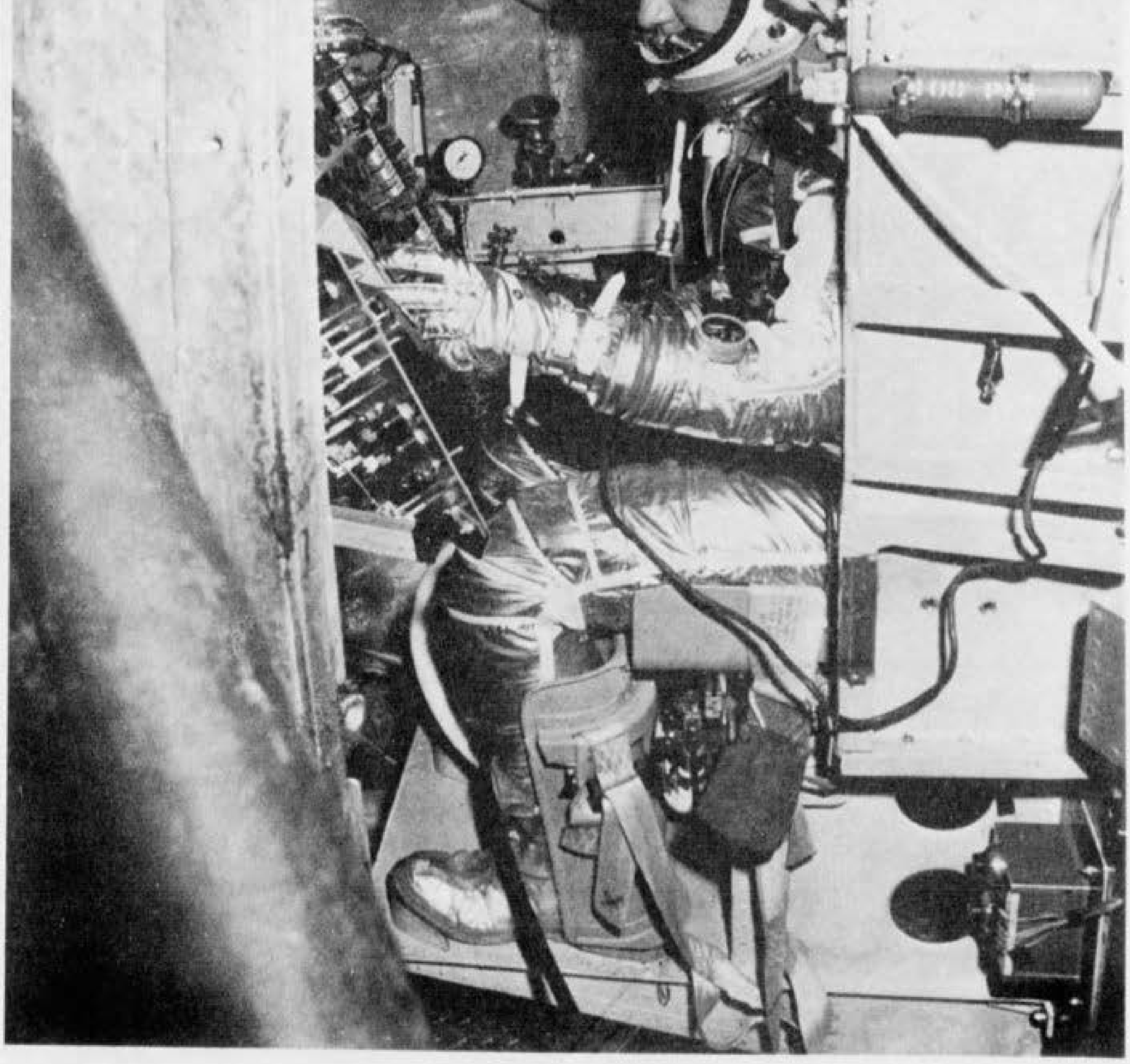

FIGURE 29.—Mercury astronaut in the AMAL centrifuge cabin.

Background

Project Mercury is now 2½ years old. Since its inception, an extensive wind tunnel and flight test program has been carried out, involving hundreds of wind tunnel and airplane drop tests and 12 successful major rocket launchings, including the first manned suborbital flight with Astronaut Alan B. Shepard, out of 15 attempts. The box score is contained in table I. The Mercury production capsules have been designed, engineered and tested. A major network of communications and tracking stations is nearing completion (table II), and training exercises of both the systems and the astronauts are progressing. Table III contains the current manning level requirements for the worldwide tracking and communications network.

TABLE I.—*Project Mercury major rocket tests*

Booster vehicle	Objectives		Purpose of test
	Achieved	Not achieved	
Little Joe I	X		Test launch vehicle.
Little Joe II	X [1]		Test capsule escape system.
Little Joe III	X		High altitude abort and capsule stability.
Little Joe IV	X		Repeat of Little Joe II.
Little Joe V		Capsule did not separate.	Capsule abort test under severe conditions.
Little Joe V-A	X [1]		Production capsule qualification test.
Little Joe V-B	X		Repeat of Little Joe V-A.
Atlas Big Joe	X		Validation of ablation heat shield and capsule dynamic stability during hypersonic reentry.
Mercury Atlas I		Atlas destroyed	Maximum reentry heat test.
Mercury Atlas II	X		Repeat of Mercury Atlas I.
Mercury Atlas III		Atlas destroyed	Unmanned orbital attempt.
Mercury Redstone I	X		Capsule qualification under normal ballistic flight conditions.
Mercury Redstone II	X		Test of capsule life support system with chimpanzee "Ham."
Mercury Redstone Booster Development.	X		Flight qualify booster control system changes.
Mercury Redstone III	X		First manned suborbital flight with Astronaut Shepard.

[1] Partially achieved.

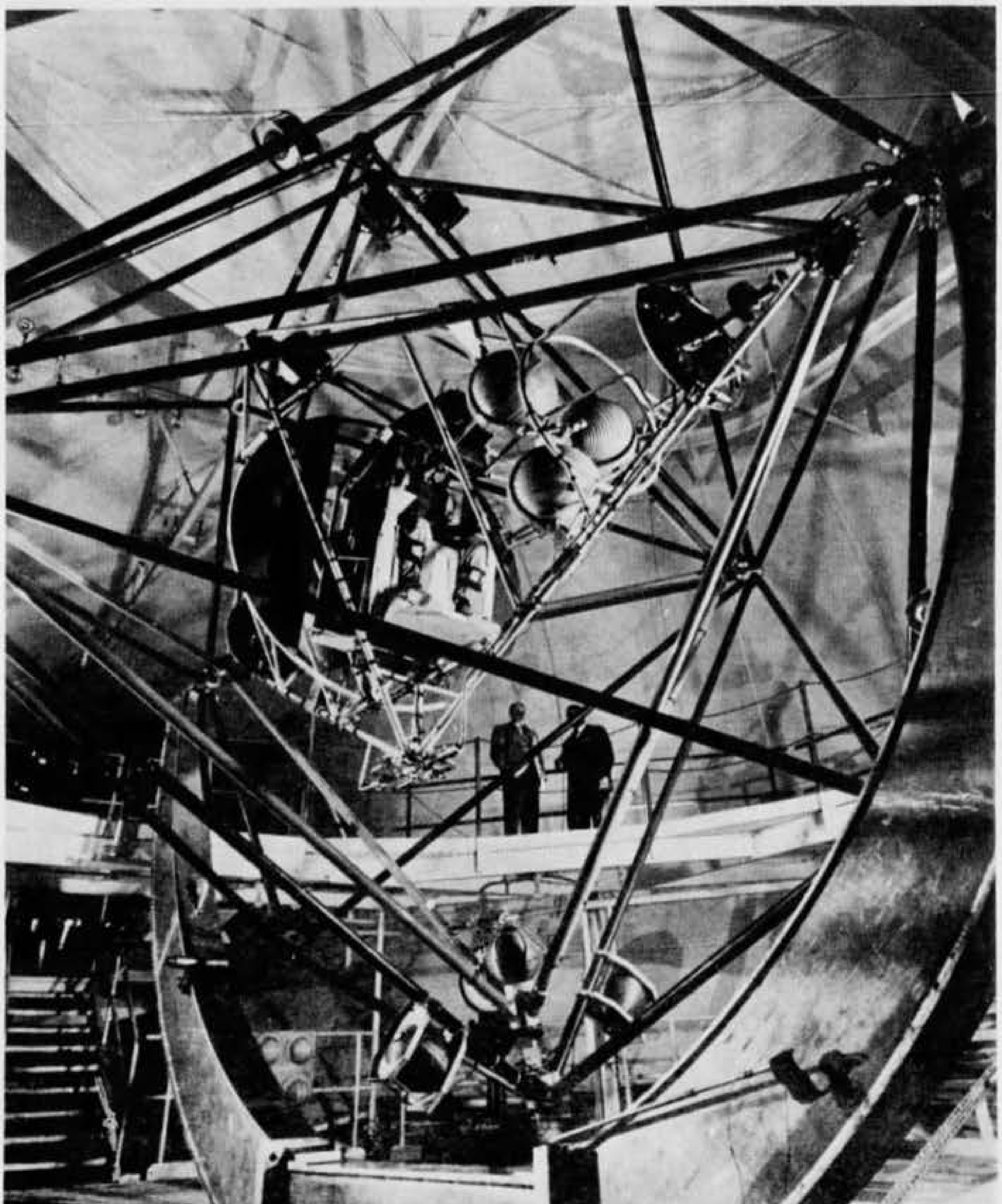

FIGURE 30.—Multiaxis motion simulation at Lewis research center.

FIGURE 31.—Mercury astronaut undergoing training in capsule egress procedures.

Pilot activities during flight

Although the capsule is only 6 feet in diameter and 10 feet high, it contains a complex array of subsystems and manual controls. The attitude control system is an example of a capsule subsystem with many modes of operation available to the pilot. The control system consists of a manual system and an automatic system; however, each of these contains several modes which can be used at the discretion of the pilot. He can select the direct manual mode in which, by means of a hand-control stick, he moves a mechanical linkage which is attached to valves in the hydrogen peroxide lines. The valves can then be opened proportionately to the amount of thrust he desires. By throwing a switch he can augment his manual input with electrically operated valves which are controlled by a separate set of gyroscopes. This additional gyro input tends to stop any capsule motion which exists. He can select a purely automatic mode in which special horizon sensing photocells send signals to stabilize a set of attitude gyros which in turn send signals to electrically operated peroxide valves. He can uncouple the attitude gyros in the automatic system so that the reaction jets are activated by angular rate gyros rather than attitude position gyros. The capsule can be manually flown on the automatic system by electrically linking the hand-control stick to the peroxide valves. During the retrofiring maneuver, the pilot would normally choose to augment the automatic system by the use of the manual system. If a valve in the automatic system were to fail in the open position, the pilot would shut off that particular axis of the automatic system and manually control the capsule attitude about that axis. The pilot would normally use the automatic mode while in orbit, thereby permitting full attention to ground and sky observations and to reporting the behavior of the various capsule systems. In all, the pilot can select any of 20 different modes for the capsule control system.

The attitude control system is only one of the capsule subsystems. Also controllable by the pilot in a number of different modes are the electrical, communications, life support, retrofiring, landing, and recovering systems. In addition to these, he can manually actuate the normal automatic sequential operations such as escape rocket firing, capsule separation, and tower separation. By providing the pilot with complete control over the capsule operation, a high degree of safety has been built into the Mercury concept.

During Shepard's flight in MR–3, the manual control system was used during all the critical maneuvers after capsule separation. The retrofire maneuver was accomplished by using the manual control system and observing the rate and attitude indicators. Shepard reported that the rocket thrust misalinement was small and caused relatively low torques on the capsule. He felt that the actual angular acceleration imparted to the capsule provided motion cues which made attitude control easier than in the fixed-base simulators.

Shepard's flight proceeded very much as planned. He did, however, notice a mild vibration during launch as the capsule progressed through the transonic speed range and continued until the maximum dynamic pressure region had been encountered. He felt that, although his vision was somewhat blurred during this 10-second vibration period, he could have improved his vision by raising his head from the couch. These vibrations were caused by aerodynamic turbulence downstream from the capsule-to-adapter clamp ring. Subsequent flights will incorporate special clamp ring fairings which should reduce the turbulence and resultant vibrations.

Physiologically Shepard's performance was very similar to that observed during his training sessions on the centrifuge. His heart rate, as monitored on EKG traces, did not exceed 135 and his respiration rate was normal. Zero-gravity caused no difficulty; in fact, the 5-minute duration of weightlessness was hardly noticeable because his attention was occupied with capsule control duties and visual observations through the periscope and windows.

Results of the MR–3 flight indicate that the pilot performed as expected and that the pilot should increase the probability of success for the orbital mission.

Program Management and Support Organization

The program management structure for Project Mercury is shown in figure 32. The Space Task Group (fig. 33), at Langley Field, Va., has the responsibility for overall project direction.

Space Task Group is under the direction of Mr. Robert R. Gilruth, and his two associates, Mr. Charles J. Donlan and Mr. Walter C. Williams.

Within the NASA organization, project support is provided by the Langley, Ames, Lewis, and Flight Research Centers. The Marshall Space Flight Center of NASA has the responsibility for providing and launching Redstone launch vehicles.

The Mercury capsules or spacecraft are produced to NASA specifications by the McDonnell Aircraft Corp. and associated subcontractors. In addition to producing the capsules, McDonnell Aircraft Corp. provides personnel services for preparation and launch of the spacecraft, associated ground support equipment, research and development hardware, flight simulators, and other training equipment.

Major subcontractors to McDonnell are as follows:

Minneapolis-Honeywell: Automatic stabilization and control system.

AiResearch: Environmental control system.

Bell Aircraft Corp.: Hydrogen-peroxide control system.

Food Machinery Corp.: Backup hydrogen-peroxide control jets.

Eagle-Picher Co.: Batteries.

Collins Radio: Communications system.

Cincinnati Testing Laboratories: Ablation heat shield.

Brush Beryllium: Beryllium heat shield.

Radiophone Division of Northrop: Landing system.

Grand Central Rocket Co.: Escape rocket.

Thiokol Chemical Corp.: Retro and posigrade rockets.

Perkin-Elmer Co.: Periscope.

Barnes Instrument Co.: Horizon scanner.

The Atlas launch vehicles for Project Mercury are produced by Convair Astronautics and associated contractors under the management of the Air Force Ballistic Missiles Division and its associated management contractor, Aerospace Corp. Launch of the Atlas vehicle is the responsibility of USAF–BMD.

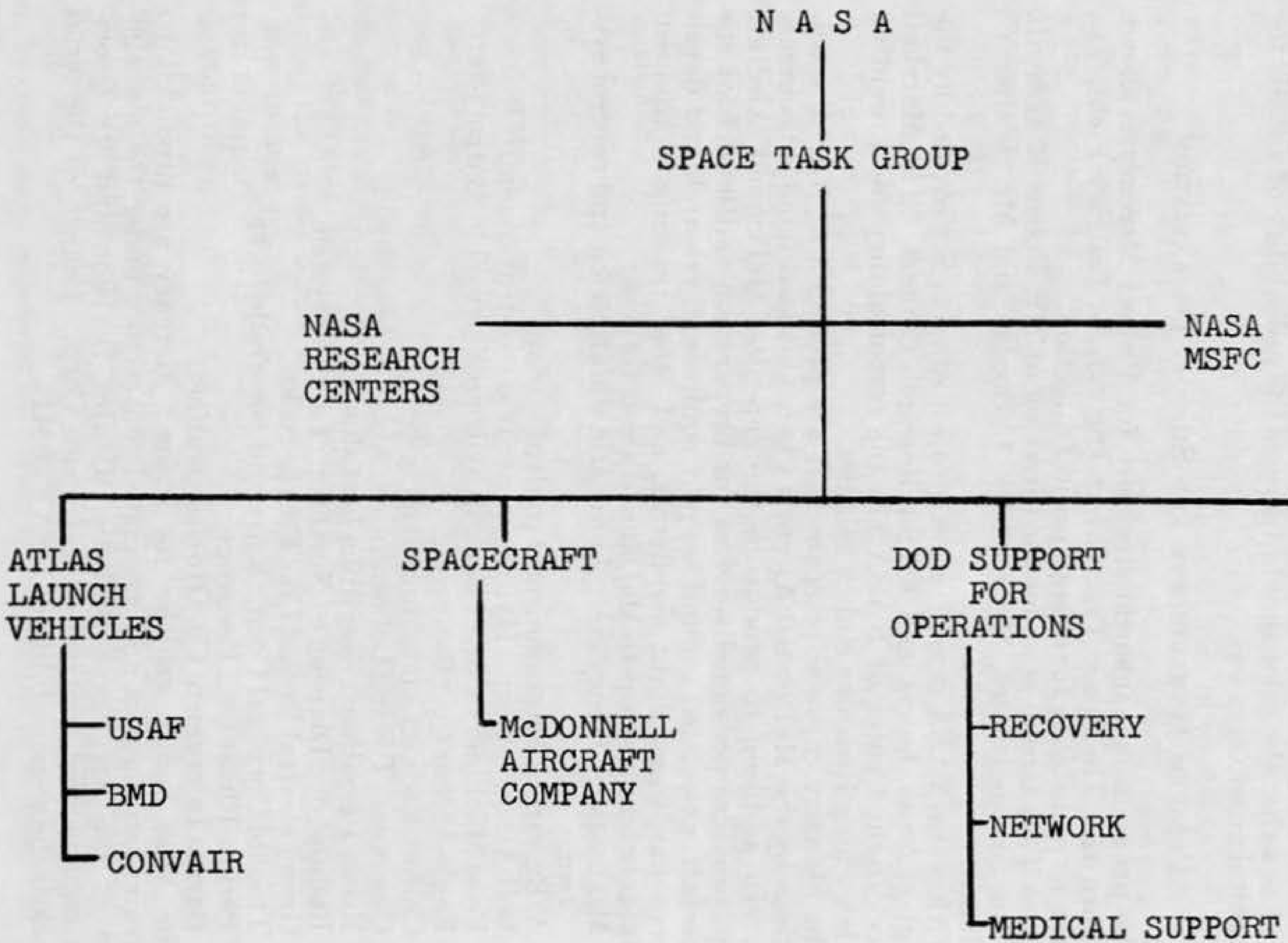

FIGURE 32.—Project Mercury management organization.

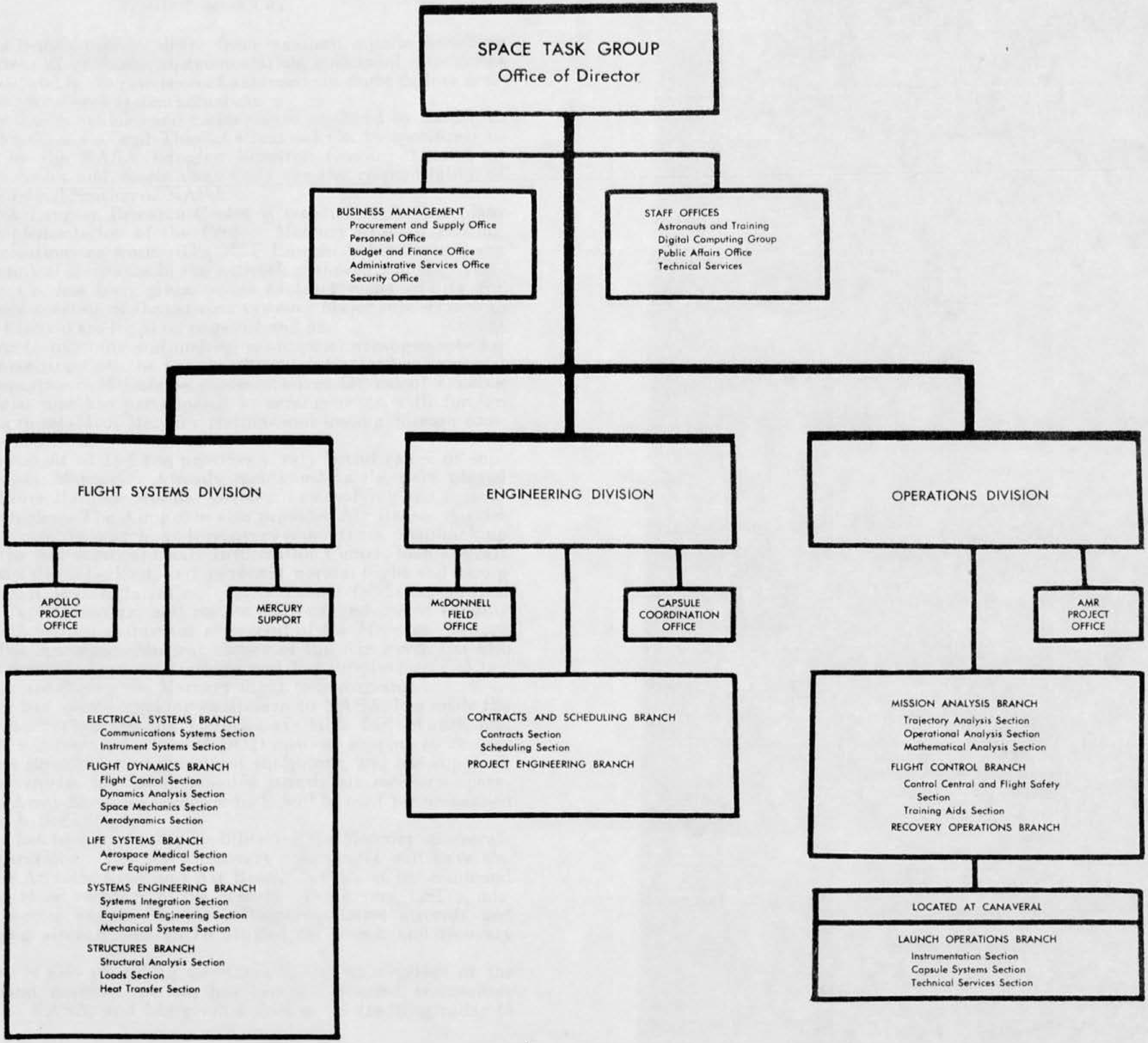

FIGURE 33.—NASA space task group organization.

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The Atlas launch vehicles differ from standard missile launching models in areas of guidance, instrumentation, structural attachment of the capsule, and in the provision of automatic in-flight failure sensing equipment for escape system actuation.

Little Joe launch vehicles and rockets were produced by the North American Aviation Co. and Thiokol Chemical Co. to specifications formulated by the NASA Langley Research Center. Launch of Little Joe vehicles and beach abort tests are the responsibility of the Wallops Island Station of NASA.

The NASA Langley Research Center is responsible for the planning and implementation of the Project Mercury ground tracking and communications network. The MIT Lincoln Laboratories have provided technical assistance in the network planning and the Western Electric Co. has been given prime contract responsibility for design and construction of the network system. Major subcontractors to Western Electric are listed on pages 51 and 52.

In addition to planning and making contractual arrangements for the network construction, the Langley Research Center has arranged with the Department of Defense representatives for use of existing range facilities and has participated in arrangements with foreign governments to establish Mercury stations and leasing foreign communications facilities.

The Department of Defense provides a very broad range of support to Project Mercury. Already mentioned is the part played by the Air Force Ballistic Missiles Division in supplying and launching Atlas vehicles. The Air Force also provides Air Rescue Service aircraft for capsule search and recovery operations, map-making services of the Aeronautical Chart Information Center, loan aircraft for network station checkout, and astronaut normal flight and zero-g training, AMR launch facilities, control center facilities, medical support at Cape Canaveral and remote stations, and use of existing network facilities and manpower at several of the Mercury network stations. The Aerospace Medical Center of the Air Force has also given assistance in astronaut training and has supplied animal test packages for use during the Mercury flight test program.

The Army has loaned tracking equipment to NASA, has made the White Sands Proving Ground facilities available for network use, will provide a substantial share of DOD medical support to Project Mercury, has supplied communications equipment, and has supplied, amphibious vehicles for use in possible launch site recovery operations. The Army Redstone launch vehicle will be used for unmanned and manned ballistic flights.

The Navy has been given responsibility for the Mercury spacecraft recovery operations. The Navy recovery commander will have elements of the Atlantic Fleet and Air Rescue Service at his command for effecting rapid recovery of the capsule. Destroyers, LSD's, miscellaneous service vessels, Marine helicopters, patrol aircraft and early warning aircraft will all be utilized for search and recovery operations.

The Navy is also providing assistance in the construction of the Canton Island network station, has loaned command transmitter equipment to NASA, and has given a number of tracking radar to NASA.

The Naval Air Material Center, Naval Air Development Center, Naval Parachute Facility, and Naval Medical Units, all have given substantial support to NASA.

Pacific Missile Range, under U.S. Navy management, is aiding in the operation of the Canton Island, Hawaii, and the southern California tracking stations.

Support by units of the Department of Defense has, in general, been formalized through a series of agreements between NASA and the particular military service concerned. As a rule, these agreements call for reimbursement by NASA for any support or services rendered over and above normal military operations.

Overall coordination of Department of Defense support for Project Mercury operations is arranged between Maj. Gen. Leighton I. Davis, USAF, Department of Defense representative for Project Mercury operations, and Mr. Walter C. Williams, Associate Director of Project Mercury.

In addition, scores of working-level committees and coordinating groups have been organized, to effect day-by-day coordination between NASA, the military services, and industry.

Project Mercury Funding

Initial funding for Project Mercury was provided in fiscal year 1959, when $46,416,333 was obligated for Mercury research and development, and $2,425,000 for construction and equipment.

In fiscal year 1960, the obligation for research and development totaled $84,328,370, and for construction and equipment $35,795,000. The fiscal year 1960 figures include supplemental funding of $12,200,000 for research and development, and $6,800,000 for construction and equipment.

Early in fiscal year 1960, Congress was advised that NASA intended to transfer $15 million from the research and development appropriation to construction and equipment for construction of the Mercury network. The fiscal year 1960 figures reflect this fund transfer.

For fiscal year 1961, the current allocation of funds is $109,525,000 for research and development and $15 million for construction and equipment.

Total Project Mercury funding obligations for fiscal year 1959 and 1960, and current allocation for fiscal year 1961, is, therefore, as follows:

Research and development:	
Fiscal year 1959	$46, 416, 333
Fiscal year 1960	84, 328, 370
Fiscal year 1961	110, 051, 000
Total	240, 795, 703
Construction and equipment:	
Fiscal year 1959	2, 425, 000
Fiscal year 1960	35, 795, 000
Fiscal year 1961	15, 000, 000
Total	53, 220, 000
Total through fiscal year 1961	294, 015, 703
Proposed "Research and development", fiscal year 1962	74, 245, 000
Proposed "Construction of facilities", fiscal year 1962	none
Grand total through fiscal year 1962	368, 260, 703

Conclusions

Project Mercury is a tremendously complex undertaking. It involves concurrent efforts in research, development, engineering, manufacturing, test, and training. It is a team effort on a national scale, directed by the National Aeronautics and Space Administration, and supported by the Department of Defense, industry, and research institutions.

Project Mercury is one of the most comprehensive research and development programs ever undertaken in this country with respect to manned flight. A major problem is the necessity to attempt to "man rate" the Redstone and Atlas rocket vehicles which were not designed for manned reliability. The reliability of these two vehicles is the ultimate key to the success of Mercury. The first manned Redstone, a major Mercury milestone, was successfully achieved May 5, 1961.

Project Mercury is actually two research and development programs joined together by the capsule—the ballistic flight program utilizing Redstone, and the orbital program utilizing Atlas. The suborbital and orbital phases of Mercury each have different complex problems to solve and each contribute equally to achieving the ultimate goal of manned-orbital flight.

Project Mercury is progressing satisfactorily. Some slippage has occurred, but it is not out of line when considering the complexity of the development and past history of other large research and development programs.

Project Mercury will make a valuable pioneering contribution to followon manned-space flight programs, such as the NASA Apollo and the DOD Dyna-Soar projects.

DOD-NASA coordination in the prosecution of Project Mercury is outstanding in every respect. Both organizations are dedicated to the success of this country's only current man-in-space program.

The cost of successfully completing Project Mercury could exceed one-half billion dollars, dependent upon the success of meeting the flight-test target goals as presently scheduled. Again, consideration must be given to the fact that Project Mercury is, in fact, two parallel research and development programs joined by the space capsule development. Booster reliability will be the key to increased program costs.

Some critics of Project Mercury believe that it is being overtaken by advancing technology; however, it appears that the state of the art provides no categorical indication that such is the case. The Air Force, NASA, and the Navy are learning together in the X–15 program as we progress in our approach to manned-space flight. The Discoverer program is providing valuable data for future space endeavor. DOD and NASA participation in numerous missile and space programs indicates no technological advancements that would negate the value of Project Mercury. Although decisions for the configuration of the capsule and the boosters were made several years ago, technology has not advanced to the extent of overtaking the basic Mercury concept which is to achieve an early capability for orbiting man in space.

Project Mercury is now 2½ years old. Since its inception, an extensive wind tunnel and flight-test program has been carried out, involving hundreds of wind tunnel and airplane drop tests, and 15 major rocket launchings; the Mercury production capsules were designed, engineered, and tested—12 were delivered by the end of April 1961; a major network of communications and tracking stations was completed; and training exercises of both the systems and the astronauts are progressing. A major flight-test program has begun, involving manned and unmanned-ballistic flights, leading to manned-orbital flight.

Project Mercury continues to move forward in an atmosphere of confidence apparent to all concerned. Morale is high, hours are long, the astronauts are busy and fit. The team is dedicated to a single goal—the achievement of successful manned-orbital flight.

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TABLE II.—*Ground instrumentation plan for Project Mercury*

Station name	Coverage, passes	Radar		Telemetry reception	Communication (capsule)	Command control	Acquisition			Ground communications			
		S	C				FA	SA	M	Voice	TTY	SSB radio	Timing
Canaveral	1, 2 and 3	(X)	X	X	X	X	X	(X)		X	X		X
Grand Bahama	1, 2 and 3		(X)	X	X				X	X	X		AMR
Grand Turk	1, 2 and 3			X	X				X	X	X		AMR
Bermuda	1, 2 and 3	X	X	X	X	X	X			X	X		X
Atlantic ship	1, 2 and 3			X	X		X				X	X	X
Grand Canary Island	1 and 2	X		X	X		X				X	X	X
Kano, Nigeria	1 and 2			X	X			X			X	X	X
Zanzibar	1 and 2			X	X			X			X	X	X
Indian Ocean ship	1, 2 and 3			X	X		X				X	X	X
Muchea, Australia	1, 2 and 3	X		X	X	X	X				X	X	X
Woomera, Australia	1 and 2		X	X	X		X			X	X		X
Canton Island	1 and 2			X	X			X			X		X
Kauai Island, Hawaii	2 and 3	X	X	X	X	X	X			X	X		X
Point Arguello, Calif.	2 and 3	X	X	X	X	X	X			X	X		X
Guaymas, Mexico	1, 2 and 3	X		X	X	X	X			X	X		X
White Sands, N. Mex	1, 2 and 3		X				X			X	X		X
Corpus Christi, Tex	1, 2 and 3	X		X	X		X			X	X		X
Eglin, Fla	1, 2 and 3	[1]	X				X			X	X		X
Goddard Space Flight Center [2]													

[1] MPQ-31.

[2] Ground communications

Site functions: FA—fully automatic; SA—semiautomatic; M—manual; SSB—single sideband.

APPENDIX

Agreement Between the Air Proving Ground Center and the NASA-Space Task Group

CONCERNING PRINCIPLES GOVERNING REIMBURSEMENT OF COSTS

(1) *Purpose.*—A DOD–NASA agreement, signed November 12, 1959, by Deputy Secretary of Defense Gates and NASA Administrator Glennan, under the provision of section 203(b) (6) of the National Aeronautics and Space Act of 1958, set forth the general principles governing the reimbursement of costs incurred by DOD or NASA in providing for use by the other of its service, equipment, personnel, and facilities and in transferring equipment and supplies. The DOD–NASA document is the authority and basic reference under which this agreement is established.

(2) *Agreement.*—It is agreed that the Air Proving Ground Center (EAFB) will bill the NASA-Space Task Group for cost of support peculiar to Project Mercury which is in addition to common range support. Common range support is defined, for the purposes of this agreement, to include but is not limited to: APGC services as a test range for satellites, space probes, missiles, drones, and related equipment, and supporting tests and training organizations. Evaluation of test results determined by data acquisition and reduction.

(A) *Common range support—nonreimbursable.*—Common range support is that normally provided as part of the range service, common to the majority of range users. It will be programed, budgeted, and funded by APGC on a nonreimbursable basis. The cost of operating existing stations will, in general, be nonreimbursable.

(1) Examples of nonreimbursable items:

(*a*) Salaries of radar operators at existing stations.

(*b*) Range time used during normally scheduled periods.

(B) *Support peculiar to Project Mercury—reimbursable.*—Support peculiar to Project Mercury is that support which would not otherwise be required to be provided by the range except for Project Mercury requirements.

(1) Examples of reimbursable support are:

(*a*) Total operating costs of new stations established for Project Mercury.

(*b*) Travel, transportation of things, per diem, and communication costs incurred on behalf of Project Mercury.

(*c*) Direct increased cost of operating existing stations.

(C) *Differences.*—Conflicts or inconsistencies in billings, or any special cases which arise, will be brought to the attention of the DOD representative whose group will establish an appropriate position for NASA consideration.

(D) *Budget estimates and financial administration.*—

(1) Two copies of the fiscal year 1962 budget estimates for Project Mercury and fiscal year 1961 financial plan for Project Mercury and

two copies of future budget estimates and financial plans will be submitted to NASA at the time of normal submission to Headquarters ARDC. NASA reimbursable costs will be reflected therein. Note: The initial fiscal year 1960 and 1961 estimates from all ranges were submitted to NASA through AFMTC (AMR) for review of format and content. (Flash estimate.)

(2) *Service order and billings.*—NASA Space Task Group will issue an order requesting range services and authorizing billings therefore based on range estimates. In accordance with this policy, APGC will submit monthly billings on S.F. 1080 showing actual costs broken down in the same way as estimates were prepared directly to:

NASA—Space Task Group
Budget and Finance Office
Langley Field, Va.

(3) *Effective date and duration of agreement.*—This agreement is effective immediately, but the provisions may, by mutual agreement, be revised at any time based upon experience of the two organizations.

ROBERT R. GILRUTH,
Director of Project Mercury.
JOE W. KELLY,
General USAF.

APRIL 11, 1960.

AGREEMENT BETWEEN THE AIR FORCE MISSILE TEST CENTER (AMR) AND THE NASA—SPACE TASK GROUP

CONCERNING PRINCIPLES GOVERNING REIMBURSEMENT OF COSTS

(1) *Purpose.*—A DOD–NASA agreement, signed November 12, 1959, by Deputy Secretary of Defense Gates and NASA Administrator Glennan, under the provision of section 205(b)(6) of the National Aeronautics and Space Act of 1958, set forth the general principles governing the reimbursement of costs incurred by DOD or NASA in providing for use by the other of its services, equipment, personnel, and facilities and in transferring equipment and supplies. The DOD–NASA document is the authority and basic reference under which this agreement is established.

(2) *Agreement.*—It is agreed that the Air Force Missile Test Center (AMR) will bill the NASA–Space Task Group for cost of support peculiar to Project Mercury which is in addition to Common Range Support. Common Range Support is defined, for purposes of this agreement, to include but is not limited to: AFMTC (AMR) services as a test range for satellites, space probes, missiles, drones, and related equipment, and supporting tests and training organization; evaluation of test results determined by data acquisition and reduction; utilities, security, and fueling of missiles on pad.

A. *Common range support—nonreimbursable.*—Common Range Support is that normally provided as a part of the range service, common to majority of range users. It will be programed, budgeted, and funded by AFMTC (AMR) on a nonreimbursable basis. The costs of operating existing stations will, in general, be nonreimbursable.

(1) Examples of nonreimbursable items:

(*a*) Salaries of radar operators at existing stations.

(*b*) Range time used during normally scheduled periods.

(B) *Support peculiar to Project Mercury—reimsburable.*—Support peculiar to Project Mercury is that support which would not otherwise be required to be provided by the range except for Project Mercury requirements.

(1) Examples of reimbursable support are:

(*a*) Total operating costs of new stations established for Project Mercury.

(*b*) Travel, transportation of things, per diem, and communication costs incurred on behalf of Project Mercury.

(*c*) Operating costs of Atlantic Ocean and Indian Ocean ships. Port facility expenses for the Atlantic Ocean ship will be nonreimbursable, since it will be based at Trinidad where AFMTC (AMR) facilities already exist as common use support. Port facility expenses for the Indian Ocean ship will be reimbursable since AFMTC (AMR) has no available Indian Ocean port facilities.

(C) *Differences.*—Conflicts or inconsistencies in billings or any special cases which arise will be brought to the attention of the DOD representative whose group will establish an appropriate position for NASA consideration.

(D) *Budget estimates and financial administration.*—(1) Two copies of the fiscal year 1962 budget estimates for Project Mercury and fiscal year 1961 financial plan for Project Mercury and two copies of future budget estimates and financial plans will be submitted to NASA at the time of normal submission to Headquarters ARDC. NASA reimbursable costs will be reflected therein. Note: The initial fiscal year 1960 and 1961 estimates from all ranges were submitted to NASA through AFMTC (AMR) for review of format and content. (Flash estimate).

(2) *Service order and billings.*—NASA Space Task Group will issue an order requesting range services and authorizing billings therefor based on range estimates. In accordance with this policy, AFMTC (AMR) will submit monthly billings on S.F. 1080 showing actual costs broken down in the same way as estimates were prepared directly to:

NASA—Space Task Group
Budget and Finance Office
Langley Field, Va.

(3) *Effective date and duration of agreement.*—This agreement is effective immediately, but the provisions may, by mutual agreement, be revised at any time based upon experience of the two organizations.

ROBERT R. GILRUTH,
Director of Project Mercury.

March 28, 1960.

DONALD W. YATES,
Major General, USAF.

Agreement Between the Chief of Naval Operations and the NASA Space Task Group

Subject: Principles governing reimbursement of costs incurred in conjunction with recovery operations.
Reference: (*a*) Section 203(b)(6), National Aeronautics and Space Act of 1958.
(*b*) Agreement between the Department of Defense and National Aeronautics and Space Administration, dated September 14, 1959.

1. *Background.*—Reference (*a*) authorizes the National Aeronautics and Space Administration to use, with their consent, the services, equipment, personnel, and facilities of other Federal agencies with or without reimbursement and requires such agencies to cooperate fully with NASA in such regard. Reference (*b*), sets forth the general principles governing the reimbursement of costs incurred by DOD or NASA in providing for use by the other of its services, equipment, personnel, and facilities and in transferring equipment and supplies.

2. *Purpose.*—It is the purpose of this agreement to—

a. Outline the elements of cost incident to Navy participation in recovery operations, outside the scope of the mutuality of interest provision of reference (*b*), and therefore subject to reimbursement by NASA.

b. Outline the general procedures for such reimbursement.

c. Provide a sound basis for budgetary planning and to insure that the additional costs involved are adequately funded.

3. *Definitions.*

a. Recovery operations include, but are not necessarily limited to, positioning of ships, craft, and aircraft of various types at predetermined bases or areas in relation to the particular mission, search and pickup of the payload, and delivery to an agreed location; training of personnel and development of recovery techniques.

b. Direct support includes, but is not necessarily limited to, ship days and/or aircraft hours devoted to direct participation in recovery operations or in operations whose sole objective is in support of Project Mercury endeavors.

4. *Basis for reimbursement and allowable costs.*

a. Ship days and aircraft hours, utilized in direct support of Project Mercury operations (and therefore subject to reimbursement) can most logically be determined by the fleet commander (or his designated representative(s)) of the operating force(s) involved. In computing the ship days and aircraft hours subject to the foregoing reimbursement, it is recognized that a portion of the days steamed or a portion of the total hours flown, incident to direct support of Project Mercury may, in some instances, be properly allocable to unique Navy effort such as training and other activity contributory to fleet readiness. Such portion is funded in regular Navy programs and is not subject to reimbursement by NASA and the determination thereof shall be made, as above, by the fleet commander or his designated representative(s).

b. Based upon prevailing Bureau of Ships and Bureau of Weapons cost factors, the following elements shall be included in arriving at the cost of a ship day and aircraft hour, by type vessel and aircraft, which are subject to reimbursement by NASA:

(1) Ships:

(*a*) Nonscheduled repairs, based on current experience, by type, calculated on a ship-day basis.

(*b*) Supplies and equipage (consumables and spare parts), based on current consumption by ship type, calculated on a ship-day basis.

(*c*) Fuel, based on average barrels consumed per hour underway X24X current Navy stock fund price per barrel.

(*d*) Costs of overhauls are excluded.

(2) Aircraft—average hourly cost, by type, to include:

(*a*) Fuel.

(*b*) Lube oil.

(*c*) Consumable supplies and spare parts.

(*d*) Prorated cost of airframe rework and engine overhaul.

c. Special equipment, including cost of installation and removal, as applicable, purchased by the Navy for direct support of Project Mercury. Title to such equipment will be held by NASA.

d. Cost on installation and removal of NASA furnished equipment.

e. Travel, per diem, telephone costs, photography, and other additional out of pocket expenses.

f. Special costs incidental to aircraft deployment for Mercury support.

5. *Budget estimates and financial administration.*—*a. Estimates.*—Fiscal year 1960 and fiscal year 1961 budget estimates of the cost of support of Project Mercury and future budget estimates will be submitted to NASA as required. NASA space task group will issue, to each cognizant Navy bureau, reimbursable Government orders based on the above estimates. It is recognized that these estimates are not limitations. Accordingly, both estimates and orders are subject to amendment based on changing operational requirements.

b. Billings.—(1) Charges for actual ship days and aircraft hours, subject to reimbursement, plus other costs, subject to reimbursement, financed from funds available to fleet activities will be billed quarterly by BuWeps and BuShips on S.F. 1080, showing actual costs, broken down in the same way as estimates are prepared.

(2) Charges for costs incurred by a field activity of the Shore Establishment will be billed by the field activity concerned on a funded basis. S.F. 1080 will be prepared as outlined above but will be submitted monthly.

(3) Billings on S.F. 1080 will be submitted to: NASA-Space Task Group Budget and Finance Office, Langley Field, Virginia.

ROBERT R. GILRUTH,
Director of Project Mercury.
JAMES S. RUSSELL,
Admiral, U.S. Navy,
Vice Chief of Naval Operations.

Dated March 30, 1960.

DEPARTMENT OF STATE

DIVISION OF LANGUAGE SERVICES

(Translation)

LS NO. 49406
T-52/R-XIX
Spanish

MINISTRY OF FOREIGN AFFAIRS,
Madrid, March 18, 1960.

No. 191.
His Excellency W. PARK ARMSTRONG,
Chargé d'Affaires ad interim of the United States of America, Madrid.

EXCELLENCY: I have the honor to acknowledge the receipt of your note No. 1097, dated March 11, the Spanish translation of which reads as follows:

"EXCELLENCY: I have the honor to refer to recent discussions between our two Governments concerning the proposal that my Government be authorized to establish and operate jointly with the Government of Spain, for scientific non-military purposes, a facility for space vehicle tracking and communications on Grand Canary Island. Such a facility is required by the United States as part of a world-wide tracking range being established in connection with its manned satellite program, known as Project Mercury, under which the United States plans to place a manned earth satellite into orbital flight and to recover it.

"The Government of Spain, desiring to cooperate with the United States in this scientific program, and thereby to contribute to the knowledge of man's spatial environment and its properties, has authorized the establishment of a tracking and communications facility on the Island of Grand Canary. Accordingly, the two Governments agree on the following general principles and procedures:

"1. The Government of Spain shall furnish land areas and rights-of-way for use by the National Aeronautics and Space Administration (hereinafter referred to as NASA) needed for the establishment and operation of the facility to be located at the southern end of the Island of Grand Canary. The specific site of the facility and quantity of land shall be as agreed upon by the authorized representatives of our two Governments. The United States Government shall be represented by NASA. The Government of Spain shall be represented by the Instituto Nacional de Técnica Aeronáutica, hereinafter referred to as INTA.

"2. The Government of the United States, for its part, shall construct, at its expense, the station that is the object of this agreement. All cost of installing, equipping and operating the facility shall also be borne by the Government of the United States, including the cost of constructing the necessary highways and access roads. The foregoing activities shall be carried out in accordance with applicable Spanish laws and the provisions of Article 9 relating to the ownership of property.

"3. The facility shall consist of installations for an S-Band radar, telemetry, a ground-to-air transmitter, and a ground receiver; subject to agreement by both governments, installations necessary for point-to-point communications to the extent that communications requirements cannot be met by local telephone and telegraph facilities; and necessary supporting buildings and structures for offices, storage, housing, sanitation, and other purposes deemed necessary. Buildings will generally be of a standard prefabricated type, transportable in sections.

"4. Power for the facility shall be generated at the site by equipment to be installed as a part of the facility.

"5. Upon the request of the United States and subject to Spain's obligations under international conventions, the Government of Spain shall authorize the use of radio frequencies required for the purposes of the facility. However, the high frequency channel required for ground-to-air communication with the space vehicle shall be determined by the Government of the United States. All radio operations shall be conducted so as not to cause interference with Spanish installations.

"6. By agreement of the two Governments, a United States contractor has been engaged to construct the facility. The contractor shall employ, to the maximum extent feasible, available local subcontractors and labor to perform the required work. Materials and supplies available locally shall be used as much as possible. The Government of Spain shall, upon request of the contractor, assist him in the local procurement of goods, materials, supplies, and services required for the construction of the facility.

"7. The special electronic equipment and related equipment required for the facility shall be United States-type equipment and shall be installed by United States technicians.

"8. The Government of Spain shall, upon request, take the necessary steps to facilitate the admission into Spain of material, equipment, supplies, goods or other items of property furnished by the Government of the United States for the purposes of the facility. Spanish authorities shall be informed in advance through INTA of the contents of such shipments. No tax, duty or charge shall be levied or assessed, either by the Government of Spain or by any other Spanish authorities, on material, equipment, supplies, goods or property brought into or procured in Spain, for use in the operation of the facility on the Island of Grand Canary.

"9. Title to all materials, equipment or other items of movable property used in connection with the facility shall remain vested in the Government of the United States. Title to all other property shall continue to be vested in the Government of Spain or other Spanish owners. Material, equipment and property of the Government of the United States at the facility may be removed free of taxes or duties by the Government of the United States at any time.

"10. The facility shall be operated by NASA, either directly or by contract with a United States firm. To the maximum extent feasible, qualified Spanish personnel shall be utilized in connection with the operation and maintenance of the facility, in addition to United States technicians and specialists assigned by NASA or the contracting firm. NASA and INTA shall cooperate closely to ensure full access by INTA to the facility in order to make possible a full exchange of information concerning both the techniques employed and the uses to which the facility is being put.

"11. (a) The Government of Spain shall take the necessary steps to facilitate admission to the Island of Grand Canary of such United States personnel as may be assigned to visit the facility or participate in its operation. Such personnel shall not exceed that necessary for the construction and effective use of the station. Their names and other related information shall be promptly communicated to the Government of Spain.

"(b) Personal and household effects of United States personnel (including personnel of NASA's contractors and subcontractors) may be brought into and removed from Spain free of all taxes and duties; such effects shall not be sold or otherwise disposed of in Spain except under conditions approved by the Government of Spain.

"(c) The presence on Grand Canary of United States personnel, personnel of NASA's contractors and subcontractors, in connection with the establishment or operation of the facility shall not constitute either residence or domicile and shall not, of itself, make such subject to taxation, either on income or property. However, such personnel shall not be exempt from indirect taxes on goods or services purchased by them in Spain.

"12. (a) The United States anticipates that the facility will be required for use until July 1, 1963. The Government of Spain agrees that the facility may be operated under the general principles and procedures provided herein until that date, and for such additional period as the two Governments may agree upon.

"(b) Should changed conditions alter the requirement of the Government of the United States for the facility prior to July 1, 1963, the Government of the United States shall have the right to terminate its use of the facility by giving ninety days' advance notice to the Government of Spain.

"(c) If, upon terminating its use of the facility, the United States Government should desire to dispose of all or part of the materials, equipment or other items of property to which it holds title on the Island of Grand Canary, the two Governments shall enter into consultation as soon as possible prior to the date of termination of use in order to make the necessary arrangements. The Spanish Government shall have a preferential right in the purchase of such material, equipment and other items of property.

"13. Supplementary arrangements between NASA and INTA shall be made from time to time as required for the carrying out of the purposes and provisions of this Agreement.

"14. It is understood that to the extent the implementation of this Agreement will depend on funds appropriated by the Congress of the United States, it is subject to the availability of such funds.

"If the foregoing general principles and procedures are acceptable to Your Excellency's Government, I have the honor to propose that this note and Your Excellency's note in reply to that effect shall constitute an Agreement between our two Governments on this matter which shall enter into force on the date of your note in reply."

On informing you of the Spanish Government's acceptance of the foregoing, I request, Sir, that you accept the assurances of my high consideration.

(Signed) FERNANDO CASTIELLA.

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INFLATABLE STRUCTURES IN SPACE

HEARING

BEFORE THE

COMMITTEE ON SCIENCE AND ASTRONAUTICS U.S. HOUSE OF REPRESENTATIVES

EIGHTY-SEVENTH CONGRESS

FIRST SESSION

MAY 19, 1961

[No. 12]

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